

IMSCI'23

The 17th International Multi-Conference on Society, Cybernetics and Informatics

September 12 - 15, 2023 – Virtual Conference

PROCEEDINGS

Edited by:

Nagib Callaos
Jeremy Horne
Belkis Sánchez
Michael Savoie



Organized by
International Institute of Informatics and Systemics
Member of the International Federation for Systems Research (IFSR)

COPYRIGHT

Copyright and Reprint Permission: Abstracting is permitted with credit to the source. Libraries are permitted to photocopy for private use. Instructors are permitted to photocopy, for private use, isolated articles for non-commercial classroom use without fee. For other copies, reprint, or republication permission, write to IIS Copyright Manager, 13750 West Colonial Drive, Suite 350 - 408, Winter Garden, Florida 34787, U.S.A.

All rights reserved. Copyright 2023. © by the International Institute of Informatics and Systemics.

The papers of this book comprise the proceedings of the conference mentioned on the title and the cover page. They reflect the authors' opinions and, with the purpose of timely disseminations, are published as presented and without change. Their inclusion in these proceedings does not necessarily constitute endorsement by the editors.

Published in the U.S. by the International Institute of Informatics and Cybernetics in 2023.

ISSN: 2831-722X

<https://doi.org/10.54808/IMSCI2023.01>

ISBN: 978-1-950492-74-9



**17th International Multi-Conference on
Society, Cybernetics and Informatics: IMSCI 2023**

HONORARY PRESIDENT

William Lesso, USA (1931-2015)

GENERAL CHAIRS

Nagib Callaos, USA

Andrés Tremante, USA

ORGANIZING COMMITTEE CHAIRS

Angel Oropeza, Venezuela

José Vicente Carrasquero, USA

PROGRAM COMMITTEE

Chair: Friedrich Welsch, Venezuela

Angelelli, Lee A.

IBM US Federal, USA

Arbez, Gilbert

University of Ottawa, Canada

Branham, David

University of Houston-Downtown, USA

Colvin, Lisa E.

Tarleton State University, USA

Detand, Jan

Ghent University, Belgium

Flammia, Madelyn

University of Central Florida, USA

Gribanova, Galina

Saint Petersburg State University, Russian Federation

Hendel, Russell J.

Towson University, USA

Köhne, Martin

St. Augustinus-Kliniken, Germany

Landu-Adams, Victoria

Argosy University Atlanta, USA

Ledesma Tan, Nemia

University of Negros Occidental-Recoletos, Philippines

Leybourne, Bruce

Institute for Advance Studies on Climate Change, USA

Mills, Melissa J.

Mills Consulting, LLC, USA

Moorning, Kim

City University of New York, USA

Orantes-Jiménez, Sandra D.

Instituto Politécnico Nacional, Mexico

Peoples, Bruce E.

Université Paris 8, France

Sala, Nicoletta

University of Lugano, Italy

Sprick, Ulrich

St. Augustinus Gruppe, Germany

Stock, Wolfgang G.

Heinrich Heine University Düsseldorf, Germany

Targamadze, Vilija

Vilnius University, Lithuania

Tavakkoli, Alireza

University of Nevada, Reno, USA

Yasinsac, Alec

University of South Alabama, USA

Zavala-Galindo, Alejandro

National Polytechnic Institute, Mexico

ADDITIONAL REVIEWERS WHO MADE AT LEAST ONE DOUBLE-BLIND REVIEW

Abd-Allah, Saber

Beni Suef University, Egypt

Alhayyan, Khalid N.

Institute of Public Administration, Saudi Arabia

Aqqal, Abdelhak

Chouaib Doukkali University, Morocco

Beer, Martin

Sheffield Hallam University, United Kingdom

Caldararu, Florin

Research Laboratory for Environmental Monitoring and Semiconductor Sensor, Romania

Carrasquero, José Vicente

Simon Bolivar University, Venezuela

Chen, Chau-Kuang
Meharry Medical College, USA

Cubukcu, Feryal
Dokuz Eylul University, Turkey

Debono, Carl J.
University of Malta, Malta

dos Reis Soeira, Elaine
Instituto Federal de Alagoas, Brazil

Farhaoui, Yousef
Moulay Ismail University, Morocco

Frosch-Wilke, Dirk
University of Applied Sciences Kiel, Germany

Hendel, Russell Jay
Towson University, USA

Janota, Ales
University of Žilina, Slovakia

Jiménez, Elsi
Central University of Venezuela, Venezuela

McConnell, Rodney
University of Idaho, USA

Mitchell, Charles
Grambling State University, USA

Nayak, Pranaba K.
Tata Institute of Fundamental Research, India

Nikolarea, Ekaterini
University of the Aegean, Greece

Odella, Francesca
University of Trento, Italy

Opfer, Neil
University of Nevada, USA

Pereira, Rafael
Federal University of Santa Maria, Brazil

Pérez, Carlos
Columbia University of Paraguay, Paraguay

Prodan, Augustin
Iuliu Hatieganu University, Romania

Sala, Nicoletta
University of Italian Switzerland Largo Bernasconi, Italy

Self, Richard
University of Derby, United Kingdom

Sureerattanan, Nidapan
Chulalongkorn University, Thailand

Tam, Wing K.
Swinburne University of Technology, Australia

Thomas, Stewart
Valparaiso University, USA

Vázquez-Álvarez, Graciela
National Polytechnic Institute, Mexico

Vintere, Anna
Latvia University of Agriculture, Latvia

Wang, Ching-Huang
National Formosa University, Taiwan

Whatley, Janice
University of Salford, United Kingdom

Yamamoto, Tatsuya
Keio University, Japan

ADDITIONAL REVIEWERS WHO MADE AT LEAST ONE NON-BLIND REVIEW

Adesina, Evaristus
Covenant University, Nigeria

Baluarte, César
Universidad Nacional de San Agustín de Arequipa, Peru

Bukiet, Bruce
New Jersey Institute of Technology, USA

Butler Carroll, Traci
University of North Texas Health Science Center, USA

Calderon, Maria Julia
Instituto Politécnico Nacional, Mexico

Camacho Vázquez, Vanessa Alejandra
Universidad UCAD, Mexico

Cruz Cortés, Nareli
Instituto Politécnico Nacional, Mexico

Delgado, Lucy
Universidad Nacional de San Agustín de Arequipa, Peru

El-Sayed, Ahmed
University of Bridgeport, USA

Gomez, Sandra
Instituto Politécnico Nacional, Mexico

Kayode-Adedeji, Tolu
Covenant University, Nigeria

Matsuno, Yu
Meiji University, Japan

Meda, Lawrence
Sharjah Education Academy, United Arab Emirates

Mohebi, Laila
Zayed University, United Arab Emirates

Morris-Pearson, Quinn I
New Jersey Institute of Technology, USA

Odarushchenko, Oleg
Poltava State Agrarian University, Ukraine

Prihodko, Ganna
Zaporizhzhya National University, Ukraine

Siemann, Catherine
New Jersey Institute of Technology, USA

Sliusar, Igor
Poltava State Agrarian University, Ukraine

Tupakhina, Olena
Zaporizhzhya National University, Ukraine

Willcox, Gregg
Unanimous AI, USA



**21st International Conference on
Education and Information Systems,
Technologies and Applications: EISTA 2023**

in the context of the 17th International Multi-Conference on Society, Cybernetics and Informatics: IMSCI 2023

GENERAL CHAIR

Nagib Callaos

ORGANIZING COMMITTEE CHAIRS

Andres Tremante, USA

Belkis Sánchez, USA

ORGANIZERS OF INVITED SESSIONS

Bill Muirhead (Canada)

Lorayne Robertson (Canada)

PROGRAM COMMITTEE

Chairs: Friedrich Welsch, Venezuela Angel Oropeza, Venezuela José Vicente Carrasquero, USA

Acioly, Mariana

Hospital Pelópidas Silveira, Brazil

Al Houqani, Mohammed

United Arab Emirates University, United Arab Emirates

Al Suwaidi, Ahmed

United Arab Emirates University, United Arab Emirates

Ash, George

Jefferson County Educational Service Center, USA

Basheer, Alsajir

United Arab Emirates University, United Arab Emirates

Beconcini, Maria Luisa

Università di Pisa, Italy

Bradford, Chelsey

Valparaiso University, USA

Bubnov, Alexey

The Czech Academy of Sciences, Czech Republic

Budkowska, Liliana

Foundation for the Development of the Education System, Poland

Cavkaytar, Atilla

Anadolu University, Turkey

Chan Mow, Ioana

National University of Samoa, Samoa

Croce, Pietro

Università di Pisa, Italy

Daiki, Tennó

Eötvös Loránd University, Hungary

De Souza Martins, Marlucio

Pontificia Universidad Javeriana, Colombia

Fernández, Trinidad

Technical University of Madrid, Spain

Formichi, Paolo

Università di Pisa, Italy

Fragoso, Viviane

Hospital Pelópidas Silveira, Brazil

Fuentes, José-María

Technical University of Madrid, Spain

Georgakopoulou, Elena

National and Kapodistrian University of Athens, Greece

Hall, Carmen

Fanshawe College, Canada

Hartmann, Mutfried

Karlsruhe University of Education, Germany

Henkel, Maria

Heinrich-Heine Universität, Germany

Hilzensauer, Marlene

University of Klagenfurt, Austria

Hrkač, Ana

Kindergarten M. Sachs, Croatia

Hsu, Mark

University of Waterloo, Canada

Javidi, Giti

University of South Florida, USA

Johnson, Daryl

Rochester Institute of Technology, USA

Killi, Steinar

Oslo School of Architecture and Design, Norway

King, Matthew

Valparaiso University, USA

Klosowski, Piotr

Silesian University of Technology, Poland

Landi, Filippo

Università degli Studi di Firenze, Italy

Lešin, Gordana

Kindergarten M. Sachs, Zagreb, Croatia

Lucio-Tavera, Paula A.

Pontificia Universidad Javeriana, Colombia

Maciel, Flaviana

Hospital Pelópidas Silveira, Brazil

Mahdjoub, Morad
University of Technology of Belfort-Montbéliard, France

Martins, Carolina
Hospital Pelópidas Silveira, Brazil

Métioui, Abdeljalil
Université du Québec à Montréal, Canada

Mitrofanova, Ksenia A.
Sechenov University, Russian Federation

Mochi, Caterina
Università di Pisa, Italy

Mohammed, Zeeshan Noor
United Arab Emirates University, United Arab Emirates

O'Sullivan, Jill Anne
Farmingdale State College, USA

Petit, Frédéric
Argonne National Laboratory, USA

Posada-Bernal, Sandra
Universidad Santo Tomás, Colombia

Poszytek, Paweł
Foundation for the Development of the Education System, Poland

Rosasco, Nicholas
Valparaiso University, USA

Rosener, Bill
Northeastern State University, USA

Roychoudhuri, Lopamudra
Angelo State University, USA

Sanger, Patrick
Alvin Community College, USA

Santos, Thalita
Hospital Pelópidas Silveira, Brazil

Schaetter, Alfred
Pforzheim University, Germany

Self, Richard
University of Derby, United Kingdom

Shaban, Sami
United Arab Emirates University, United Arab Emirates

Shahrier, Sayem
Farmingdale State College, USA

Singh, Harwinder
Guru Nanak Dev Engineering College, India

Smyrnaïou, Zacharoula
National and Kapodistrian University of Athens, Greece

Sparkes, Douglas
University of Waterloo, Canada

Takahashi, Kaoru
Tokyo University of Science, Japan

Tenhunen, Hannu
KTH Royal Institute of Technology, Sweden

Tepeš, Krunoslav
City Office for Transport, Zagreb, Croatia

Thomas, Stewart
Valparaiso University, USA

Vaida, Mircea-Florin
Technical University of Cluj-Napoca, Romania

Whitworth, Sheila
University of South Alabama, USA

Wieckert, Sarah
Technical University of Dortmund, Germany

Williams van Rooij, Shahron
George Mason University, USA

Woodside, Joseph M.
Stetson University, USA

Xeni, Elena
University of Cyprus, Cyprus

Zainon Hamzah, Zaitul A.
Putra Malaysia University, Malaysia

Zsakó, László
Eötvös Loránd University, Hungary

ADDITIONAL REVIEWERS WHO MADE AT LEAST ONE DOUBLE-BLIND REVIEW

Abe, Jair Minoro
Paulista University, Brazil

Abubakar, Ahmed
United Arab Emirates University, United Arab Emirates

Aldana Segura, Waleska
Galileo University, Guatemala

Andreopoulou, Zacharoula
Aristotle University of Thessaloniki, Greece

Ariton, Viorel
Danubius University, Romania

Ash, George
Franciscan University, USA

Atan, Mohd Farid
Universiti Malaysia Sarawak, Malaysia

Beer, Martin
Sheffield Hallam University, United Kingdom

Bhatt, Rakesh Mohan
Institute of Technology and Management, Dehradun, India

Caldararu, Florin
Research Laboratory for Environmental Monitoring and Semiconductor Sensors, Romania

Chaikla, Nidapan
Freelance, Thailand

Chan, Kan Kan
University of Macau, Macau

Chekour, Adam
University of Cincinnati, USA

Chen, Chau-Kuang
Meharry Medical College, USA

Cretu, Daniela-maria
Lucian Blaga University of Sibiu, Romania

Cubukcu, Feryal
Dokuz Eylul University, Turkey

Debono, Carl J.
University of Malta, Malta

Dereshiwsky, Mary
Northern Arizona University, USA

Dingu-Kyrklund, Elena
Stockholm University, Sweden

Dronyuk, Ivanna
Lviv Polytechnic National University, Ukraine

Duse, Dan Maniu
Lucian Blaga University, Romania

Federici, Stefano
University of Perugia, Italy

Finkbine, Ronald
Indiana University Southeast, USA

Fogarty, Emily A.
Farmingdale State College, USA

Frosch-Wilke, Dirk
University of Applied Sciences Kiel, Germany

Gedviliene, Genute
Vytautas Magnus University, Lithuania

Herget, Katrin
University of Aveiro, Portugal

Hsu, Donald
Dominican College of Blauvelt, USA

Ikeguchi, Cecilia
Tsukuba Gakuin University, Japan

Ionita, Angela
Romanian Academy Institute for Artificial Intelligence, Romania

Izydorczyk, Jacek
Silesian University of Technology, Poland

Janota, Ales
University of Žilina, Slovakia

Kesharwani, Subodh
Indira Gandhi National Open University, India

Kim, E-Jae
LG Electronics Institute of Technology, South Korea

Kirova, Snezana
Goce Delcev University, Macedonia

Klein, Barbara
University of Michigan Dearborn, USA

Klimo, Martin
University of Žilina, Slovakia

Klosowski, Piotr
Silesian University of Technology, Poland

Koul, Saroj
Acadia University, Canada

Kropid, Wendy
University of Wisconsin Superior, USA

Kroumov, Valeri
Okayama University of Science, Japan

Kurdi, M. Zakaria
University of Lynchburg, USA

Letia, Tiberiu
Technical University of Cluj Napoca, Romania

Lowes, Susan
Columbia University Teachers College, USA

Lygo-Baker, Simon
King's College London, United Kingdom

Macianskiene, Nemira
Vytautas Magnus University, Lithuania

Makhachashvili, Rusudan
Borys Grinchenko Kyiv University, Ukraine

Martínez, Liliana Inés
National University of Central Buenos Aires, Argentina

Masouras, Panicos
Cyprus University of Technology, Cyprus

McConnell, Rodney
University of Idaho, USA

McMahon, Ellen
National Louis University, USA

Metrolho, Jose
Polytechnic Institute of Castelo Branco, Portugal

Michaelides, Panagiotis G.
University of Crete, Greece

Mladenov, Valeri
Technical University of Sofia, Bulgaria

Morgado, Lina
University Aberta, Portugal

Mullins, Michael
University of Aalborg, Denmark

Musto, Daniela
National Research Council of Italy, Italy

Narwadiya, Sachin
Vigyan Prasar, India

Ng, Annie W. Y.
The Hong Kong University of Science and Technology, Hong Kong

Niegemann, Helmut
University of Erfurt, Germany

Nikolarea, Ekaterini
University of the Aegean, Greece

Nogueira, Sónia
Polytechnic Institute of Bragança, Portugal

Nugraheni, Cecilia Esti
Parahyangan Catholic University, Indonesia

O'Sullivan, Jill Anne
Farmingdale State College, USA

Papadourakis, George
Hellenic Mediterranean University, Greece

Poobrasert, Onintra
National Electronics and Computer Technology Center, Thailand

Prescott, Chusak
Chalermkarnchana University, Thailand

Prodan, Augustin
Iuliu Hatieganu University, Romania

Riihentausta, Juhani
University of Oulu (Retired), Finland

Rizzo, Rosalba
University of Messina, Italy

Rodi, Anthony
University of Pittsburgh, USA

Semenist, Ivan
Borys Grinchenko Kyiv University, Ukraine

Shaaban, Safaa
The British University in Egypt, Egypt

Soltes, Dusan
Comenius University in Bratislava, Slovakia

Stvan, Laurel
University of Texas Arlington, USA

Suranauwarat, Sukanya
Johnson and Wales University, USA

Suviniitty, Jaana
Aalto University, Finland

Swart, William
East Carolina University, USA

T. S., Arulananth
MLR Institute of Technology, India

Taylor, Stephen
Sussex University, United Kingdom

Thiruvengadam, Pushpanathan
Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya
(Deemed to be University), India

Thurasamy, Ramayah
Science University of Malaysia, Malaysia

Tobos, Valentina
Lawrence Technological University, USA

Tse, Kaho
The Education University of Hong Kong, Hong Kong

Tuzun, Hakan
Hacettepe University, Turkey

Utama, Anak Agung Gde Satia
Universitas Airlangga, Indonesia

Vaida, Mircea-Florin
Technical University of Cluj-Napoca, Romania

Valova, Irena
University of Rousse, Bulgaria

Vintere, Anna
Latvia University of Agriculture, Latvia

Wang, Ching-Huang
National Formosa University, Taiwan

Wang, Hongmei
Northern Kentucky University, USA

Wang, Jau-Shyong
Shu Te University, Taiwan

Wang, Zhigang
Fort Valley State University, USA

Weeden, Elissa
Rochester Institute of Technology, USA

Whatley, Janice
Manchester Metropolitan University, United Kingdom

Wielki, Janusz
Opole University of Technology, Poland

Williams van Rooij, Shahron
George Mason University, USA

Wortley, David
Gamification and Enabling Technologies Strategic Solutions,
United Kingdom

Wu, Tung-Xiung (Sean)
Shih Hsin University, Taiwan

Yagcioglu, Ozlem
Dokuz Eylul University, Turkey

Zainon Hamzah, Zaitul Azma
Putra Malaysia University, Malaysia

ADDITIONAL REVIEWERS WHO MADE AT LEAST ONE NON-BLIND REVIEW

Alemaw, Berhanu Fanta
University of Botswana, Botswana

Alvarez, SJ, Francis
Ateneo de Manila University, Philippines

Arter, Patricia
Winthrop University, USA

Ash, George
Franciscan University, USA

Besdin, Bonnie
Wentworth Institute of Technology, USA

Carreño Adasme, Mónica
Universidad de las Américas, Chile

Chen, Hao
The University of British Columbia, Canada

Diteeyont, Watsatree
Kasetsart University, Thailand

Ellappan, Sivakumar
TJS Engineering College, India

Galella, Suzanne
Marywood University, USA

Hetzner, Sónia
Friedrich-Alexander University, Germany

Hoffmann, Dorothea
The Language Conservancy, USA

Hsu, Donald
Dominican College of Blauvelt, USA

Huang, Qian
Miami University, USA

Inchamnan, Wilawan
Dhurakij Pundit University, Thailand

Jirapanthong, Waraporn
Dhurakij Pundit University, Thailand

Krach, R. Michael
Towson University, USA

Lazebna, Nataliia
University of Wuerzburg, Germany

Leroy, Gondy
The University of Arizona, USA

Mena Lorca, Jaime
Pontificia Universidad Católica de Valparaíso, Chile

Moyer, Todd
Towson University, USA

Nicdao, Rhodora
Ateneo de Manila University, Philippines

Ojo, Olumuyiwa Idowu
Ladoke Akintola University of Technology, Nigeria

Ortiz Aldean, Oswaldo
Universidad de las Fuerzas Armadas, Ecuador

Perez-Rifareal, Joan Mae
Ateneo de Manila University, Philippines

Prihodko, Ganna
Zaporizhzhya National University, Ukraine

Rombaoa Tanaka, Naomi
University of Hawai'i at Mānoa, USA

Sakata, Kuniko
Tohoku University, Japan

Salgado, Nelson
Pontifical Catholic University of Ecuador, Ecuador

Saljic, Eldar
American University in the Emirates, United Arab Emirates

Songkram, Nutthakorn
King Mongkut's Institute of Technology Ladkrabang, Thailand

Sookhanaphibarn, Termpetch
King Mongkut's University of Technology North Bangkok,
Thailand

Starren, Justin
Northwestern University, USA

Tillmanns, Tanja
Friedrich-Alexander University, Germany

Tupakhina, Olena
Zaporizhzhya National University, Ukraine

Valença, Marcelo Moraes
Universidade Federal de Pernambuco, Brazil

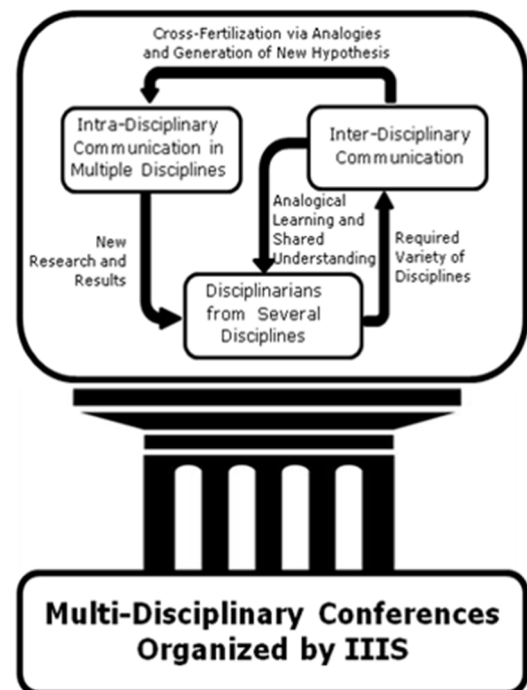
Wa Kalenga, Michel
University of Johannesburg, South Africa

FOREWORD

Informatics and Cybernetics (communication and control) are having an increasing impact on societies and in the globalization process that is integrating them. Societies are trying to regulate this impact and adapt it to their respective cultural infra-structures. Societies and cultures are in reciprocal co-adaptations with Information and Communication Technologies. Synergic relationships might emerge in this co-adaptation process by means of positive and negative feedback loops, as well as feedforward ones. This would make the whole larger than the sum of its parts, generating emergent properties in the parts involved as well as in the whole coming forth. The academic, private, and public sectors are integrating their activities; multi-disciplinary groups and inter-disciplinary teams are being formed, and collaborative research and development projects are being organized in order to facilitate and adequately orient the design and implementation of the feedback and the feedforward loops, and potentially generating synergic relationships. This phenomenon persuaded the Organizing Committee to organize the 17th International Multi-Conference on Society, Cybernetics and Informatics (IMSCI 2023) in a multi-disciplinary context along with other collocated events. Consequently, participants may focus on one discipline, while allowing them the possibility of attending conferences from other disciplines. This systemic approach stimulates cross-fertilization among different disciplines, inspiring scholars, originating new hypothesis, supporting production of innovations and generating analogical thinking.

IMSCI 2023 was organized and sponsored by the International Institute of Informatics and Systemics (IIS, www.iis.org), member of the International Federation of Systems Research (IFSR). The IIS is a **multi-disciplinary organization for inter-disciplinary communication and integration**, which includes about 5000 members. Consequently, a main purpose of the IIS is to foster knowledge integration processes, interdisciplinary communication, and integration of academic activities. Based on: 1) the transdisciplinarity of the systemic approach and its emphasis on *relationships* and *integrating* processes, and 2) the multi-disciplinary support of cybernetics' and informatics' concepts, notions, theories, technologies, and tools, the IIS has been organizing multi-disciplinary conferences as a platform for fostering inter-disciplinary communication and knowledge integration processes.

Multi-disciplinary conferences are organized by the IIS as support for both **intra-** and **inter-disciplinary** communication. Processes of intra-disciplinary communication are mainly achieved via traditional paper presentations in corresponding disciplines, while conversational sessions, regarding trans- and inter-disciplinary topics, are among the means used for inter-disciplinary communication. Intra- and inter-disciplinary communications might generate *co-regulative cybernetic loops*, via negative feedback, and *synergic* relationships, via positive feedback loops, in which both kinds of communications could increase their respective effectiveness. Figure (at the right side) shows at least two cybernetic loops if intra- and inter-disciplinary are adequately related. A necessary condition for the effectiveness of Inter-disciplinary communication is an adequate level of **variety** regarding the participating disciplines. *Analogical thinking and learning processes* of disciplinarians depend on it, which in turn are potential sources of the creative tension required for cross-fertilization



among disciplines and the generations of new hypothesis. An extended presentation regarding this issue can be found at <http://www.iiis.org/MainPurpose/>

One of the main purposes of IMSCI 2023 is to bring together academics, professionals, and managers from the private and the public sectors, in order to share ideas, results of research, and innovative services or products, in a multi-disciplinary and multi-sector forum. Educational technologies, socioeconomic organizations, and sociopolitical processes are essential domains among those involved in the evolving co-adaptation and co-transformation between societies and cultures on the one hand, and between informatics and cybernetics (communication and control) on the other hand. Consequently, the main conference in the context of the IMSCI 2023 Multi-Conference is the 21st International Conference on Education and Information Systems, Technologies and Applications: EISTA 2023. The relationship between education/training and Information and Communication Technologies (ICT) is quickly intensifying and sometimes appears in unexpected forms and in combination with original ideas, innovative tools, methodologies, and synergies. Accordingly, the primary purpose of EISTA 2023 has been to bring together researchers and practitioners from both areas together to support the emerging bridge between education/training and the ICT communities.

In the context of EISTA 2023, practitioners and consultants were invited to present case studies and innovative solutions. Corporations were invited to present education/training information systems and software-based solutions. Teachers and professors were invited to present case studies, specifically developed information systems, and innovative ideas and designs. Educational scientists and technologists were invited to present research or position papers on the impact and the future possibilities of ICT in educational systems, training processes, and methodologies. Managers of educational organizations and training consultants were invited to present problems that might be solved with ICT or solutions that might be improved by different approaches and designs in ICT.

EISTA 2023 provides a forum for the presentation of solutions and problems in the application of ICT in the fields of education/training. Authors of the papers included in the proceedings provided diverse answers to the following questions:

- What is the impact of ICT in education and training?
- How ICTs are affecting and improving education and training? What networks and models are emerging?
- How are universities, schools, corporations and other educational/training organizations making use of ICT?
- What electronic tools are there to facilitate e-learning, distance education and co-operative training?

On behalf of the Organizing Committees, I extend our heartfelt thanks to:

1. The 91 members of the Program Committee from 30 countries (including the events and the special tracks organized in the context of IMSCI 2023);
2. The 133 additional reviewers, from 45 countries, for their *double-blind peer reviews*; and
3. The 56 reviewers, from 17 countries, for their efforts in making the *non-blind peer reviews*. (Some reviewers supported both: non-blind and double-blind reviewing for different submissions).

A total of 320 reviews made by 189 reviewers (who made at least one review), from 45 countries, contributed to the quality achieved in IMSCI 2023. This means an average of 5.71 reviews per submission (56 submissions were received). *Each registered author had access, via the conference web site, to the reviews that recommended the acceptance of their respective submissions.* Each registered author could also get information about: 1) the average of the reviewers evaluations according to 8 criteria, and the average of a global evaluation of his/her submission; and 2) the comments and the constructive feedback made by the reviewers, who recommended the acceptance of his/her submission, so the author would be able to improve the final version of the paper.

In the organizational process of IMSCI 2023, about 56 articles were submitted. These proceedings include about 30 papers, from 11 countries that were accepted for presentation (28 countries taking into account the presentations in collocated events). We extend our thanks to co-chairs special tracks organizers for their support. The submissions were reviewed as carefully as time permitted; it is expected that most of them will appear in a more polished and complete form in scientific journals.

This information about IMSCI 2023 is summarized in the following table, along with the other collocated conferences:

| Conference | # of submissions received | # of reviewers that made at least one review | # of reviews made | Average of reviews per reviewer | Average of reviews per submission | # of papers included in the proceedings | % of submissions included in the proceedings |
|-------------------|---------------------------|--|-------------------|---------------------------------|-----------------------------------|---|--|
| WMSCI 2023 | 130 | 335 | 523 | 1.56 | 4.02 | 79 | 60.77 % |
| IMSCI 2023 | 56 | 189 | 320 | 1.69 | 5.71 | 30 | 53.57 % |
| WMSCI/IMSCI 2023 | 186 | 524 | 843 | 1.61 | 4.53 | 109 | 58.60 % |
| CISCI 2023 | 75 | 285 | 565 | 1.98 | 7.53 | 55 | 73.33 % |
| TOTAL 2023 | 261 | 809 | 1408 | 1.74 | 5.39 | 164 | 62.84 % |

All submissions were peer reviewed by the two-tier reviewing methodology of the International Institute of Informatics and Systemics (IIS, www.iis.org). As it might be noticed, from the table above, 5.71 reviews were made, in average, for each submission we received. After the conference is over, the names of the reviewers will be published on the IIS web site along with the titles of the papers each reviewer reviewed. This means that what had been a double-blind review, up to the conference, is transformed to single-blind review, after the conference is over. In this way, each author would have information about the names of the reviewers of his/her submission, but not vice-versa. Likewise, each author would know how many reviewers reviewed his/her submission and relate it to the average, being informed in the above table, of 5.71 reviews per paper.

Our two-tier reviewing methodology meet two different objectives of peer-review: 1) to improve the paper via non-anonymous reviewers (non-blind reviews) and 2) to improve the acceptance/non-acceptance decision of the Organizing Committee via traditional anonymous reviewers (double-blind reviews) A recommendation to accept, made by non-anonymous reviews, is a **necessary** condition, but it is not a **sufficient** one. A submission, to be accepted, should also have a majority of its double-blind reviewers recommending its acceptance. These two necessary conditions generate a **more reliable and rigorous** reviewing than any of those reviewing methods, based on just one of the indicated methods, or just on the traditional double-blind reviewing.

We extend our gratitude to the co-editors of these proceedings for the hard work, energy and eagerness they have shown in organizing their conferences and preparing their respective sessions. We express our intense gratitude to Professor William Lesso (1931-2015) for his wise, timely, adequate and valuable tutoring, as well as for his eternal energy, integrity, and continuous support and advice, as the Program Committee Chair of past conferences, and as Honorary President of WMSCI 2023, as well as for being a very caring old friend and intellectual father to many of us. We also extend our gratitude to Professor Belkis Sánchez, who brilliantly managed the organizing process.

We would like also to extend our gratefulness to Professor Shigehiro Hashimoto for his yearly support in the last 23 years as well as for his editorial work for the journal; as well as to Professor Grandon Gill, Dr. Jeremy Horne, Professor Thomas Marlowe, Professor Matthew E. Edwards, Dr. Robert Cherinka, Eng. Joseph

Prezzama, Dr. Fr. Joseph Laracy, and Dr. Russell Jay Hendel, for their continuous advice and support in the conferences they participated in, along the last 15 years; as well as in the conferences they were not able to participate in. Their advices and the kind of care they provided us with are highly valued and appreciated.

We also extend our gratitude to the following scholars, researchers, and professionals who generously accepted to deliver keynote addresses or to organize invited sessions.

Plenary Keynote Speakers (*Alphabetical order by last name*)

Dr. Risa Blair, USA, Purdue University Global, USA, Adjunct Faculty, Department of Humanities and Social Sciences, School of General Education; Instructional Associates, Director of HR and Operations.

Dr. Robert Cherinka, USA, MITRE Corporation, Chief Engineer, Software Engineering Innovation Center.

Dr. Jasmin (Bey) Cowin, USA/Germany, Associate Professor and TESOL Practicum Coordinator, Touro University, Graduate School of Education, TESOL/BLE Department.

Professor Alptekin Erkollar, Austria, ETCOP Institute for Interdisciplinary Research.

Professor Fuensanta Fernández de Velazco, Mexico, Benemérita Universidad Autónoma de Puebla, Faculty of Arts, professor, researcher, an active member of the Seminar on Theories, Methods, and Models of Social Complexity, the Complexity Sciences Center (C3) of the National Autonomous University of Mexico.

Professor Shigehiro Hashimoto, Japan, Professor of Kogakuin University (Former Councilor and Former Dean, Faculty of Engineering, Former Associate to the President, Former President of the Society of Life Support Engineering Japan), Doctor of Engineering and Doctor of Medicine, Research Area: Biomedical Engineering.

Dr. Russell Jay Hendel, USA, Towson University, Dept. of Mathematics, doctoral program at the Spertus Institute for a degree in Jewish studies.

Professor Mohammad Ilyas, USA, Florida Atlantic University, College of Engineering and Computer Science, Former Dean of the College of Engineering and Computer Science, Member of Global Engineering Deans Council.

Professor Cyril S. Ku, USA, William Patterson University, Department of Computer Science.

Fr. Dr. Joseph R. Laracy, USA, Seton Hall University, Department of Systematic Theology & Department of Mathematics and Computer Science.

Dr. James Lipuma, USA, New Jersey Institute of Technology, Director of the Collaborative for Leadership Education, and Assessment Research.

Professor Rusudan Makhachashvili, Ukraine, Borys Grinchenko Kyiv University, Head of Germanic Philology Department.

Professor Emeritus Thomas Marlowe, USA, Seton Hall University, Department of Mathematics and Computer Science, PhD in Computer Science and PhD in Mathematics.

Professor Rita Micarelli, Canada/Italy, IIAS International Institute for Advanced Studies in System Research and Cybernetics in Ontario / Polytechnic University of Milan.

Professor Ryohei Nakatsu, Japan, Kyoto University, Specially Appointed Professor, Art Innovation Academia-Industry Joint Research Division, Disaster Prevention Research Institute.

Professor Birgit Oberer, Austria, ETCOP Institute for Interdisciplinary Research.

Patrick O’Leary, USA, MITRE Corporation, Software Application Development Engineer.

Professor Giorgio Pizziolo, Canada/Italy, IIAS International Institute for Advanced Studies in System Research and Cybernetics in Ontario / Polytechnic University of Milan.

Joseph Prezzama, Msc., USA, MITRE Corporation, Group Leader for the Joint Operations Southeast, Tampa office of the MITRE Corporation.

Professor Richard Segall, USA, Arkansas State University, Department of Information Systems & Business Analytics (ISBA), Neil Griffin College of Business.

Richard Self LLM, UK, University of Derby, The School of Computing and Mathematics, Senior Lecturer in Governance of Advanced and Emerging Technologies.

Professor Ivan Semenist, Ukraine, Borys Grinchenko Kyiv University, Dean of Oriental Languages Faculty.

Dr. Robert A. Smith, USA, Boeing Company and Virginia Tech, Calhoun Honors Discovery Program.

Dr. Maurício Vieira Kritz, UK/Brazil, University of Manchester, Faculty of Biology, Medicine, and Health / National Laboratory for Scientific Computing, Petrópolis, Graduate Program on Modelling Knowledge Diffusion.

Cristo E. Yáñez-León, MSc., Ph.D. candidate, USA, New Jersey Institute of Technology, Director of Research, CSLA, Office of Research & Development.

Invited Sessions Organizers (Alphabetical order by last name)

Professor Elina Gaile-Sarkane, Latvia, Riga Technical University, Dean of the Faculty of Engineering Economics and Management.

Professor Shigehiro Hashimoto, Japan, Professor of Kogakuin University (Former Councilor and Former Dean, Faculty of Engineering, Former Associate to the President, Former President of the Society of Life Support Engineering Japan), Doctor of Engineering and Doctor of Medicine, Research Area: Biomedical Engineering.

Professor Natalja Lace, Latvia, Riga Technical University, Head of Department of Corporate Finance and Economics, Faculty of Engineering Economics and Management.

Professor Inga Lapina, Latvia, Riga Technical University, Vice Dean for Academic Affairs, Faculty of Engineering Economics and Management.

Many thanks to the members of the Organizing Committee and to those who chaired special tracks. We would also like to express our special gratefulness to Professor Thomas Marlowe. Professor T. Grandon Gill, Dr. Jeremy Horne, Professor Shigehiro Hashimoto, Dr. Russell Jay Hendel, Professor Michael Savoie, Professor Hsing-Wei Chu, Dr. Robert Cherinka, and Eng. Joseph Prezzama, for their generosity in providing support

with their advices and for answering our inquiries, as well as for their spontaneous and timely alerts. Thank you so very much.

Our gratefulness is also extended to the organizations that provided scientific, academic, professional, or corporate co-sponsorships in this conference and/or previous ones. The following are among these organizations:



Special thanks to Dr. Jeremy Horne, Dr. Harvey Hyman, Dr. Robert Cherinka, Eng. Joseph Prezzama, and Ms. Molly Youngblood Geiger (Google Partners Community Ambassador) for their efforts in helping us with the identification of above shown co-sponsors.

Professor Nagib C. Callaos, Ph.D.
IMSCI 2023 General Chair
www.iis.org/Nagib-Callaos

TABLE OF CONTENTS

| | |
|--------------------------|---|
| Table of Contents | i |
|--------------------------|---|

Application of Education Technologies

| | |
|--|---|
| Krisberg, Jeremy; Swango, Logan (USA): "The Language Conservancy; Developing eLearning Content and Curricula for Indigenous Communities" | 1 |
|--|---|

| | |
|--|---|
| Poolsawas, Banyapon; Chotikakamthorn, Nopporn (Thailand): "Using Mozilla Hubs for Online Teaching: A Case Study of an Innovation Design Method Course" | 7 |
|--|---|

Applications of Information and Communication Technologies in Education and Training

| | |
|--|----|
| Kopishynska, Olena; Utkin, Yurii; Makhmudov, Khanlar; Kalashnik, Olena; Moroz, Svitlana; Somych, Mykola (Ukraine): "Digital Transformation of Resource Management of Territorial Communities Based on the Cloud ERP System in the Concept of Industry 4.0" | 13 |
|--|----|

| | |
|---|----|
| Makhachashvili, Rusudan; Semenist, Ivan; Prihodko, Ganna; Prykhodchenko, Olexandra; Tupakhina, Olena (Ukraine): "Systemic Challenges of Digital Foreign Languages Education in Global Emergency Meta-Context (The Pandemic and Warzone Perspectives)" | 21 |
|---|----|

| | |
|---|----|
| Martins, Carolina; Martins, Antonio; Pimentel, Camila; Siriani Oliveira, Marilda; Barbosa Seiffert, Otília Maria Lúcia (Brazil): "Virtual Meeting as Didactic Strategy and Teaching Archive in Health Residencies: An Integrative Review" | 26 |
|---|----|

| | |
|--|----|
| Shibata, Kuniomi; Hattori, Akira; Matsumoto, Sayaka (Japan): "A Sign Language Learning Application for Children with Hearing Difficulties" | 34 |
|--|----|

Education and Training Systems and Technologies

| | |
|---|----|
| Makhachashvili, Rusudan; Semenist, Ivan (Ukraine): "Metadigital Skills Development for Foreign Languages Education in Wartime Digitization" | 40 |
|---|----|

| | |
|---|----|
| Montenegro, Sandra; Mendoza, Karina; Chancay, Carlos; Posligua, Katty; Meza, Jaime (Ecuador): "Teacher Digital' Skills for Online Education in Preschool and Schools Education Careers" | 45 |
|---|----|

Education in Science, Technology, Engineering and Mathematics

| | |
|--|----|
| Lipuma, James; León, Cristo (USA): "Disclosure of Support Statement: Increasing Student Transparency About Support from Software Like ChatGPT" | 51 |
|--|----|

| | |
|---|-----|
| Lugoma, Masikini; Ilunga, Masengo (South Africa): "A Markov Chain for the Evaluation of Completion Rate in Engineering Technical and Vocational Education and Training Colleges of South Africa" | 56 |
| Maduna, Lusiwe; Ilunga, Masengo (South Africa): "Assessing Knowledge Areas of Advanced Certificate in Engineering Technology Using Analytic Hierarchy Process (AHP)" | 62 |
| Mathenjwa, Samukelisiwe; Ilunga, Masengo (South Africa): "Measuring Entropy Associated with First Time Undergraduate Students' Enrolments in South African Public Universities" | 67 |
| Suddee, Nuttaporn; Songkram, Noawanit (Thailand): "Self-Physical Fitness Training Program with Sit up Sensor to Enhance the Abdominal Muscle Strength" | 73 |
| Tardieu, Gregory; Tekle, Senait; Zanin, Linda; Capshaw, Ter L.; Libin, Alexander; Zeng-Treitler, Qing (USA): "Teaching Health Informatics in Middle School: Experience from an NIH AIM-AHEAD Pilot" | 81 |
| Educational Research, Theories, Practice and Methodologies | |
| Balajadia, Janine Marie; Dy, Maria Micole Veatrizze; Pariñas, Lukas; Taguba, Christine Leila; Tan, Alessandra Grace; Tuazon, Maxine Therese; Uy, Jerome Patrick; Adarlo, Genejane (Philippines): "The Influence of Basic Psychological Needs Satisfaction on Well-Being: A Study on Higher Education Faculty in the New Normal" | 87 |
| Balajadia, Janine Marie; Dy, Maria Micole Veatrizze; Pariñas, Lukas; Taguba, Christine Leila; Tan, Alessandra Grace; Tuazon, Maxine Therese; Uy, Jerome Patrick; Adarlo, Genejane (Philippines): "Stressors and Coping Strategies in the New Normal: A Case Study of Teachers in a Higher Education Setting" | 92 |
| Gaete-Peralta, Claudio; Delgado, Katherine; Huincahue, Jaime (Chile): "Uses of Quantification and Modelling Category – The Case of Antimicrobial Coating Development" | 99 |
| Hendel, Russell Jay (USA): "A Mathematical-Logic Technique Facilitating Good Teaching" | 105 |
| Kusumi, Ariyoshi; Hama, Yasukazu (Japan): "Refining the Art of Judgment Education: Evaluation of an Educational Case Study on Making Judgments About the Pros and Cons of COVID-19 Vaccination During the Pandemic" | 110 |
| Kyriakidis, Kleanthis; Koikas, Evgenia (United Arab Emirates): "Roma Youth's Right to Education (Case Studies: Greece and Hungary)" | 115 |
| Paciej-Woodruff, Amy; Brown, Tammy (USA): "Building Bridges to Gen Z in Online Coursework in Teacher Education" | 122 |
| Sánchez-Montecinos, Solangela; Huincahue, Jaime; Gaete-Peralta, Claudio (Chile): "Teacher Professional Development in Inclusive Education in Chile: A New Perspective" | 126 |

Xiao, Lijian; Zhang, Xinhui; Ganapathy, Subhashini (USA): "Efficiently Solving High School Timetable Scheduling Problems with Various Neighborhood Operators" 131

Entrepreneurship Education

Cowin, Jasmin *; Oberer, Birgit **; Leon, Cristo * (* USA, ** Austria): "Trans-Disciplinary Communication in the ChatGPT Age: A Systems Perspective" 138

Informatics and Cybernetics on Societies

ElSary, Areej (United Arab Emirates): Codesign a Digital Mental Health Application to Promote Young People's Cyber-Behavioral Competence and Sustain Their Wellbeing: A Literature Review" 145

Eltaeib, Tarik; McCloud, Robert; O'Sullivan, Jill A. (USA): "Is the Cyberwar on the Horizon or Has It Already Begun? Russian Cyberattack Strategies Against Ukraine - Lessons Learned" 151

Medina, Brandon; Acevedo, Elena; Acevedo, Antonio; Orantes, Sandra (Mexico): "Network Attacks Classification Using Computational Intelligence" 156

Pérez-Castillo, Yadira-Jazmín; Orantes-Jiménez, Sandra-Dinora; Acevedo-Mosqueda, María-Elena (Mexico): "Toward Automated Project Management" 161

Rosenberg, Louis (USA): "Generative AI as a Dangerous New Form of Media" 165

Interdisciplinary Research, Education, and Communication

Makhachashvili, Rusudan; Semenist, Ivan (Ukraine): "Transdisciplinary Transformation of Digital Education: Emergency, Sustainability and Universality" 171

Authors Index 179

The Language Conservancy; Developing eLearning Content and Curricula for Indigenous Communities

Jeremy KRISBERG

eLearning Content Developer, The Language Conservancy
New York, NY 10014, USA

Logan SWANGO

IT Manager, The Language Conservancy
Bloomington, IN 47404, USA

ABSTRACT

This extended abstract describes eLearning projects of The Language Conservancy, specifically examining the eLearning platform developed to service the creation of online and mobile curricula geared towards education of younger generations within respective Indigenous communities across the United States. Following an illustration of the eLearning platform's overall structure and functionality is a description of the diverse content creation strategies which are applied to the unique needs of different communities.

Keywords: Learning Path, Level, Unit, Lesson, Exercise, and Card.

1. INTRODUCTION

Online learning is a well-established and widely-used component of education. Its popularity has surged during the COVID-19 pandemic, and educational institutions are integrating it now in record numbers [2]. Through the work being done by The Language Conservancy, or TLC, a nonprofit organization headquartered in Bloomington, Indiana, USA, resources and online learning materials are being developed to provide the reach, flexibility, and benefits of language learning to under-resourced and endangered Native languages.

Owóksape, which translates to “Place of Knowledge” in Lakota, is the first eLearning platform developed by The Language Conservancy to support revitalization efforts of the Lakota language [3]. Originally intended to reach younger generations of learners and provide tools to complement traditional teaching methods, the

project grew out of various multimedia resources with the intention to combine their most effective aspects into a single, self-paced learning tool [3].

From Owóksape, the platform was expanded with the capabilities of supporting other languages. Theming components such as color palette and user interface graphics were also modified to be more easily customizable, providing the platform with the flexibility to adapt to a broader range of cultures and educational institutions. Projects are currently underway to support more languages, including Crow, Ute Mountain Ute, Ho-Chunk, and Cowlitz Salish. The platform is still in active development, and new functionalities are being added to further enhance its utility, such as the addition of a Teacher Portal, which provides school teachers with the capability to create and manage virtual classroom groups, curate custom lessons, and keep track of students' progress & scores.

2. E-LEARNING FRONTEND AND BACKEND INTERFACE

Figure 1 depicts the main page that learners see when the platform is accessed.

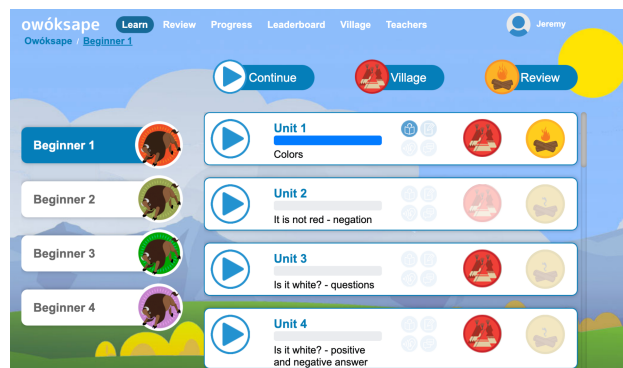


Figure 1: eLearning Frontend Overview

The learning structure consists of unique learning paths, which are broken down into levels consisting of separate groupings of units. Users progress through units and levels in a linear fashion, unlocking access to more advanced material as units are completed. Each unit is made up of sequences of lessons and exercises (see Figure 2), which are followed by a review portion upon successful completion of the entire unit.

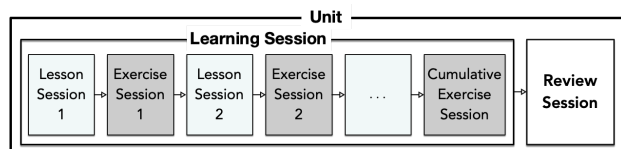


Figure 2: Lesson-Exercise sequence within a unit

These review sessions are automatically generated using a modified version of the SM-2 spaced repetition algorithm [1]. Correct or incorrect responses to exercise questions are weighed against the number of times the user has been exposed to that content, and the time since it was most recently shown, to assign a numerical index for that specific learning content. Each time the user completes an activity, that index is reevaluated so that new, more difficult, or less often seen exercises rise to the top of the list. This ensures that as the user continues to review, they are being given exercises that are most pertinent to their individual learning experience, while still reinforcing new and core concepts [3].

Language data are uploaded to the platform in the form of cards (see Figure 3), each of which is an element of language data that may consist of anything from individual sounds to morphemes, words, phrases, or complete sentences.

| Example Card Data | |
|--------------------|----------|
| Card ID | 3 |
| Card Type | word |
| Lakota Text | tʰó |
| English Text | blue |
| Lakota Audio | blue.mp3 |
| Grammatical Gender | none |
| Image | blue.png |

Figure 3: Backend Card Data

Cards incorporate text, audio, and graphic content for use in both lessons and exercises. Lessons may present cards as well as additional text, graphic, and audio data for providing explanations, and have been used for teaching alphabets, pronunciation, vocabulary, and advanced grammatical concepts (see Figure 4).



Figure 4: Lesson frame with text and card data

Lesson materials are then tested and reinforced with sets of exercises of varying types. A broad set of exercise types are programmed into the eLearning platform with the intent of introducing learners to Indigenous language through reading, writing, and listening. Exercise types include multiple choice, match the pairs, typing, fill in the blanks, anagrams, and true/false (see Figures 5 and 6).

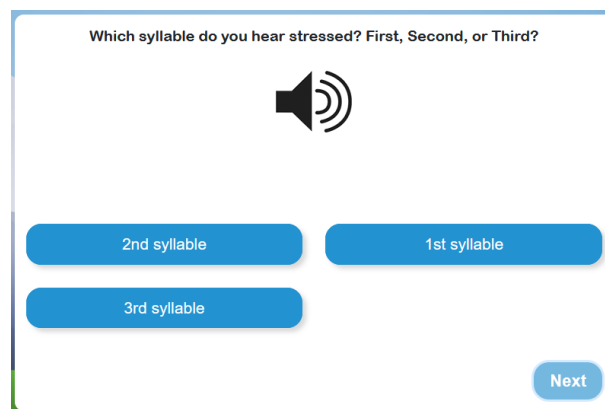


Figure 5: Example multiple choice exercise; listening

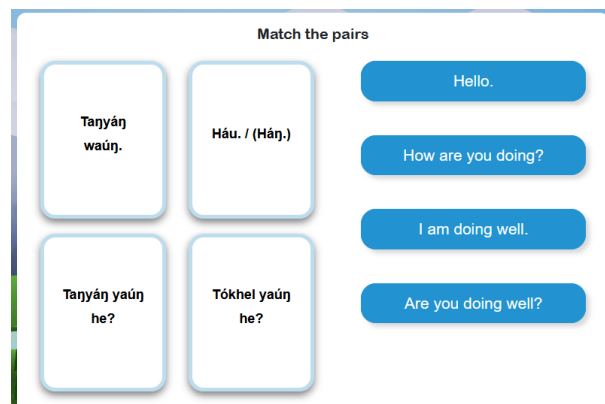


Figure 6: Example match the pairs exercise; reading

As curriculum is developed for varying proficiency levels and complexity of information, lessons and exercises remain flexible in their ability to teach and

test a wide range of information, from simple phonemic concepts to more advanced grammatical patterns.

When progressing through a learning path, the learner collects experience points and accolades (see Figures 7 and 8).



Figure 7: Lesson completion popup

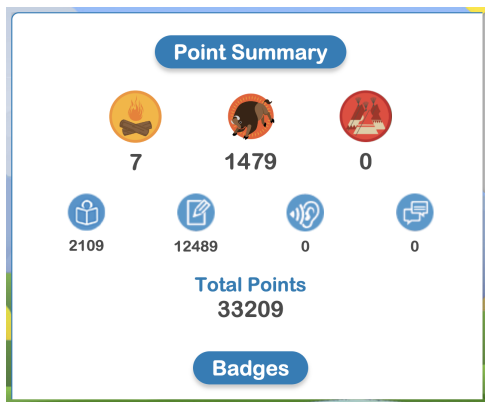


Figure 8: Gamification of eLearning; experience points and badges

At the end of each unit, users can quick-review the content they were just presented with, and are awarded badges. This both gives the users encouragement to continue on and allows for friendly competition amongst friends and classmates trying to out-score each other when completing their activities. Each unit also has its own forum section, known as the Village, where learners can discuss unit-specific content and get help. By connecting language learners within communities, the discussion boards aim to create an environment of cooperative learning where users come together and help each other progress in their language learning journey.

The eLearning backend user interface provides curriculum designers & content developers with a comprehensive system for data uploading and content customization (see Figures 9 and 10).

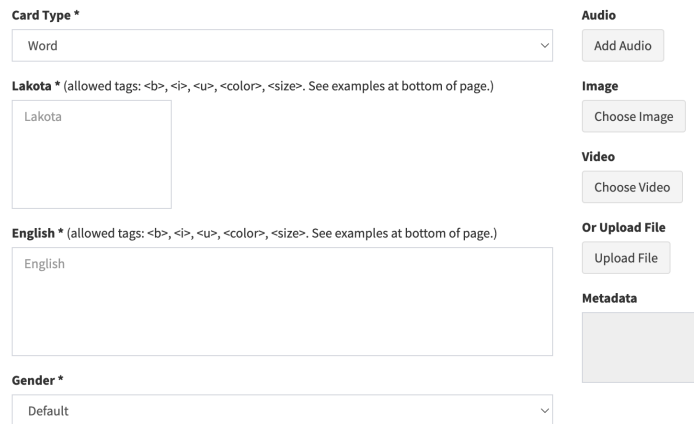


Figure 9: Page for manually adding/editing card data

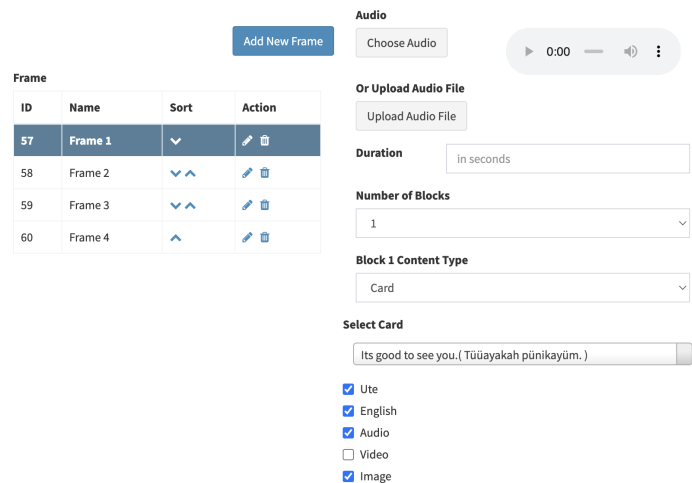


Figure 10: Page for manually adding/editing lessons

Audio and graphics can be uploaded to the platform database to be connected to lesson or card data. Cards, lessons, and exercises are created and edited either with an automated bulk uploader or individually within the backend's content creation interface.

In many cases, manual customization of individual lessons and exercises is employed to suit specific instructional goals, while bulk uploading of card data is used to incorporate more generalized language data and associate it with existing graphic and audio content automatically (see Figure 11).

| Frame | Block Type | Type | Language | English | Gender | Audio | Image |
|--------|------------|--------|----------|---------------------|-----------|-------------------|----------|
| Ignore | - Card - | Worc - | Jee | 3rd Person Standin | default - | 06132_je--standi | file.png |
| Ignore | - Card - | Worc - | Haje | 1st Person Standin | default - | | file.png |
| Ignore | - Card - | Worc - | Raje | 2nd Person Standir | default - | | file.png |
| Ignore | - Card - | Worc - | Nak | 3rd Person Sitting | default - | 9.4.1.1_nak_prese | file.png |
| Ignore | - Card - | Worc - | Šanak | 2nd Person Sitting | default - | | file.png |
| Ignore | - Card - | Worc - | Nak | 1st Person Sitting | default - | 9.4.1.1_nak_prese | file.png |
| Ignore | - Card - | Worc - | Ak | 3rd Person laying o | default - | 74026_ak--current | file.png |
| Ignore | - Card - | Worc - | Mak | 1st Person laying o | default - | 36550_ak--current | file.png |
| Ignore | - Card - | Worc - | Šawak | 2nd Person laying | default - | 36550_ak--current | file.png |
| Ignore | - Card - | Worc - | Hiža | A | default - | hizha.mp3_2_hiza | file.png |
| Ignore | - Card - | Worc - | Wa'q | To be | default - | 40372_wau--be_A | file.png |

Figure 11: Example unit contents excel file, used for bulk card creation

The overall structure and ordering of content, such as learning paths, levels, and unit contents is easily customisable as well.

As distance learning has become more widespread and important, especially in the wake of COVID-19 [2], we've been challenged to adapt to this situation. This prompted the development of the Teacher Portal (see Figure 12).

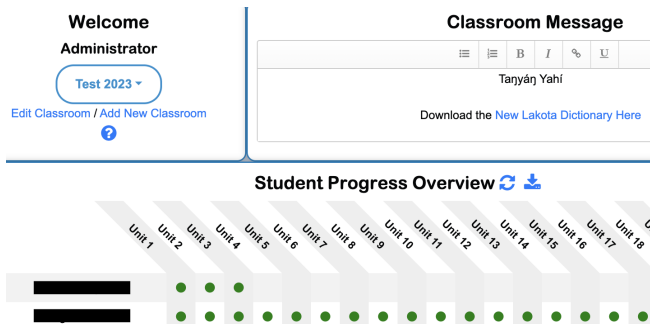


Figure 12: Teacher Portal Dashboard

An interface designed specifically for schools and teachers, the Teacher Portal contains areas for customizing curriculum content, managing assignments and tests, student rosters, and school management. With the lessons tab, teachers can create their own custom levels using existing content on the platform.

Teachers are then able to reuse and share levels created by other teachers, and teachers are given the option to make specified units available to students only after a certain date. Teachers can also monitor student progress, both overall and on-the-fly, gaining insight about which topics students are having trouble with, such as a particular grammar structure or vocabulary. While many language learning platforms offer a set learning path that must be followed, the Teacher Portal makes it possible to connect the TLC platform to existing classrooms with the flexibility to modify curricula to the needs of individual students and classes. Teacher training sessions have been conducted that reached more than 100 teachers and administrators. Usage data for one successful eLearning platform, Owóksape, made with the Lakota community, is as follows: 10,450 users (4,533 new users in 2020), 4,596,338 activities completed (2,341,696 in 2020), 882,474 minutes spent (411,316 in 2020), and 533 school users registered (480 students, 53 teachers). Since August 2020, 36 schools have registered and 13,047 activities have been completed in teacher-created

levels.

Each eLearning platform is separated into distinct websites, mobile apps, and codebases for each individual language. This empowers Indigenous communities by allowing an easy transfer of ownership of each platform to the community for which it was made. Whereas learning platforms often make use of a single site or app that keeps all offered languages tied together with the platform creator, the TLC platform can be easily transferred to community ownership without having their educational content tied to TLC and other communities' content. This separation between platforms for different languages is also what allows each community's culture to be appropriately represented in the theme, background, icons, and graphics of each individual platform, as opposed to many other learning platforms which support multiple languages all with the same art.

3. CONTENT CREATION AND CURRICULUM DEVELOPMENT

Different language partnerships require unique content development strategies, depending on available resources. This dynamic approach to generating custom curriculum serves to exemplify the adaptability of the platform, and to showcase its potential as a vanguard in the field of Native language education technology. In the case of the Lakota eLearning project, Owóksape, existing educational materials were available to be converted to eLearning content [7]. Beginner level materials such as the L1 and L2 textbooks (see Figure 13), as well as more advanced materials such as the Lakota Grammar Handbook (see Figure 14) had already been developed by TLC in conjunction with the Lakota Language Consortium prior to the inception of the Lakota eLearning project [5, 6, 8].

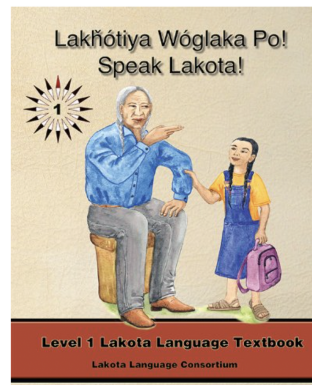


Figure 13: Lakota Level 1 Language Textbook

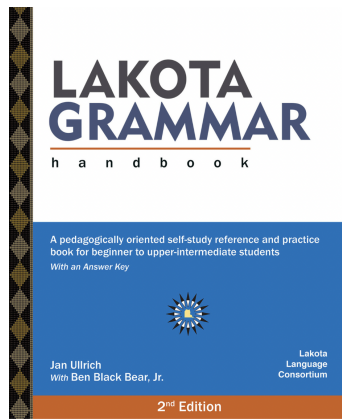


Figure 14: Lakota Grammar Handbook

The language data, images, and tables in use in these materials were uploaded to the eLearning platform with audio data for each and every example. The New Lakota Dictionary has also been fundamental to providing language data and audio for curriculum development on Owóksape [4]. By combining the existing information in these textbooks with audio capability, learners are familiarized with the sounds of Lakota and are able to develop listening skills along with reading and writing. Learning paths, levels, and units have been created on the eLearning platform corresponding to each textbook, chapter, and unit. All existing lessons and exercises from these books were added and formatted to fit within the structure of the platform.

In some cases, there are no existing educational materials developed by TLC which can be adapted into an eLearning path, or TLC may not have access to in-house linguists who specialize in a particular language. In these situations, TLC works closely with Indigenous educators and members of language & culture departments within the partnering communities to develop materials for their respective eLearning project. After communicating the structure and capabilities of the platform to inform their development of the curriculum, TLC then provides complete technical assistance, custom audio recording software, access to in-house graphic designers, as well as a means to change the styling of the interface itself, including culturally-relevant color themes, backgrounds, and icons. As the eLearning curriculum is modeled by partners and educators, TLC creates corresponding lessons and exercises on their platform to be reviewed and updated to their specifications. A continuous dialogue takes place between the local curriculum designers and TLC specialists

interacting with the eLearning backend interface to build and enhance an effective online learning space over time.

In other instances, Indigenous partners may not have the availability of local educators or graphic designers to develop curricula and graphics on their own, in which case TLC in-house linguists and illustrators work to design the eLearning curriculum and graphics with the assistance of Indigenous speakers. Through ongoing elicitation meetings with Native speakers, TLC linguists identify relevant language information and patterns for inclusion in the eLearning curriculum. Units, lessons, and exercises are then planned and created, informed by the successes and challenges of other eLearning projects. The TLC graphics team creates culturally relevant images to be approved by the Indigenous partners, and review of the created material is conducted by both partners and TLC linguists.

4. CONCLUSION

Online learning tools offer a great deal of accessibility, as well as structure for different learning paradigms. These benefits are significant and crucial components in the field of under-resourced language revitalization. In communities with an availability of educators and learning materials, the eLearning platform and its Teacher Portal offer a high degree of customization suitable to a wide range of material, from beginner to advanced language learners seeking improvement in reading, writing, and listening skills. In communities lacking consistent availability of educators and applicable learning resources, TLC linguists, graphic designers, and content developers work in partnership with Native speakers and community leaders to develop an online learning curriculum which meets the goals of the community. As TLC continues to partner with Indigenous communities to develop eLearning materials, the flexibility of content creation strategies and the platform itself will continue to be leveraged to adapt to the culture, resources, and educational goals of each individual community.

5. BIBLIOGRAPHICAL REFERENCES

- [1] Kramar, E. A., Babayan, A. H., Gavin, C. F., Cox, C. D., Jafari, M., Gall, C. M., Rumbaugh, G., and Lynch, G. (2012). "Synaptic evidence for the efficacy of

- spaced learning”. **Proceedings of the National Academy of Sciences**, 109(13):5121–5126.
- [2] R. Bansal, A. Gupta, R. Singh and V. K. Nassa, "Role and Impact of Digital Technologies in E-Learning amidst COVID-19 Pandemic," **2021 Fourth International Conference on Computational Intelligence and Communication Technologies (CCICT)**, Sonapat, India, 2021, pp. 194-202.
- [3] Ullrich, J., Thornton, E., Vieira, P., Swango, L., and Kupiek, M. (2020). "Owóksape - An Online Language Learning Platform for Lakota". **Proceedings of the 1st Joint Workshop on Spoken Language Technologies for Under-resourced languages (SLTU) and Collaboration and Computing for Under-Resourced Languages (CCURL)**.

6. LANGUAGE RESOURCE REFERENCES

- [4] Lakota Language Consortium, Inc. (2018). *New Lakota Dictionary. Version 1.1*. May 24, 2018. URL: <https://lakhota.org>.
- [5] Lakota Language Consortium, Inc. (2004). *Lakhotiya Woglaka Po! - Speak Lakota! Level 1 Lakota Language Textbook*. 2004. URL: <https://www.llcbookstore.com/lak-otiya-woglaka-po-speak-lakota-level-1-textbook/>.
- [6] Lakota Language Consortium, Inc. (2005). *Lakhotiya Woglaka Po! - Speak Lakota! Level 2 Lakota Language Textbook*. 2005. URL: <https://www.llcbookstore.com/lak-otiya-woglaka-po-speak-lakota-level-2-textbook/>.
- [7] Lakota Language Consortium Inc. (2019). *Owóksape*. Version 1.5. Dec. 9, 2019. URL: <https://owoksape.com>.
- [8] Ullrich, J. and Black Bear Jr., B. (2016). *Lakota Grammar Handbook*. Lakota Language Consortium, Inc., Bloomington, IN, USA, 1st edition.

Using Mozilla Hubs for Online Teaching: A Case Study of An Innovation Design Method Course

Banyapon POOLSAWAS

Faculty of Information Technology, King Mongkut's Institute of Technology Ladkrabang
Bangkok, 10520, Thailand

Nopporn CHOTIKAKAMTHORN

Faculty of Information Technology, King Mongkut's Institute of Technology Ladkrabang,
Bangkok, 10520, Thailand

ABSTRACT

During the Covid-19 pandemic, video conferencing platforms such as Zoom Online, MS Team Meeting, and Google Meets have been primary remote teaching tools. 3D immersive and non-immersive social platforms such as Mozilla Hubs have been studied as alternative tools for organizing remote teaching. This study aimed to assess the usability of Mozilla Hubs when applied to remote teaching and compared it to that of the widely used Zoom platform. An undergraduate course on innovation design methods was selected as the case study. Students enrolled in this course were divided into two groups. Distance learning was conducted through the Zoom platform for the first group of students. In contrast, the other group participated in the course activities through the Mozilla Hub platform within a non-immersive setting. The students in the Hubs group were requested to participate in the Hub pre-training class a week before the first week of the course's lecture. Six everyday tasks requiring student interaction with each of the two platforms were selected for the study. Usability was measured in terms of efficiency and ease of use. The time taken to complete each of the selected tasks was used to measure the efficiency of each platform. The System Usability Scale (SUS) questionnaire was used to measure ease of use. For most tasks, both platforms yielded comparable results regarding task efficiency. The only exception is for the room transition task, where the results differed between the two platforms depending on whether the teleport or 3D navigation methods were chosen by students in the Hubs group in order to complete the task. Discussion on the factors affecting the efficiency of the room transition task was provided. Using the SUS questionnaire, it was found that both platforms yielded comparable SUS scores of 68.91 and 70.66 for the Zoom and Mozilla Hubs platforms, respectively. Similar ease-of-use results were due to the offering of the Hubs pre-training class to the students using the Mozilla Hubs platform.

Keywords: mozilla hubs, virtual reality, remote teaching.

1. INTRODUCTION

During the Covid-19 pandemic, colleges and universities have been impacted, as students were requested to adjust their learning methods to an online and remote lecture system. Video conferencing systems such as Zoom Online, MS Team Meeting and Google Meets became a principal teaching platform used by students and instructors [1]. However, despite widespread

satisfaction with Zoom or Zoom-alike systems, many individuals reported experiencing "Zoom fatigue." [2] VR platforms offer an alternative to Zoom or similar apps by providing users an immersive and interactive online collaboration experience. While zoom and other video conferencing apps allow users to communicate in real-time, they do not offer the same level of engagement and interaction as VR platforms [3]. VR can be displayed in two visual formats: Immersive and Non-Immersive, viewed through VR Headsets and Desktop VR, respectively. The main challenge with Immersive VR is the high cost of VR headsets and the potential for unfamiliarity and motion sickness among some users [4]. While VR equipment has become increasingly affordable and user-friendly in recent years, access to such equipment among university students remained limited during the COVID-19 pandemic, particularly for those in lockdown who could only use equipment already available in their homes. Desktop VR is an alternative to Immersive VR in providing 3D collaboration experience without such limitations. This study focuses on the use of Non-Immersive VR for remote lectures. In our study, Mozilla Hubs was the chosen VR collaboration platform. The open-sourced platform can be used with a VR headset or a desktop computer. It can be accessed directly through a web browser. However, due to the lack of VR headsets among students in our case study and the potential VR sickness problem, the platform was adopted and used only in desktop settings. In addition, being an open-sourced software, the platform provides ample opportunities to customize to meet specific needs. This study aimed to assess the usability of Mozilla Hub, a non-immersive VR platform, among learners by comparing learning activities with groups using the Zoom Online Meeting. This evaluation was aimed to determine the feasibility of selecting a platform like Mozilla Hubs in non-immersive VR mode for teaching purposes. The 'Innovative Design Method' course utilized the platform for distance teaching activities. The curriculum was designed to create a conducive learning environment and foster awareness among learners through content placement, 3D Object models, and graphics summarizing key points. Furthermore, the platform featured a timer to collect data and measured the results of various activities while teaching through this platform. This paper is organized as follows. Section 2 presents the literature review, covering distance learning, remote classrooms, and remote lectures, as well as desktop or non-immersive virtual reality (VR) technologies and their applications in educational settings. Next, the research methodology used in this study is presented. Results are reported in Section 4, result and discussion with discussion provided. Concluding remarks are given in Section 5, conclusion.

2. LITERATURE REVIEW

Distance learning, remote classroom, and remote learning technology have become increasingly important during the COVID-19 pandemic [5]. These distance learning methods provide a flexible and accessible learning environment that can help save costs and reduce the need for physical resources. They also promote the distribution and accessibility of education, especially for students in remote areas [6]. Two primary modes of distance learning are synchronous e-learning and asynchronous e-learning. Asynchronous e-learning is an online learning mode where teachers and students interact at different times using a Web board or email for communication. Its advantages include the flexibility of self-study. Limitations include reduced instructor interaction and requiring students to be self-motivated and self-disciplined in their studies. Synchronous e-learning is a real-time online learning mode that offers several advantages, including live interaction with instructors and peers, immediate feedback, and a structured learning environment. However, it has some limitations, including scheduling conflicts and technical issues. There are several online tools available for synchronous e-learning.

Zoom, MS Teams, Google Meets, and similar programs are among the primary learning tools popular for synchronous e-learning due to their efficient facilitation. These programs gained significant popularity during the pandemic as a means of remote teaching. The use of video conferencing apps like Zoom and MS Teams for remote lecturing has been studied, with previous research reporting on the benefits and drawbacks of their usage. One of the issues highlighted with these apps is the phenomenon of "Zoom fatigue" [7]. Zoom fatigue is characterized by feelings of exhaustion, burnout, and increased stress resulting from prolonged periods of virtual meetings conducted on video conferencing platforms such as Zoom. The research study found that virtual meetings offer many benefits, including increased flexibility and reduced travel time. However, they also have adverse effects, such as increased stress and fatigue [8]. It was found that a common symptom is constantly staring at the camera to maintain eye contact during virtual meetings, which can be tiring and unnatural [9]. The study also revealed that this need could increase stress and cognitive load.

VR technology has been applied in various application areas. One of them is in education. The use of VR in education has been studied extensively in Learning in collaborative virtual environments: Design and Implementation [10]. VR has been used in simulations for educational purposes to enhance the learning experience by providing a safe and immersive environment that allows learners to practice and develop their skills, and its use for remote teaching has also been explored. VR technology can be utilized to enhance teaching and learning, such as by integrating it into online meeting applications like Zoom. However, implementing VR technology in teaching presents its challenges, particularly for immersive VR, such as the issue of motion sickness. Alternative to immersive VR is desktop or non-immersive VR. Desktop VR in education has been studied in [11]. In the research, as mentioned earlier, web-based desktop VR was used so students would not need to install any application, and it offers opportunities to build and customize a virtual environment. Other works, such as [12], focus on studying the usability of a desktop VR in the classroom. Mozilla Hub is one of the desktop VR platforms that can be used for remote classrooms. In the research as mentioned above, studies use Mozilla Hub for this purpose. The research results claimed that

the hypothesis that Mozilla Hubs would work well for all course learning activities was disproven. While it was adequate for smaller supervision meetings, it faced technical issues with audio and performance in more extensive gatherings of 25 students, making it inappropriate for such settings. Mozilla Hubs worked well for smaller supervision meetings with a handful of students. In previous works [12], the research explored the usability of desktop VR platforms by analyzing student experiences in attending lectures and giving project presentations using Mozilla Hubs. The author conducted 28 supervision sessions, of which 24 were immersive VR sessions in Mozilla Hubs, and during 6 of these, students shared their screens for collaborative work. However, no comparison with conventional online teaching tools such as Zoom was reported in [12].

This paper concentrates on applying a desktop VR platform, Mozilla Hubs, for remote teaching activities. Mozilla Hubs was chosen due to its support for immersive and non-immersive experiences, accessibility through a standard web browser, and open-source nature for future customization. The platform was applied to remote lectures and workshops in an undergraduate course on Innovation Design Method. The goal was to evaluate its usability and potential issues in using Mozilla Hubs compared to the Zoom application. The study employed both quantitative and standard usability questionnaire survey measures. The performance of two sample groups using Zoom Online and Mozilla Hubs Desktop VR was used to demonstrate similarities and differences between the two platforms.

3. RESEARCH METHODOLOGY

- 1) **Research Questions:** In this research, we aimed to study the usability of Mozilla Hubs as applied for remote teaching and to make a comparison with that of the Zoom Online application. We sought to measure the usability of both tools in facilitating remote learning and make a comparative analysis between Zoom Online and Mozilla Hubs.
- 2) **Experimental Design Setup:** The case study of an innovation design method course involving 102 students was conducted in collaboration with SCG Chemical Co., Ltd. to address a specific problem in their Operations Department at Height. The students were divided into two sections: the first section of 52 students attended the class via Zoom Online, while the rest (50) attended the class using Mozilla Hubs. Among these 102 third-year students, 53 are males, and 49 are females. Participants were randomly divided into one of two treatment groups for safety training with online materials such as website multimedia, text, and non-immersive VR. The course consisted of two learning activities, remote lectures, and online workshops, spanning over an 11-week period. Progress of the group assignments was reported and discussed during the workshop activities. Remote lectures were typically delivered in a main (virtual) room at the beginning of each weekly class. Each lecturer was followed by a workshop conducted in breakout rooms. Each week, After the lecture ends, students are asked to join the breakout room with respect to their assigned group; for the students trained using Mozilla Hub, a 3-hour training session was provided to teach the students how to use the platform. The platform training session was delivered a week before the first teaching class. The 3D scene design of Mozilla Hubs for virtual classroom spaces is shown in Figure 1.

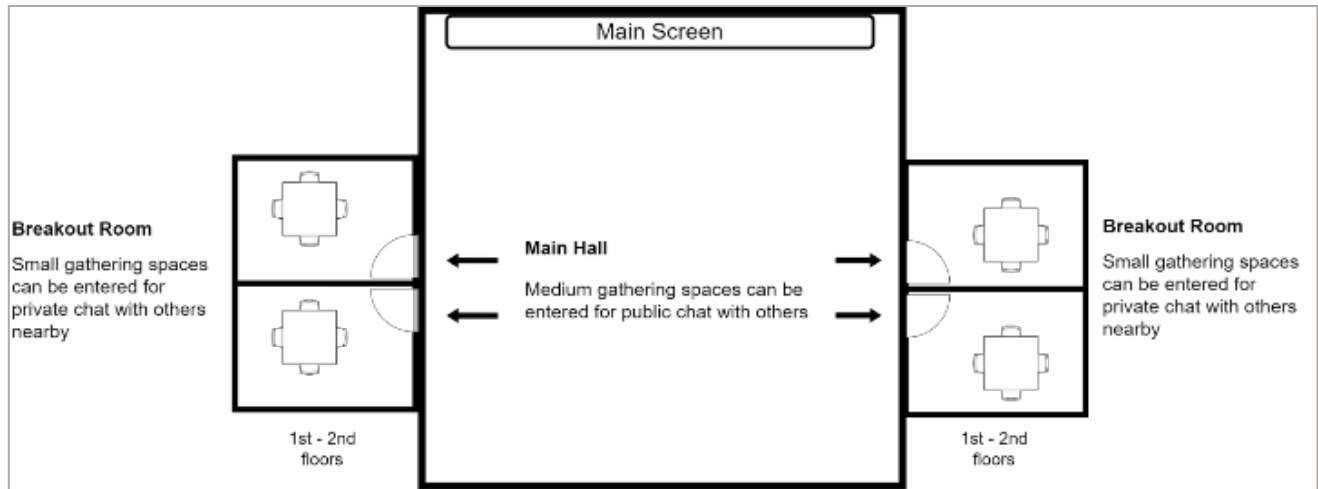


Fig 1: The 3D scene design of Mozilla Hubs for virtual classroom spaces.

The virtual classroom space was shared with participants, with each component being created in a separate virtual room. The main hall served as the initial starting point, from which individuals could navigate into breakout rooms designed for each conference component. The main screen in the main hall was used for presenting videos and presentation files from lecturers or guest speakers, while breakout rooms could be accessed through virtual doorways in the top section of the main hall. The room used for the keynote speaker could be accessed through doorways on the left and right sides of the main hall. The size and components of each room were customized based on the number of participants expected for each activity, following platform recommendations.

- 3) **Evaluation Methods:** For the students in both Zoom and Hub sections to participate in the learning activities, interactions with their respective learning platforms are needed to carry out certain tasks. The task list is shown in Table I. A typical flow of tasks and actions is described as follows: students and participants join the Main room, change their Display Name, check The Microphone and Speaker Settings, share screen or show presentation slides with others, answer in class questions and move to a breakout room.

Table1: Tasks and actions involved in interaction between students and each of the two platforms.

| Task | Task Detail | Action 1 (Zoom Online) | Action 2 (Mozilla Hubs) |
|------|-----------------------------|---|---|
| A | Join the Main room | Zoom Logged in (6 steps) | Magic link Logged in (6 steps) |
| B | Change Student Display Name | Edit Display Name in Zoom Setting Menu. (3 steps) | Edit Display Name and Avatar in Hubs Settings Menu. (5 steps) |

| | | | |
|---|---|--|--|
| D | Screen Sharing or Show Presentation slide with others | Click the Zoom screen-sharing button. (5 Steps) | Click the share icon button in the middle of the screen (4 Steps) |
| E | Answers in class questions | Use the Zoom chat function to send/submit answers. (2 Steps) | Use the Chat function in the toggle menu or icon chat at toolbars to send/submit answers. (3 Steps) |
| F | Move to a breakout room | Users are assigned to the breakout room by the moderator. | Press WASD or Arrow keys to move along a 3D scene to a breakout room or teleport to a breakout room. |

The first task in Table I involves connecting the main room in both Zoom Online and Mozilla Hubs, each with different steps. Tasks B and C involve changing the display name and checking the microphone settings in both platforms. To verify the presence of participants, Zoom Online relies on the display name, while Mozilla Hubs uses email verification. In Zoom, the number of chats can be counted using video recordings, while in Mozilla Hubs, responses during chats and student movements to breakout rooms were monitored using the WASD keyboard and a trigger timer.

4. RESULT AND DISCUSSION

When a task and action involve recording data through video, these tools can capture video and track event statistics on websites such as Mozilla Hubs, as well as timekeeping data from videos for each student activity in both tools. Usability issues, their measuring metrics, and the results due to each of the two platforms are summarized in Table II. The metrics used to measure the efficiency issues were collected using average times and number of steps to complete the task.

Table2: Efficiency Metrics, and their values for the cases of Zoom Online and Mozilla Hubs.

| Task | Metrics | Zoom Result | Hub Result |
|------|---|-------------|------------|
| A | Average time taken to login (seconds) | 2.49 | 2.11 |
| B | Average time taken to change their display name (seconds) | 1.2 | 1.7 |
| C | The number of operations needed to complete the task (number of steps) | 5 | 4 |
| D | Average time of user responding (seconds) | 1.41 | 1.73 |
| E | Average time of user responding * (seconds) | 0.73 | 0.88 |
| F | Average time spent moving to a breakout room. (seconds) Provide instructions to students on how to enter the breakout room for the first time. | 72 | 37 |
| | Provide instructions to students on how to enter the breakout room for the second time. | - | 60.6 |

Table II considers the efficiency of all tasks listed in Table I. The results are measured by recording the time taken for each task via video recordings of learning groups on both the Zoom Online platform and Mozilla Hubs.

From Table II, the average time required to complete task A (joining the main room) was 2.49 and 2.11 for the Zoom and Hub platform cases, respectively. The time required for the Zoom case was slightly longer than that of the Mozilla Hubs. As a preliminary step in this process, there is training for students on the basic usage of the Mozilla Hubs tool. The steps involved in using the platform include registration and identity verification through a session called the Magic Link component. This reduces the need for separate user account registration steps, saving time compared to this process in Zoom Online. In Zoom Online, some students may not be logged in initially, but they are prompted to perform additional login steps upon entering the program's main page.

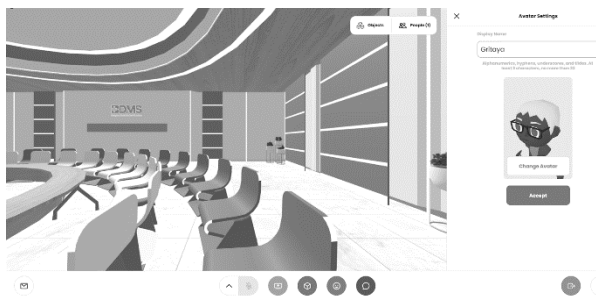


Fig 2: The login menu of Mozilla Hubs was hidden under the Toggle Menu

The Hub platform could have been more efficient for tasks B and F. For Task B, for Mozilla Hubs, the menu was more complicated. It required a user to access more menu levels than Zoom Online. Additionally, the task command was not immediately visible on the screen, as it was hidden under the Toggle Menu.

Task C, “Checking Microphone and Speaker Settings,” has a different number of operations. Zoom Online is used to test and select the device to capture the input of learners’ voices and the output of another in an online classroom. Is the signal sent to the correct channel for effective communication? The procedure will be tested, and their sound will be recorded in 5 steps. After that, learners usually mute the sound channel. Unlike Mozilla Hubs, the operation count will be four steps through the basic features of the web browser, where the learners can mute or unmute their own sound using the icon on the bottom bar of the program.

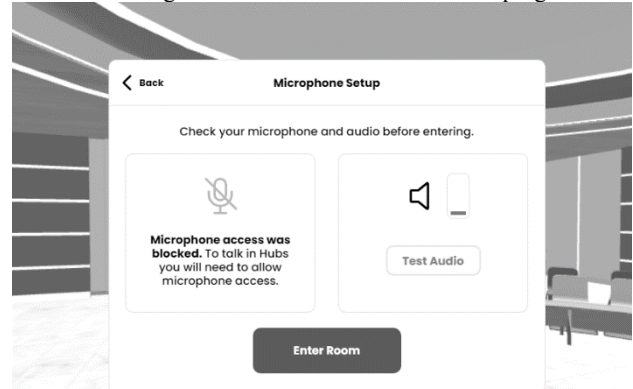


Fig 3: Check microphone and speaker settings.

Compared to Tasks A and B, the time to complete the task was not measurable. Therefore, task efficiency was evaluated using the number of operations required to complete the task for each platform. Table II shows that the number of required operations on both platforms is comparable. The average user response time, measured in Task D, is a test of student share screen time in Zoom Online and Mozilla Hubs.

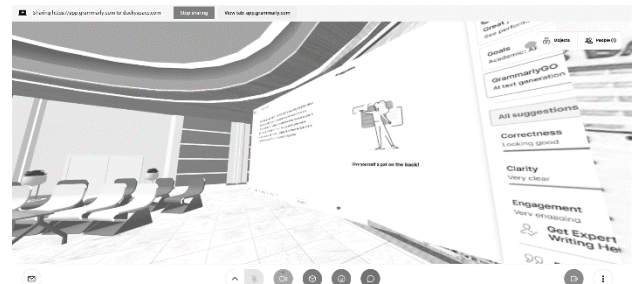


Fig 4: Sharing or Show Presentation slide with others, Mozilla Hubs operations involves a drag-and-drop direct manipulation action.

For Task D, in Zoom Online, four operations are needed for anyone, given permission, to share his/her screen. The average time required to complete the task is 1.41 seconds. For Mozilla Hubs platform, 3 operations are required to complete the task. While the number of required operations under the Mozilla Hub platform is one step fewer than that of the Zoom platform, the platform’s average completion time is 1.73 seconds, which is slightly longer than that of the Zoom platform. This is because one of the Hub operations involves a drag-and-drop direct manipulation action, which in general takes longer time than a simple mouse clicks.

For capturing engagement in the classroom or answering questions about how learners interact in an online classroom, both Zoom Online and Mozilla Hubs focus on response speed in Task Name "Answers question in the classroom via Chat." For Task E, the average time users took to answer in-class questions

was not significantly different for Zoom Online and Mozilla Hubs at 0.73 and 0.88 seconds, respectively.

For Zoom Online, Task F was carried out by an instructor, not students. Members of each subgroup were assigned to their breakout room by the primary instructor of each class group. Unlike Zoom Online, for the Mozilla Hubs platform, each student was responsible for moving from the main lecture room to a breakout room according to the learners' assigned class group. The learners using the Mozilla Hubs platform in Task F can move around by using these two ways. The first one is to press "WASD" on the keyboard and move in their desired direction. The second is to press the right mouse button while dragging to the targeted area in Virtual Space. These methods take about 37 seconds to access the Breakout Room in the first assembly announcement and 60.6 seconds in the second round. However, neither method captured the video shots of the learners who did not move or follow the instructor's order to gather in the Breakout Room. As for the analysis, it is better to further compare the angle of time and "Ease of Use" utilization in the next phase.

The SUS is a standardized questionnaire used to evaluate the usability of a system or product, and it provides a score between 0 to 100, indicating the overall usability of the system. The Ease-of-Use factor result or System Usability Scale result for two applications, Zoom Online, and Mozilla Hub, has not been provided in the given information. Instead, the information given is the number of email login operations which can be determined through video analysis for each application. For Zoom Online, the number of email login operations is 6, and for Mozilla Hub, the number of email login operations is 6.

One of the most significant features that a VR Desktop can bring to remote teaching and classrooms is the sense of presence in a virtual classroom. To measure this, we selected ten items from the SUS-Presence Questionnaire [14] and reworded them to fit the context of a VR desktop with Mozilla Hubs.

The SUS (System Usability Scale) score obtained from using Mozilla Hubs is 70.66, rated as "GOOD." [15] A SUS score above 68 is considered above average, while anything below 68 is deemed below average compared to similar platforms; the SUS score for Zoom Online averaged 68.91. However, compared to similar platforms, the SUS score for Zoom Online averaged 68.91, which is also considered exemplary. Therefore, the choice between the two platforms largely depends on the specific needs and preferences of the users. This study used standard usability questionnaires called SUS [16] to measure usability and user satisfaction.

5. CONCLUSION

The study analyzed the efficiency and ease of use of Zoom Online and Mozilla Hubs for various tasks such as login, screen sharing, answering questions, and moving to a breakout room. The efficiency of tasks was evaluated by analyzing the number of clicks and action steps required to complete each task. While Mozilla Hubs requires more steps and time to complete tasks, its function design uses colors and symbols to make the process less complicated than Zoom Online.

The login system's efficiency was measured by the average time users took, which improved from 2.49 to 2.11 seconds. However, the System Usability Scale (SUS) score, which provides an overall usability score between 0 to 100, was not provided for either application. The efficiency of screen sharing and

answering questions was also compared, with Zoom Online being slightly more efficient than Mozilla Hubs. Finally, moving to a breakout room was more efficient in Zoom Online than in Mozilla Hub, taking less time for users to move to a breakout room. Mozilla Hubs has a 15-minute pre-training process to teach students to understand the system and its functions before it is used as a primary teaching tool. In comparing "Feature Walk" and "Teleporting," we find that "Teleporting" offers the use of shortcuts and reduces movement time in the 3D world. It can navigate in a 2D space more effectively than movement in a 2D world. This makes "Teleporting" a convenient and problem-free method of transportation. Using 3D as an interface for user interaction provides a better user experience. It has a similar usage pattern to games, allowing users to understand it easily with common sense, without requiring specialized technical knowledge or expertise. This enables learners to access and utilize it more quickly and conveniently compared to other formats when interacting with more complex technologies than 3D.

Unlike Zoom Online, which is sometimes regularly used in remote teaching, the ease of use of the Mozilla Hubs platform is not guaranteed without pre-training. The data, as stated in this paper, cannot be directly compared to that of Zoom Online. In conclusion, using the Mozilla Hubs platform is problematic in terms of requiring additional pre-training steps and complex sequences of actions. However, logging in and performing various tasks leads to engagement in the system, with each action defined quite quickly. Users spend less time learning and interacting faster than with Zoom Online. The ease of use of the Mozilla Hubs platform may only be comparable to Zoom Online if pre-training is provided.

6. REFERENCES

- [1] Sjölie, D., Eriksson, T., Samuelsson-Gamboa, M., and Wideström, J.: 'Practical use of off-the-shelf virtual reality for distance education – a look at the feasibility of non-expert use'. Proc. EDUlearn, 2020
- [2] Karl, K. A., Peluchette, J. V., & Aghakhani, N. (2021). Virtual Work Meetings During the COVID-19 Pandemic: The Good, Bad, and Ugly. *Small Group Research*, 10464964211015286.
- [3] Sigander, M.Z., and Söderström, L.P.: 'Meeting applications in VR', (Chalmers University of Technology, 2020, edn.).
- [4] Kennedy, R. S., Drexler, J. M., & Kennedy, R. C. (2010). Research in visually induced motion sickness. *Applied Ergonomics*, 41(4), 494-503.
- [5] Rajabion, L., Azadnia, A. H., & Dabbaghian, V. (2021). Online learning in times of crisis: A systematic review of empirical evidence. *Computers & Education*, 160, 104002.
- [6] Geyer, W., & Effelsberg, W. (1998). The digital lecture board-a teaching and learning tool for remote instruction in higher education. In *EdMedia+ Innovate Learning* (pp. 63-69). Association for the Advancement of Computing in Education (AACE).
- [7] Reis, D., & Hopwood, N. (2020). Zoom fatigue? Teaching synchronous online classes during the COVID-19 pandemic. *American Psychologist*, 76(3), 363-364.
- [8] Karl, K. A., Peluchette, J. V., & Aghakhani, N. (2021). Virtual Work Meetings During the COVID-19 Pandemic: The Good, Bad, and Ugly. *Small Group Research*, 10464964211015286.
- [9] Barakat, L., Abouchedid, K., & El-Rassi, M. (2021). Examining factors contributing to Zoom fatigue and their impact on academic performance during the COVID-19 pandemic. *Journal of Educational Technology Systems*, 49(2), 147-161.
- [10] De Back, T. T., Tinga, A. M., & Louwense, M. M. (2021). Learning in immersed collaborative virtual environments: design and implementation. *Interactive Learning Environments*, 1-19.

- [11] Yoshimura, A., & Borst, C. W. (2021). A study of class meetings in VR: Student experiences of attending lectures and of giving a project presentation. *Frontiers in Virtual Reality*, 2, 648619.
- [12] Eriksson, T. (2021, May). Failure and success in using mozilla hubs for online teaching in a movie production course. In *2021 7th International Conference of the Immersive Learning Research Network (iLRN)* (pp. 1-8). IEEE.
- [13] Kumar, V. (2012). *101 design methods: A structured approach for driving innovation in your organization*. John Wiley & Sons.
- [14] Brooke, J. (1996). SUS-A quick and dirty usability scale. *Usability evaluation in industry*, 189(194), 4-7.
- [15] Sauro, J. (2011). SUSTisfied? Little-known System Usability Scale facts. *User Experience: The Magazine of the User Experience Professionals Association*, 10(3). [Last accessed: 9 March 2020].
- [16] Bangor, A., Kortum, P. and Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of usability studies*, 4(3), 114-123.

Digital Transformation of Resource Management of Territorial Communities Based on the Cloud ERP System in the Concept of Industry 4.0

Olena KOPISHYNSKA

Educational Research Institute of Economics, Management, Law and Information Technologies, Poltava State Agrarian University
Poltava, 36003, Ukraine

Yurii UTKIN

Educational Research Institute of Economics, Management, Law and Information Technologies, Poltava State Agrarian University
Poltava, 36003, Ukraine

Khanlar MAKHMUDOV

Educational Research Institute of Economics, Management, Law and Information Technologies, Poltava State Agrarian University
Poltava, 36003, Ukraine

Olena KALASHNIK

Educational Research Institute of Economics, Management, Law and Information Technologies, Poltava State Agrarian University
Poltava, 36003, Ukraine

Svitlana MOROZ

Educational Research Institute of Economics, Management, Law and Information Technologies, Poltava State Agrarian University
Poltava, 36003, Ukraine

Mykola SOMYCH

Educational Research Institute of Economics, Management, Law and Information Technologies, Poltava State Agrarian University
Poltava, 36003, Ukraine

ABSTRACT

The aim of this study is to explore the potential for creating a unified digital information space using a modern ERP system to manage all processes and resources of territorial communities, which are categorized as non-industrial enterprises. This research is conducted in the context of building a modern landscape of Industry 4.0 technologies, which are considered to be the future of industrialization. The practical case of Ukraine is used to illustrate the typical problems associated with the uncoordinated use of different types of software in the management of enterprises and organizations operating in territorial communities. Furthermore, the advantages of switching to a new ERP platform are discussed. The benefits of deploying the system's multi-tier architecture in the cloud and implementing a corporate model for parallel management of individual divisions and organizations are also highlighted. Overall, this study lays a foundation for the possibilities of creating a unified digital information space on the platform of a modern ERP system, which could potentially transform the way territorial communities manage their processes and resources.

Keywords: Industry 4.0, Cloud ERP, Community 4.0, Digital Technologies, Project Management

1. INTRODUCTION

The 21st century has witnessed the emergence of Industry 4.0, which is characterized by the dominance of knowledge and digital data. In this era, the development of new technologies for the automation of production processes requires a greater

emphasis on knowledge and skills regarding learning. The human-machine (H2M) relations are also shifting towards a reverse type of M2H, where machines interact without human participation (M2M) [1]. Despite the diversity of the technologies involved in Industry 4.0, four key technologies are essential: smart automation using artificial intelligence (AI) and the Industrial Internet of Things (IIoT), analytics and processing of big data (Big Data), and decentralization of management.

The reorganization of traditional hierarchical automation systems into self-organizing cyber-physical production systems (CPS) is a significant consequence of Industry 4.0 for all types of industrial production systems. This system allows for flexible mass production to order [2]. The "Industry 4.0" project was one of the ten "Future Projects" identified by the German government as part of the High-Tech Strategy - 2020. Countries that adopt a similar strategy will have a significant advantage in maintaining their competitiveness in world markets, not only in industrial production but also in all other areas.

In the pursuit of European integration, Ukraine has made significant strides toward implementing Industry 4.0 technologies, leveraging its robust scientific, intellectual, and educational capabilities. However, progress across industries and other spheres of activity has been inconsistent. Industry and engineering culture in Ukraine at the start of the 21st century can be broadly classified as being at the 2.0 or 3.0 level, depending on the sector. While metallurgical plants and enterprises in the aerospace industry are better positioned for digital transformation due to their export-oriented nature and global competitiveness, other industries such as power engineering lag significantly behind in terms of automation. The Association of Industrial Enterprises of Ukraine (APPAU), established as a funding and strategic development entity for Industry 4.0, has grown into a large expert community owing to the opening of

Industry 4.0 centers in the country's leading universities [3]. Given the varying levels of readiness across industries, these centers can help drive the Industry 4.0 movement in Ukraine by providing the necessary resources and expertise.

In contrast to well-automated industries and businesses, many state institutions and organizations, particularly local self-government in territorial communities, face challenges in processing large volumes of data and information. They require digitalization of operational activities, analytics, and decision-making support. The reform of the state administration system and the emergence of territorial communities is a key pro-European reform that is currently underway. With the support of international organizations and the Ministry of Digital Transformation, the Community 4.0 program was launched in Ukraine. The goal is the implementation of digital projects to ensure sustainability, attractiveness for investments, and new concepts. This paper explores the possibilities of creating a unified digital information space on a modern cloud Enterprise Resource Planning system to improve the management of all subjects in the territorial community and facilitate the transition to the Industry 4.0 technology landscape. We present a case study on the preparation of a pilot project for local self-government bodies in Ukraine. We discuss the selection and implementation of ERP modules with further prospects for scaling and integration with other systems and technologies.

2. AUTOMATION ON THE ERP PLATFORM AS A CONDITION FOR THE TRANSITION TO INDUSTRY 4.0

At the beginning of the Industry 4.0 era, the focus was solely on industrial production, but the paradigm has since expanded to include other areas of human activity. The paper [4] illustrates the convergence of 12 revolutionary technologies, including 3D printing, artificial intelligence, augmented reality, big data, blockchain, cloud computing, drones, the Internet of Things, nanotechnology, robotics, modeling, and synthetic biology in various sectors such as agriculture (Agriculture 4.0), healthcare (Healthcare 4.0), logistics (Logistics 4.0), energy (Energy 4.0), and elements of new educational technologies (Education 4.0). Sectors of the economy that encompass automated production, energy efficiency, and enhanced manufacturability will be transformed with new models of the value chain. Global megatrends such as globalization, urbanization, demographic changes, and energy transformation are factors that are driving the technological impulse to create innovative solutions in today's world.

In recent years, the development of Industry 4.0 technologies has expanded beyond the field of industrial production. This expansion includes agriculture (Agriculture 4.0), healthcare (Healthcare 4.0), logistics (Logistics 4.0), energy (Energy 4.0), and elements of new educational technologies (Education 4.0). However, many countries and certain industries still lack development of the previous level of Industry 3.0 technologies, even in developed countries, leading to a gap in competitiveness and opportunities [5]. Enterprises that have started digital transformation create pressure on others to keep up, but this presents risks related to security, personnel competence, data retention, and analytics [6]. The role of powerful Enterprise Resource Planning systems in processing new types of data, globalization of production, and decentralization of management remain debatable. ERP software will have to solve new tasks, such as data correlation and managing larger and more complex

volumes of data [7]. Experts believe that ERP software will be directly related to the control of the management system at the production level and will support Industry 4.0 technologies.

The authors of the work [8] have substantiated the main aspects of creating information systems for the management of production processes for agricultural enterprises and the role of ERP systems in processing big data. The leading role of universities in training modern specialists capable of mastering new IT technologies and e-competencies is shown in [9-10]. Therefore, in this work, the broader application of modern ERP class systems is considered a necessary element of the strategy to achieve the level of technology and culture 4.0 for non-manufacturing companies and organizations. It is important to note that Industry 4.0 is an evolution and continuation of Industry 3.0, and their connection and imitation are important. One cannot "jump" over Industry 3.0, which has not been fully achieved in both industrial and service industries. Industry 4.0 also has great potential to improve the efficiency of businesses and organizations and help restore the natural environment through better asset management, potentially even reversing all the damage caused by previous industrial revolutions.

An ERP-class information system (IS) is a sophisticated software product comprising interrelated technical means, procedures, and personnel that facilitate the storage, processing, and transmission of information while addressing specific tasks. The object of management in this context is information processes, which are typical across enterprises and organizations of various spheres of activity. As a result, it is possible to achieve a high level of universality of work methods across various systems.

Several independent sources have compared modern ERP systems [11-12] and found that they have a standardized composition. ERP systems, which have undergone continuous improvement over time, have a modular structure, with modules working as separate components, and should be easily combined when interacting with the database (Figure 1).



Figure 1. Module's types in a modern ERP system [13]

Most ERP solutions are adaptable and scalable according to the company's needs, which helps to prepare for any situations in business processes or changes in the market and respond promptly to them.

The uniqueness of ERP technologies lies in their ability to serve as universal software capable of integrating any business process. Combined with processes, systems, and data, ERP systems provide the analytics, acceleration, and adaptability needed to optimize business processes. ERP systems can increase the efficiency of organizations in three ways [13]:

- 1) Increasing productivity: ERP-based solutions provide analytics that helps to make informed decisions and suggests directions for further improvements in operational efficiency.
- 2) Accelerating operational decisions: Based on unified data and processes, the visibility and agility of employees increase, helping them to take action faster and achieve greater results.
- 3) Business flexibility: Most ERP solutions are adapted and scaled according to needs and provide prompt responses to risks and changes in business processes.

In summary, ERP systems are universal software that can integrate any business process. They are adaptable and scalable, and their use can lead to increased productivity, accelerated operational decisions, and business flexibility.

The Enterprise Resource Planning system is a complex software product that comprises a set of technical means, methods, procedures, and personnel interconnected to perform the storage, processing, and transmission of information for solving specific tasks. The information processes are the objects of management, some of which are typical in various enterprises and organizations, making it possible to achieve a high level of

universality in work methods across different systems. Modern ERP systems have a modular structure, and their components work as separate modules that can be easily combined when interacting with the database. The adaptability and scalability of most ERP solutions allow organizations to prepare in advance for any situation in business processes or changes in the market, as well as to respond promptly to them.

The division of ERP into subsystems provides several benefits, including the consideration of production needs during the development and modernization of the IS, the phasing of implementation, and the ease of operation of such IS due to the specialization of employees in the subject area for which separate modules have been developed. Organizations must carefully weigh their options for implementing the system, as the ideal strategy for phasing depends on several factors such as the speed of adaptation of the new ERP, types of risks and their consequences, willingness to invest, etc.

According to the international analytical company Panorama Consulting Group (PCG), as of the end of 2022, the majority of ERP users (64.4%) chose the cloud version of ERP systems (Figure 2), with usage options including hosted, manage - 48.3%, or SAAS - 51.7% [14].

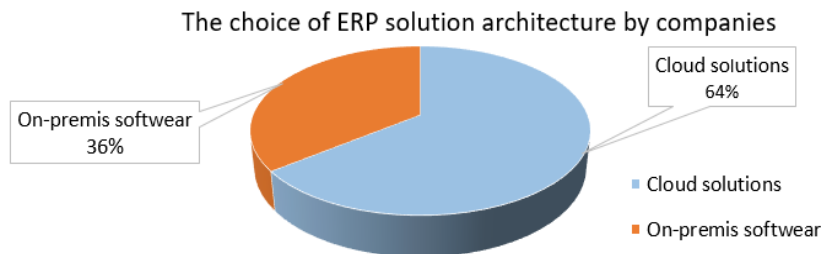


Figure 2. Distribution of companies' choices between cloud services and local system placement in the world [14]

PCG has identified the reasons why companies do not always choose a cloud solution. The largest part of respondents (40.91%) has insufficient information about the operating conditions of the system in the cloud; mistrust of information protection is observed in 27.27%. Because of the risk of data loss, a third of respondents choose the local installation.

To choose the optimal solution for their needs, companies should familiarize themselves with the offers and conduct an audit of their business processes and needs while weighing the risks and benefits. In 2022, less than half of organizations used a phased approach, while more than half used either an all-at-once approach or a hybrid approach. ERP Microsoft Dynamics 365, SAP S/4HANA, and Oracle are the most commonly used ERP systems among the 32 considered systems by PCG.

3. COMMUNITY'S INFORMATION PROCESSES STUDY DURING THE FORMATION OF A DIGITAL SPACE ON THE ERP PLATFORM: CASE OF UKRAINE

In 2023, there are 1,439 territorial communities functioning as administrative centers in 24 regions of Ukraine, except for temporarily occupied territories [15]. This study employs data gathered during advisory consultations provided by the Department of Information Systems and Technologies at Poltava State Agrarian University (PSAU) in the Poltava region. These consultations were conducted in 18 different communities, and

four pilot projects were discussed to establish a unified digital information space through modern ERP systems. The aim was to improve the efficiency of management of all processes and resources and to further implement 4.0 technologies. The selected communities had a population of 24,000 and were managed by the executive committee of the city council. Figure 3 illustrates the general structure of these communities.

The executive committee of the city council manages several departments, some of which are similar to enterprises (such as accounting, finance, land, legal, and communal management). They also have collaboration and contacts with external organizations. The objective of this study is to combine the activities of all structural units of the executive committee of the city council and other organizations and enterprises in a single information space.

There are several unique aspects to this task:

- 1) The city council consists of separate departments that do not engage in production but have a staff, an accounting department, deal with budgeting, conduct analytics, manage budget expenditures, cooperate with budget-forming organizations, and keep records of communal property.
- 2) Budget-forming enterprises have separate accounts, conduct accounting and management operations, and submit accounting and financial reporting to relevant organizations, including the city council.

- 3) Communal enterprises of the city council perform joint tasks of providing services to citizens of the community and keep financial records of resources and operations, partially financed from the budget of the city council.
- 4) The city council supports several secondary educational, cultural, social, and medical institutions. Budgetary funds are distributed to them, and reporting, accounting of fixed assets, and other types of provisions are conducted.
- 5) Document circulation is conducted between all constituents and external counterparties, state authorities, and various meetings, planning, and discussions of strategies take place.

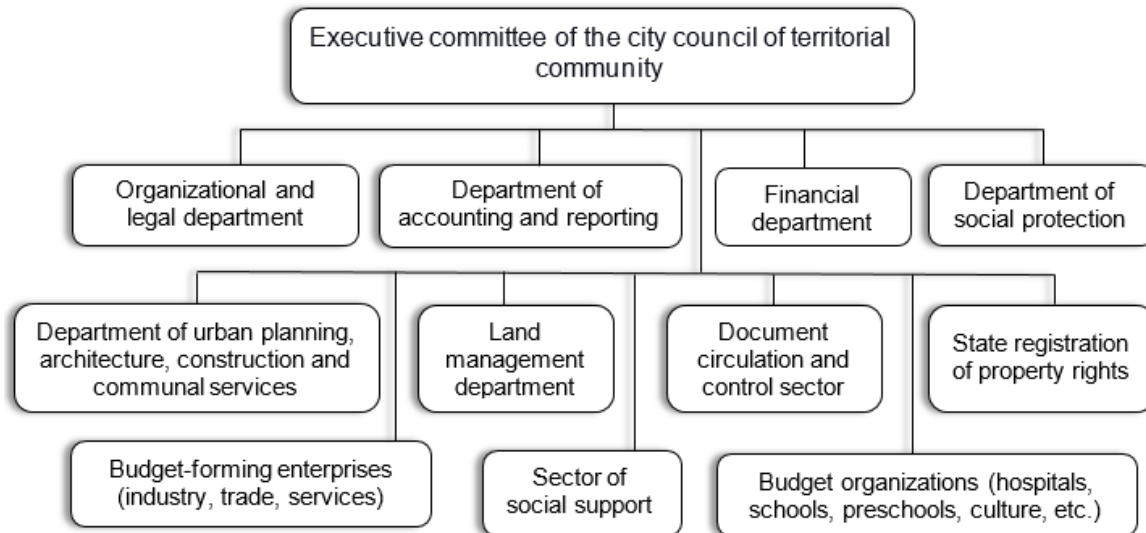


Figure 3 – Diagram of the organizational structure of the Executive committee of the city council

Results of the analysis of information activities and software of enterprises of the territorial community

Thus, the executive committee of the city council's activity involves a set of information flows classified as business processes, budget activity and analytics, legal activity, land accounting, etc. The management of information and business processes in the organization is approaching a crisis state. The city council leadership has initiated the transition from old management methods and software products, aiming to automate all information and management processes on a single platform of the ERP system. The top-down initiative in this situation is positive, as it reduces the period and complexity of staff adaptation to new conditions, and the decision-making center for the project coincides with the proposals of project stakeholders. One of the first questions that arise is which processes (accounting, management, financial) should be automated first. What approach to automation should be chosen for such an organizational structure? Ultimately, which of the known ERP systems will be the most effective for implementation in the organization?

University scientists, in collaboration with city council specialists, analyzed the functionality of the most popular international and domestic ERP systems in Ukraine [16-19], as well as the conditions of implementation projects, deployment, cost, and availability of post-project technical support. The results are presented in Table 1.

A thorough analysis of Enterprise Resource Planning (ERP) systems based on various sources [16-19] has revealed that these systems share a common set of functions, which automate the management of production, procurement, finance, personnel, costs, sales, budgeting, analysis of indicators, accounting according to legislation, payroll, GPS monitoring of transport management, and electronic document management.

Additionally, the systems offer Customer Relationship Management (CRM) modules and cloud solutions of the Software-as-a-Service (SAAS) model. Domestic systems have an edge in reporting documentation and integration with other systems of domestic production, such as electronic document management.

Based on this analysis, the "Universal 9" ERP system of the SoftPro company, which has a successful track record of over 30 years in implementing ERP systems in major industrial enterprises in Ukraine and other organizations, was selected for pilot projects.

The analysis of the organization's activities in collaboration with key specialists helped to identify problems that require precise solutions due to the introduction of a single ERP management system. Our survey of leading specialists from various organizations and enterprises operating as part of the territorial community and with various sources of funding has revealed the presence of different accounting departments, including accounting, contract accounting, cash accounting, salary and personnel, accounting of tangible and intangible assets, accounting of goods and material values, accounting of transport, and production accounting. These departments use different information systems, which can be grouped into accounting and tax reporting systems, accounting systems, specialized IT related to the specifics of the organization, and general-purpose software such as MS Word and MS Excel. Unfortunately, the accounting software is incompatible with the outdated personnel management system and attempts to integrate them have been unsuccessful.

Basic software complexes are hindering development. Until recently, individual departments and enterprises operating as part of the city council had sufficient basic tools. However, due to the implementation of local self-government reforms, tax changes,

requirements for electronic document flow, land reform, and other factors, the current program is insufficient and inhibits market advancement. As a result, opportunities for global growth are limited, and losses of budget revenues are being observed. It is, therefore, necessary to form a single software ecosystem on an ERP platform that is more flexible to support growth.

Cooperation with external organizations becomes more difficult when we fail to meet customer expectations. The only way to maintain a competitive advantage is to provide our staff with the necessary tools for success.

Table 1. Main advantages of choosing and using well-known ERP systems

| The name of the ERP system | Summary of the main advantages and characteristics of each system |
|---|--|
| Dynamics 365 (Microsoft) | Typically serves small to mid-sized organizations with \$250 million to \$750 million in annual revenue. An open system: the development and expansion of functionality are handled by the Microsoft company (one of 72 solutions of the Microsoft ecosystem), and partners from all over the world adapt to the laws of countries. There is localization for 90 countries (as of June 2022); teach users how to use the system and customize Business Central if the customer wants to cover individual non-standard business processes. It is possible to collect consolidated reporting in a single system from at least a dozen countries where companies have branches, to centrally make changes to processes without additional settings for each company, the usual Microsoft interface. |
| SAP ERP | Full automation of many work processes in large enterprises with a large number of workplaces, a complex production process. Adapted to Ukraine, it has all possible tools for controlling finances, accounting, and expenses. Automated with a separate CRM module or others |
| IT-Enterprise ERP (IT Enterprise, Ukraine) | It has an open platform, several industry solutions that can work both in the cloud and the installed version, are suitable for both service and production business processes, configured to manage large enterprises. High level of technology and automation in the market. |
| Universal 9 ERP (SoftPro, Ukraine) | A multi-level complex solution for the formation of a single information space of any enterprise or organization. Has a set of contours that the client chooses as needed; flexible configuration, and integration with other systems: CRM or separate electronic document flow. They have a line of solutions for small and medium enterprises to large enterprises and corporations. |

To implement a new ERP system, we can use project or standard technology. Our organization's management is considering the option of project implementation, which involves a pre-project study of the state of information processes management, existing databases, available technical support, and development of a technical task compatible with the executor, thereby reducing the risks of implementation and obtaining the predicted and intended result.

Details of the preparation of the ERP system implementation project

For the successful implementation of the IS implementation project in the organization, we have prepared its description, indicating the goals (SMART rule), tasks, expected results, necessary resources, and financial support. The project's description is the result of joint work by a group consisting of leading specialists of the organization, representatives of Infosvit IT Service LLC, and scientists of PSAU.

The selection of a project solution was determined by several peculiarities of the organization, which make it necessary to create a special project. These peculiarities include:

- 1) The complexity and scope of activities and tasks of automation cover a significant number of management and accounting contours, such as production, trade, warehouse, procurement, budgeting, personnel, and more.
- 2) The need to control the timing of implementation and the size of the allocated budget.
- 3) The automation of a complete set of business processes within the organization is envisaged.
- 4) At the beginning of the project, there is a vision of how the information system should work, but there are no clear requirements for the elements of the system.

- 5) There is no relevant industry solution at the time of implementation.
- 6) During the implementation of the project, it is necessary to monitor the progress of tasks.
- 7) It is necessary to monitor the budget development at the various stages of the project.
- 8) There is a need for resource planning, such as specialists, time, material support, and communications.
- 9) The need to minimize losses when switching to a new system.
- 10) The automation objects are geographically dispersed.
- 11) There are several legal entities with different account types that require automation.
- 12) Integration with other systems is planned in the future, such as electronic document flow for local self-government and "Kadastr.UA".

The above-mentioned factors facilitated the choice of a project solution that addresses the peculiarities of the organization and enables the automation of all business processes. The project solution also takes into account the need for monitoring and control of progress, budget development, resource planning, and integration with other systems. By addressing these challenges, the project solution minimizes losses and ensures a smooth transition to the new system.

To implement the ERP system effectively, a four-phase model of the project life cycle has been chosen. The model includes the following phases:

- 1) Analysis of business processes: The IT company, in collaboration with the customer's representatives, analyzes the efficiency of the business processes. If required, they reorganize the processes, build an information model of the

- system based on the principle of "how it should be," and formalize it into a technical task.
- 2) Adaptation of the system and trial operation: This phase is divided into several stages, each corresponding to a logical business process. Each stage is adapted and tested by the customer's specialists. At this stage, it is crucial to model the system's performance in various critical situations to minimize risks before it is put into industrial operation.
 - 3) System launch: In this phase, a large volume of existing information that cannot be lost is transferred to the system environment. Key indicators obtained from predecessor systems are also checked. Before starting the system, a "clean" data import is performed.
 - 4) Service, support, and development: The supplier company provides technical support to the customer's specialists as part of the implementation contract.

During stages 3 and 4 of the phase, personnel must undergo initial training to learn the new system. The IT company employees, along with PDAU (Poltava State Agrarian University) teachers, plan the training. The experience of the university's cooperation with IT companies has been used for more than 5 years [20]. Senior students are involved in the processing and transferring of previous data to ease their adaptation to the conditions of professional activity. The

Employers' Requirements-Oriented Study is described in detail in works [9, 10].

To customize the ERP system modules for specific organizations, the IT company creates the company's database model based on Oracle technologies. They also significantly refine program codes at the level of the system's programming. The "Universal" core is created using programming languages such as Alaska Xbase++, SQL/SQL scripts, Delphi, MS VBA, and popular web technologies like HTML 5&CSS3, PHP, JavaScript, Java, and others.

Before selecting and implementing a specific version of the "Universal" system, a comparison of the automation needs and the chosen solution's capabilities is necessary to avoid redundancy and unnecessary costs.

Most of the structural elements of the Executive committee of the city council are budget organizations with the same accounting methods, while individual enterprises and the territorial community council itself are not prepared to invest a significant amount from the budget for technical re-equipment. Hence, the latest version of the cloud-based "Universal 9" ERP system has been implemented, which incorporates all modern technologies for processing large volumes of data, user interface, and architectural solutions, and has all the advantages of cloud solutions. The structure of the "Universal 9" architecture is schematically presented in Figure 4.

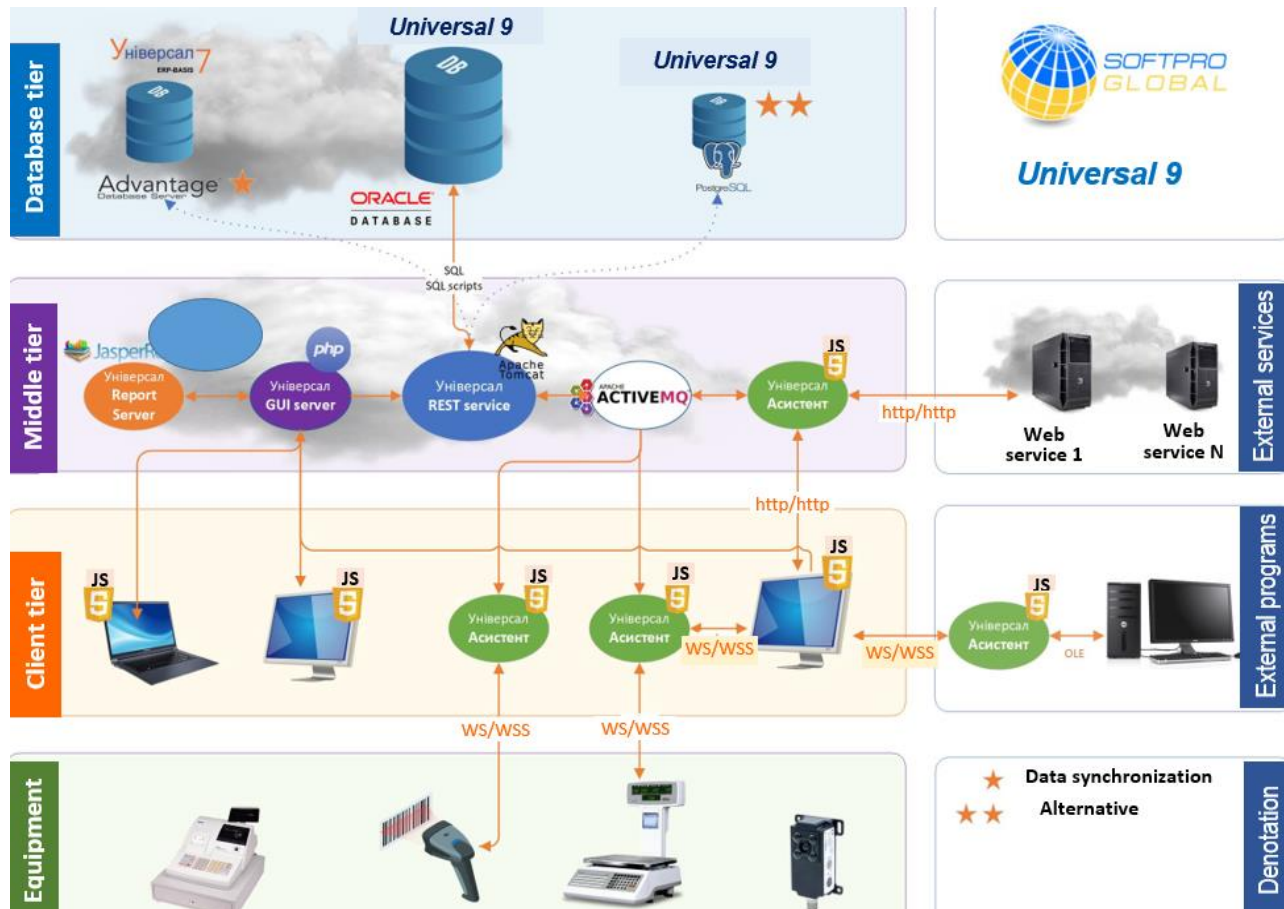


Figure 4. Multi-layered client-server architecture implemented in the "Universal 9" cloud (based on [19])

This architecture built according to the principle of a multi-tier system (multitier architecture) that contains and processes huge

amounts of data that come from both users and various equipment.

The advanced architecture of ERP "Universal 9" makes it possible to scale the system to most enterprises in the future, including those that plan to use special sensors to collect operational data from hundreds of meters using a combination of artificial intelligence and Internet of Things (AI + IoT) technologies based on algorithms described in [21-22]. System developers abandoned Windows client applications in favor of Web-oriented thin clients, for which one of several popular web browsers is sufficient. This approach significantly reduces the costs of deploying and maintaining client applications of the system.

The transition to utilizing a selected ERP system in a workplace environment commenced with the implementation of the accounting circuit. One of the primary tasks for launching the system in the organization was the creation of a new database model and transferring data from existing accounting systems to the new platform. For organizations with complex structures (as

illustrated in Fig. 3), "Universal 9" offers the key advantage of being able to manage several enterprises with different accounting schemes in one database, encompassing both accounting and operational accounting.

Each enterprise and accounting type within each structural unit is represented as a single linear list of charts of accounts. The same operation can be displayed according to specific rules in one or both charts of accounts. The core system enables accounts to be presented in different currencies and according to different customized standards. This architecture allows for several "spaces" to be located in one database, each of which stores a list of "its" enterprises. In turn, each enterprise has two levels of accounting: accounting and operational accounting. The developers themselves present such an accounting architecture using the example scheme shown in Figure 5.

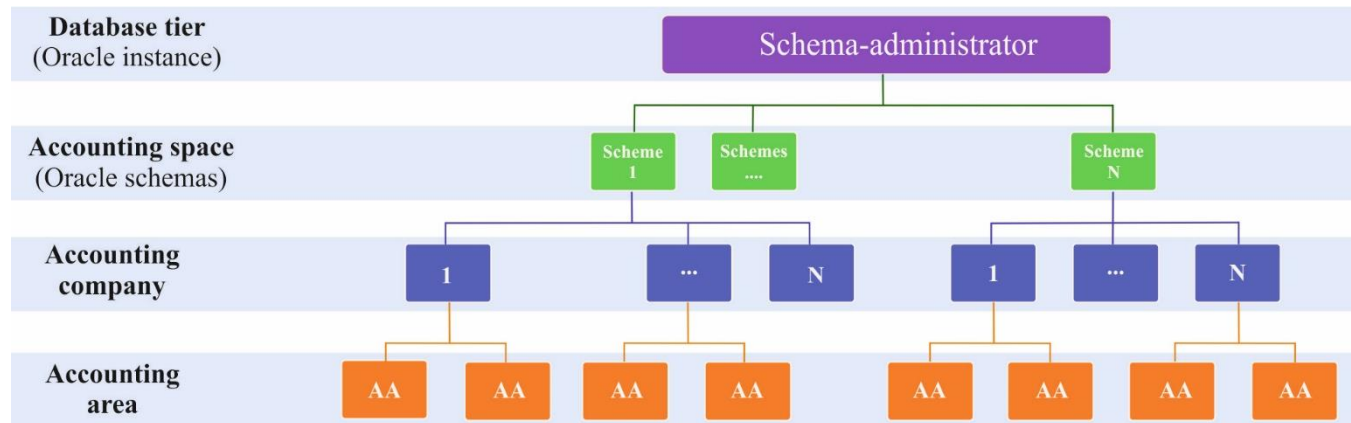


Figure 5. Schematic representation of corporate accounting architecture in "Universal 9" ERP

This approach facilitates making unified centralized settings and administration rules for several organizations (enterprises) with subsequent data exchange between them. Technically, this approach allows for creating a test enterprise, carrying out settings on it, transferring the settings to the main (dispatch) scheme, and then applying them as needed for existing enterprises.

4. CONCLUSIONS

As many enterprises and organizations move towards implementing Industry 4.0 technologies (Economy 4.0, etc.), they must first reform their automation of production and management processes at the 3.0 level. In many cases, this is accomplished on the platforms of modern ERP systems. The type of organization considered in this work, such as the executive committee of the city council of the territorial community, is not a typical representative of business or industrial enterprises but rather has a complex organizational structure comprising various divisions or individual enterprises.

They have their codes in the registers of enterprises and organizations, and charts of accounts, and some of them are taxpayers and budgetary organizations of the territorial community. The presence of various types of software, applied IS, the loss of effectiveness in solving common tasks, and the need for complex analytics and control prompt managers to modernize the management and accounting system by creating a

single information space on the platform of a modern ERP system.

Upon completing the formation of a single information space for managing the operational and prospective activities of local self-government bodies, it is worth emphasizing the benefits that most enterprises and departments will receive after transitioning to the ERP platform:

- 1) A common database that centralizes information from many departments and provides a consistent cross-functional view of the company.
- 2) A consistent user interface (UI) and user interaction (UX) across departments and roles. The ERP's Inventory, HR, and Finance modules share the same look and functionality, provided they are sourced from the same vendor. A consistent UX and UI also drive efficiency, as users can quickly find and understand information from all corners of the business.
- 3) Integration of business processes. ERP is capable of supporting and integrating a diverse set of processes that make all kinds of business and other activities successful. This increases productivity and visibility and therefore lowers costs.
- 4) Automation of repetitive tasks, reducing manual data entry and sometimes duplication, saving time, and minimizing errors.
- 5) Data analysis is one of the most valuable aspects of ERP that breaks down information silos. The ability to mix and match data from almost any part of a large enterprise organization

into in-depth reports reveals areas that are performing exceptionally well and those that are not meeting expectations. Leaders can analyze problems and start solving them immediately.

Further research should focus on developing a stack of technologies that can integrate with the cloud ERP system, leading to the creation of a modern software landscape that aligns with the Industry 4.0 framework.

5. REFERENCES

- [1] A. Rojko, "Industry 4.0 Concept: Background and overview", **International Journal of Interactive Mobile Technologies (IJIM)**, Vol 11, No. 5, 2017, pp. 77-90. doi: 10.3991/ijim.v11i5.7072.
- [2] Singh G., G. Bhardwaj, S. V. Singh, P. Chaturvedi, V. Kumar and S. Gupta, "Industry 4.0: The Industrial Revolution and Future Landscape in Indian Market," *2021 International Conference on Technological Advancements and Innovations (ICTAI)*, Tashkent, Uzbekistan, 2021, pp. 500-505, doi: 10.1109/ICTAI53825.2021.9673154.
- [3] Yurchak O. Ukrainian strategy of Industry 4.0 – 7 directions of development. URL: <https://industry4-0-ukraine.com.ua/2019/01/02/ukrainska-strategiya-industrii-4-0-7-napriankiv-rozvitku/> [accessed 2023/03/11].
- [4] Bongomin, O., Yemane, A., Kembabazi, B., Malanda, C., Chikonkolo Mwape, M., Sheron Mpfu, N., & Tigalana, D., "Industry 4.0 Disruption and Its Neologisms in Major Industrial Sectors: A State of the Art", **Journal of Engineering**, 10 October 2020, pp.1–45. DOI: 10.1155/2020/8090521
- [5] Reinhard Geissbauer, Jesper Vedso, Stefan Schrauf. Industry 4.0: Building the digital enterprise. URL: <https://www.pwc.com/gx/en/industries/industries-4-0/landing-page/industry-4-0-building-your-digital-enterprise-april-2016.pdf> [accessed 2023/03/10].
- [6] Queiroz, M. M., Pereira, S.C.F., Telles, R. and Machado, M.C. "Industry 4.0 and digital supply chain capabilities: A framework for understanding digitalisation challenges and opportunities", **Benchmarking: An International Journal**, Vol. 28 No. 5, 2021, pp. 1761-1782. DOI: <https://doi.org/10.1108/BIJ-12-2018-0435>.
- [7] J. Hietaniemi. Industry 4.0 Brings A Paradigm Shift. URL: <https://gofore.com/en/industry-4-0-brings-a-paradigm-shift/> [accessed 2023/03/11].
- [8] O. Kopishynska, Y. Utkin, O. Galych, M. Marenych and I. Sliusar, "Main Aspects of the Creation of Managing Information System at the Implementation of Precision Farming", *2020 IEEE 11th International Conference on Dependable Systems, Services and Technologies (DESSERT)*, 2020, pp. 404-410, doi: 10.1109/DESSERT50317.2020.9125072
- [9] O. P. Kopishynska, Y. V. Utkin, S. V. Voloshko, I. I. Sliusar and O. G. Kartashova, "Algorithm of creating of an efficient cooperation between universities, business companies and agriculture enterprises during studying and implementation of information systems," *2018 IEEE 9th International Conference on Dependable Systems, Services and Technologies (DESSERT)*, 2018, pp. 682-686, doi: 10.1109/DESSERT.2018.8409219
- [10] Kopishynska, Olena; Utkin, Yurii; Lyashenko, Viktor; Barabolia, Olha; Kalashnik, Olena; Mororz, Svitlana; Kartashova, Olga, "Information Systems and Technologies in Agronomy and Business: Employers' Requirements-Oriented Study in Agricultural Universities", Proceedings of the 25th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2021), July 18-21, 2021. Pp. 113–118.
- [11] Md. Tareq Hasan, "Impact of ERP System in Business Management", **International Journal of Management Studies**, Vol. 4, No.4, 2021, pp.24-31. DOI: 10.18843/ijms/v5i4(4)/03
- [12] H. Hassabelnaby, D.Hwang, M. Vonderembse, "The impact of ERP implementation on organizational capabilities and firm performance", **Benchmarking An International Journal**, Vol. 19, Issue 4/5, 2012, pp. 618 – 633. DOI: 10.1108/14635771211258043
- [13] Aniruddh Parmar, Supriya Bajaj, "Different Types of ERP Modules and It's Business Benefits", November 28, 2022. URL: <https://www.softwaresuggest.com/blog/erp-system-modules/#> [accessed 2023/03/11].
- [14] The 2023 ERP Report. **Panorama-Consulting Group**. URL: <https://www.panorama-consulting.com/resource-center/erp-report/> [accessed 2023/03/10].
- [15] Communities. URL: <https://decentralization.gov.ua/en/newgromada> [accessed 2023/03/10].
- [16] Dynamics Microsoft. URL: <https://dynamics.microsoft.com/en-us/> [accessed 2023/03/10].
- [17] IT-Enterprise. URL: <https://www.it.ua/products> [accessed 2023/03/10].
- [18] "SAP S/4HANA Cloud, the cloud ERP for every business need". URL: <https://www.sap.com/products/erp.html> [accessed 2023/03/10].
- [19] SoftPro. URL: <https://www.wgsoftpro.com/2017/main.php> [accessed 2023/03/10].
- [20] Olena Kopishynska, Yurii Utkin, Ihor Sliusar, Vadym Sliusar, Nadiia Protas, Olha Barabolia, "Professional-oriented training of specialists under implementation of cloud computing information systems in cooperation between universities and IT companies" *Proceedings of The 14th International Multi-Conference on Society, Cybernetics and Informatics (IMSCI 2020), September 13-16, 2020*, pp.17-22. URL: <https://www.iis.org/CDs2020/CD2020Summer/papers/EA790UO.pdf> [accessed 2023/03/10]
- [21] Vadym Sliusar, Ihor Sliusar, Nataliia Bihun, and Volodymyr Piliuhin, "Segmentation of analogue meter readings using neural networks", 4th International Workshop on Modern Machine Learning Technologies and Data Science MOMLET&DS2022, 23 -25 Nov. 2022, pp. 165–175. URL: <https://ceur-ws.org/Vol-3312/paper14.pdf> [accessed 2023/03/10].
- [22] Vadym Sliusar, Mykhailo Protsenko, Anton Chernukha, Stella Gornostal, Sergey Rudakov, Serhii Shevchenko, Oleksandr Chernikov, Nadiia Kolpachenko, Volodymyr Timofeyev, Roman Artiukh, "Construction of an advanced method for recognizing monitored objects by a convolutional neural network using a discrete wavelet transform", **Eastern-European Journal of Enterprise Technologies**, Vol. 4, No. 9(112), 2021, Pp. 65 - 77. DOI: 10.15587/1729-4061.2021.238601

Systemic Challenges of Digital Foreign Languages Education in Global Emergency Meta-Context (The Pandemic and Warzone Perspectives)

Rusudan MAKHACHASHVILI

Germanic Philology Department
Borys Grinchenko Kyiv University, Bulvarno-
Kudryavska-st., 18/2,
Kyiv, Ukraine

Ivan SEMENIST

Oriental Studies Department
Borys Grinchenko Kyiv University, Bulvarno-
Kudryavska-st., 18/2,
Kyiv, Ukraine

Ganna PRIHODKO

English Philology Department
Zaporizhzhya National University,
Zhukovsky-st., 66a,
Zaporizhzhya, Ukraine

Olexandra PRYKHODCHENKO

English Philology Department
Zaporizhzhya National University,
Zhukovsky-st., 66a,
Zaporizhzhya, Ukraine

Olena TUPAKHINA

German Philology and Translation Department
Zaporizhzhya National University,
Zhukovsky-st., 66a,
Zaporizhzhya, Ukraine

ABSTRACT

The worldwide pandemic and, subsequently, the active warzone in Eastern Europe (Ukraine) has posed a variety of difficulties for construction, procedure and methodology of higher education that impacted the extent of personal experience, results and quality of university education worldwide.

The COVID-19 pandemic induced amplified digitalization measures in the higher education sphere, informed by the need to take quick comprehensive action in order to achieve the overarching result to transform educational scenarios into interdisciplinary digital, blended, and hybrid frameworks.

The objective of the study was to assess the dynamic changes in the effectiveness of digital education for Foreign Languages programs in Ukraine, in the pandemic and wartime emergency timespan (2021 to 2023). The comparative survey benchmarking of various dimensions of digital learning is implemented to evaluate the progress individual quality and efficiency of transforming traditional Foreign Languages Acquisition process into online remote and hybrid format, facilitated by digital technologies.

Keywords: Systemic Challenge, Digitization, Dynamics, Foreign Languages Education (FLE), Wartime Digitization

1. INTRODUCTION

The worldwide pandemic and, subsequently, the active warzone in Eastern Europe (Ukraine) has posed a variety of difficulties for construction, procedure and methodology of higher education that impacted the extent of personal experience, results and quality of university education worldwide [1, 2, 3, 4, 5].

The COVID-19 pandemic induced amplified digitalization measures in the higher education sphere, informed by the need to take quick comprehensive action in order to achieve the overarching result to transform educational scenarios into interdisciplinary digital, blended, and hybrid frameworks [6, 7].

Taking into account the context of the erupted military intervention on Ukraine in February 2022, and the ensuing information warfare in various digital ambients (social media, news coverage, digital communications), the specific value of the learning outcomes and outputs is allocated to the digitally enhanced foreign languages education as a tool of the internationally broadcast strife of Ukraine for freedom and sovereignty.

The consequent functional tasks to meet this challenge in the educational sphere are estimated as 1) adapt the existent educational scenarios to digital, remote and hybrid formats; 2) to upgrade ICT competence and digital literacy of all participants of the educational process under extreme duress; 3) to activate

¹ Peer-editor: Nataliia Lazebna, Hab. Doc., Würzburg University, Germany

complex interdisciplinary (soft and hard) skillsets, otherwise latent or underutilized in the educational process.

The objective of the study is to evaluate the dynamic changes in the effectiveness of digital education for Foreign Languages programs in Ukraine, in the pandemic and wartime emergency timespan (2021 to 2023). The comparative survey benchmarking of various dimensions of digital learning is implemented to evaluate the progress individual quality and efficiency of transforming traditional Foreign Languages Acquisition process into online remote and hybrid format, facilitated by digital technologies.

2. STUDY DESIGN

The digital and hybrid learning activities in Foreign Language Education were qualitatively profiled in order to design an online survey to evaluate individual experiences in emergency digitization paradigm for university students of Oriental and European Languages programs.

The study mission scope permits to disclose the following tracks of findings:

Modelling of various digital distant learning formats (u-learning, m-learning, hybrid learning) and modes for university-level Foreign languages programs and projected digital literacy requirements for different groups of stakeholders;

Comparative analysis of in-depth assessment of individual digital and hybrid learning experiences and by different groups of stakeholders in European and Oriental Languages university level programs in regions of Ukraine according to such dimensions:

Dimension A: individual perception of e-learning and hybrid learning quality of foreign languages acquisition programs by different groups of stakeholders according to the role in educational process, previous experiences and foreign language proficiency;

Dimension B: variation in e-learning and hybrid learning quality assessment on foreign languages programs in different regions of Ukraine due to educational factors (core competences, soft skills proficiency; learning design);

Dimension C: variation in e-learning and hybrid learning quality assessment on foreign languages programs in different regions of Ukraine due to social and psychological factors (information fatigue, stress, community influence);

Dimension D: variation in e-learning and hybrid learning quality assessment on foreign languages programs in different regions of Ukraine due to technological factors (digital literacy, digital divide, digital gap);

Institutional recommendations for customization of digital and hybrid learning models and procedures, tailored to the individual and group needs of stakeholders in Foreign Language Acquisition on university level beyond the continuous emergency measures.

The inquiry design incorporates the following consecutive steps: digital and hybrid learning activity, experience and application profiling;

The online survey method applied to conduct in-depth assessment of individual digital distance and blended learning experiences and practices by relevant groups of stakeholders (students, faculty and administrative staff) in Oriental and European Languages university level programs in regions of Ukraine;

digital content analysis of individual associations with different modes of learning by relevant groups of stakeholders in Oriental and European Languages university level programs in regions of Ukraine (via corpus and text-mining tools);

digital and hybrid learning models and procedures adaptation and customization, tailored to the individual and group needs of stakeholders in Foreign Language Acquisition on university level.

Three consecutive online surveys of over 700 teachers and students of European and Asian Languages provide for assessment of progressive dynamics of efficiency of digitized foreign languages education, assessment of changes in quality evaluation of digital and hybrid education in the timespan of the pandemic measures through the years 2021-2022 and wartime digitization measures of 2022-2023; assessment of changes in quality evaluation of digital and hybrid through the pandemic as compared to regular, in-presence and wartime emergency foreign languages learning modes; quality evaluation of education design, dynamic development of learning results and acquired competences for university-level Foreign Languages programs in the timespan of 2021-2022 quarantine limitations and 2022-2023 wartime challenges.

The survey was launched for the first time in January 2021 to evaluate the quality of emergency digitization experiences of students in 2020 (the first academic year of the quarantine measures). The non-comparative results are published separately [5]. The survey was then repeated in November 2021, to evaluate the quality of ongoing digitization experiences of Foreign Languages students and to estimate positive or negative dynamics in e-learning quality assessment in 2021 (the second academic year of the quarantine measures). The survey was again repeated in December 2022, to evaluate the quality of emergency digitization experiences of Foreign Languages students in the active warzone to estimate positive and negative dynamics in e-learning quality assessment (the first academic year of the wartime measures in Ukraine).

The online questionnaire for both benchmarking iterations was identical and comprised of 21 questions total, divided into such dimensions:

- 1) Questions that disclose the generic evaluation of individual experiences of digital education for Foreign Languages Programs in the global lockdown measures and active warzone measures;
- 2) Questions that disclose the comparison of individual experiences and quality of individual experiences of digital emergency education and traditional, in-presence education in Foreign Languages Programs;
- 3) Questions that disclose the individual quality assessment of the emergency induced digital education design and workflow, education results and skills, developed in HEI programs of Foreign languages.

3. FINDINGS

In technological and professional teaching as well as education methods, difficulties containing insufficient distant teaching and structural disadvantages, have appeared in the crisis. Disruptions in workplaces complicated apprenticeship projects as well as, the main constituents of a market-responsive technical and vocational system.

In higher education, online instruction has been provided through different recorded assignments and distance platforms. On the other hand, this form of learning and teaching has been postponed by a number of institutions of higher education, owing to the lack of instructions concerning technological communications. Moreover, there are problems with how to adjust terms and educational schedules, as some sets of courses can be successfully realized in distant forms and some cannot [9, 10, 11, 12].

Qualitative assessment of the e-learning and hybrid learning was conducted through the retrospective evaluation of respondents' individual experience through the span of emergency digitization measures, in order identify and select the preferred features and elements of e-learning and hybrid learning among the following:

- 1) Ability to work from home (ability to study/teach in evacuation);
- 2) Ability to customize of the study space (video conferencing or LMS);
- 3) Adaptability and flexibility of the work schedule;
- 4) Save time for commute (save time to a bomb shelter);
- 5) Parallel performance of several tasks and activities;
- 6) Opportunity to technologically diversify educational activity, educational materials and methods;
- 7) Ability to adapt the structure and content of curricula of disciplines to the conditions of online learning;
- 8) Ability to activate and improve different types of soft skills;
- 9) Opportunity to improve digital literacy;
- 10) Ability to work independently in the learning process;
- 11) No need for constant interpersonal communication;
- 12) Ability to engage international professionals through digital means.

Evaluation of respondents' individual experience through the span of emergency digitization measures, in order identify and select the features and elements of e-learning and hybrid learning, considered drawbacks, challenges or a hindrance among the following:

- 1) Forced need to work at home (uncomfortable living conditions, the need to use a bomb shelter, displacement); 2
- 2) Impossibility / difficulty of adaptation and flexibility of the work schedule;
- 3) The need for specialized technical means of training and online communication / technical limitations;
- 4) Lack of interpersonal communication with students and colleagues on a regular basis;
- 5) Emotional burnout;
- 6) The need to activate and improve different types of soft skills;
- 7) The need to improve digital literacy;
- 8) Increasing the amount of workload in preparation for training sessions and ensuring the learning process;
- 9) The need to adapt the structure and content of curricula of disciplines in terms of online learning;
- 10) The need to organize and control the independent work of students;
- 11) Availability of mechanisms for control and accounting of the educational process.

Respondents of all groups were prompted to identify the key challenges [16] that impaired effective and qualitative adaptation of learning process design into hybrid and digital distant format. The following types of impediments were derived from the individual experiences of Oriental and European languages programs stakeholders in the timeframe of COVID-19 in regional universities of Ukraine:

Social and psychological – Emotional burnout; Stress; Fatigue; Health; Domestic difficulties / limitations; Time restrictions in connection with the introduction of quarantine restrictions;

Technical challenges and digital literacy: Technical difficulties (lack of stable Internet connection, lack of necessary equipment, capacity of household computer equipment, blackouts due to active warfare); Lack of digital literacy skills; Lack of experience in transforming the curriculum and training materials into an online format; Lack of digital communication experience; Lack of experience with electronic learning management systems

(Moodle, GoogleClass, etc.); Lack of experience with auxiliary ICT tools for organizing the learning process (video conferencing, testing, surveys, online boards, etc.);

Soft skills: Lack of skills of adaptation and self-organization; Lack of situational learning and training skills; Lack of communication and cooperation skills.

Problems with learners' apprehension or despair may be recognized by regular viewing of the school or university residents. At elementary school pupils' viewing relates to tutors and pupils. They fill in short opinion polls regarding pupils' feelings and activities. In case of middle and high school viewing contains learners' opinion polls devoted to the regularity or sternness of any emotional and expressive issues [3].

Psychologists can help students who are very touchy and sensitive. The final aim is to assist the most favourable progress of every teenager. Tutors are able to notice and identify all transformations in students' temper, behaviour, and training [14, 15].

It turns out to be very important to make use of own abilities and developed anti-strain techniques, as well as the help of other people. One may gradually diminish nervous tension, and hence properly deal with anxiety. It is necessary to identify what observations and state of affairs generate anxiety. This may give a reply to what approach have to be accepted for anti-strain actions and deeds which permit evading or adjusting to the tense environment.

The evasion policy intends to eliminate the tension motivation by removing it. In order to be influenced by nervous tension, a person must avoid too much traumatic information (e.g. news programs on TV, radio, or the Internet doom-scrolling). The emergency state requires not to be talked about constantly. Persons who sustain or generate tension must be avoided as well. One must examine which tense circumstances have the rank of "obligation" and which are "favors". Those which are not required to be visited can be cut off.

The method of reformulation is an evasive means used when a source of stress cannot be escaped, although there is an opportunity to reorganize it. One is able to create a suitable program for this time. Due to the fact that, in the current condition, relatives live together in the same location for a long period of time, this fact possibly will create a lot of quarrels and conflicts. All of them may be avoided if plans of obligations for the family members, a set of laws for using tools required for learning or work are set up.

The method of adjustment and recognition [13] is applied when the elimination of the tension motivation cannot happen. In the situation of the present pandemic, this is a plan that must be considered nowadays in the future. We have to search for encouraging features in this condition and think about what's taking place in our livelihood owing to remoteness (perhaps it is a moment when relations with other people may be developed; it is a suitable occasion when we are able to manage with affairs that were overlooked earlier or abandoned, etc.). There may perhaps be a lot of thoughts for constructing today's life and finding optimistic and hopeful aspects in it. Moreover, the method of adjustment and recognition may answer the actual questions about distant education and how by means of different schemes and systems to reduce nervousness and anxiety.

The study limitations stem from the content and range of the iterative survey results. The potential of further studies encompasses evaluation of quality and efficiency assessment dynamics of digital education in regions of Ukraine; comparative case studies of different types of Foreign languages programs and different regional programs transformation due to emergency digitization in the framework of the pandemic and warfare

measures; sustainable modes of Foreign languages programs digital adaptation in countries of the world beyond the timespan of the pandemic restrictions.

4. CONCLUSIONS

The worldwide pandemic and ensuing emergency digitization have influenced profoundly the design and workflow of higher education. That caused fundamental shifts in the range of experiences, learning results and quality assessment of Foreign languages education in Ukraine.

The qualitative evaluation of digital and hybrid education through the iterative benchmarking of the students' experiences was conducive for identification of the comprehensive, functional scale of the comparative dimensions of positive and negative dynamics of digital education quality assessment.

Through the time period of 2020 to 2021 digital and hybrid education in Foreign languages programs has been progressively evaluated as increasing from mostly to fully comparative in quality to traditional in-presence learning in the pre-pandemic timespan.

The evaluation of digital education design, leaning outcomes and acquired skills in Foreign Languages programs in the timeframe of the pandemic helped disclose the dynamics in socio-psychological challenges that prevent efficient transformation of learning process into online and hybrid mode for all groups of respondents that were consistently surveyed.

The overall positive dynamics of the evaluation of identified challenges of efficient digital educational adaptation is informed by the arrangement of factors: 1) consistently improved level of digitalization of the teaching resources and implementation of a functional e-learning environment in the form of a digital campus; 2) consistently improved and adapted digital competence level through various types of training and activities; 3) consistent professional psychological, communicative, technological and organized peer support to ensure the alleviation of challenges and impeding factors of foreign languages programs adaptation to digital and hybrid format. These elements of educational procedure and management at Borys Grinchenko Kyiv University can be scaled to serve as best practices and recommendations to ensure sustainable quality of transformation of Foreign Languages programs into digital, blended and hybrid formats in the capital city universities as well as regional universities of Eastern Europe.

The study limitations stem from the content and range of the iterative survey results. The potential of further studies encompasses evaluation of quality and efficiency assessment dynamics of digital education in regions of Ukraine; comparative case studies of different types of Foreign languages programs and different regional programs transformation due to emergency digitization in the framework of the pandemic and warfare measures; sustainable modes of Foreign languages programs digital adaptation in countries of Asia and Europe beyond the timespan of the pandemic restrictions.

5. ACKNOWLEDGEMENT

The paper has been reviewed by Nataliia Lazebna, Hab. Doc., Wursburg University, Germany. Empirical findings and survey procedures have been conducted under the auspices of Integrated Research framework of Germanic Philology Chair *Digital Transformative Linguistics and Cross-cultural Communication in Romance and Germanic Languages (0123 U 102796)* and Integrated Research framework of Oriental Studies Chair of Borys Grinchenko Kyiv University *Oriental Studies development in the framework of Higher Education Internationalization (0116*

U 007073). The authors extend special acknowledgement to the Armed Forces of Ukraine for providing safety to complete this work.

6. REFERENCES

- [1] Aristovnik, A., Kerz'ič, D., Ravšelj, D., Tomaz'evič, N., Umek, L. **Impacts of the COVID-19 pandemic on life of higher education students. A global perspective.** Retrieved from <https://www.mdpi.com/2071-1050/12/20/8438>. 2020.
- [2] Bruff, I. Making sense of the globalisation debate when engaging in political economy analysis. **British Journal of Politics & International Relations**, 7(2), 2005, 261-280
- [3] Dowdy, E., Furlong, M., Raines, T. C., Boverly, B., Kauffman, B., Kamphaus, R. W., Murdock, J. Enhancing school-based mental health services with a preventive and promotive approach to universal screening for complete mental health. **Journal of Educational and Psychological Consultation**, 25 (2-3), 2015, pp. 178-197.
- [4] Held, D., & McGrew, A. **Globalization theory: Approaches and controversies.** Cambridge: Polity Press, 2005.
- [5] Kuban, C., Steele, W. Restoring safety and hope: From victim to survivor. **Reclaiming Children and Youth** 20(1), 2011, 41-44.
- [6] Makhachashvili, Rusudan and Semenist, Ivan V. "Progress of Digital Learning Individual Quality Assessment In Oriental and European Languages University Programs through the Pandemic". **Computer Science and Technologies in Education**, 4, 2022, pp. 133-138.
- [7] Makhachashvili, R., Semenist, I. "Digital Distance and Blended Learning Quality Assessment in Oriental and European Languages University Programs: Regions of Ukraine Survey Study". **9th International Conference on Information and Education Technology**, ICIET 2021, 2021, pp. 149-156.
- [8] Makhachashvili, R., Semenist, I. "Digital hybrid learning individual quality assessment in european and oriental languages programs: Student case study in Ukraine". **14th International Conference on ICT, Society, and Human Beings, ICT 2021, 18th International Conference on Web Based Communities and Social Media, WBC 2021 and 13th International Conference on e-Health, EH 2021 - Held at the 15th Multi-Conference on Computer Science and Information Systems, MCCSIS 2021**, 2021, pp. 11-22.
- [9] Marinoni, G., van't Land, H., Jensen, T. **The impact of Covid-19 on higher education around the world.** Retrieved from https://www.iau-aiu.net/IMG/pdf/iau_covid19_and_he_survey_report_final_may_2020.pdf. 2020
- [10] Miliszewska, I. Is It Fully 'On' or Partly 'Off'? The Case of Fully-Online Provision of Transnational Education. **Journal of Information Technology Education: Research**, 6(1), 2007, 499-514.
- [11] Rashid, S., Yadav, S. **Impact of Covid-19 Pandemic on Higher Education and Research.** Retrieved from <https://journals.sagepub.com/doi/full/10.1177/0973703020946700>. 2020.
- [12] Reiss, M. J. Science Education in the Light of COVID-19: The Contribution of History, Philosophy, and Sociology of Science. **Science and Education**, 29, 2020, 1079-1092.
- [13] Sfetcu, N. **COVID-19 Pandemic – Philosophical Approaches.** MultiMedia Publishing. Retrieved from

<https://www.telework.ro/en/e-books/covid-19-pandemic-philosophical-approaches>. 2020.

- [14] Weeden, K. A., Benjamin, C. The small-world network of college classes: implications for epidemic spread on a university campus. **Sociological Science**, 7, 2020, 54-94.
- [15] Zimmermann, M, Bledsoe, C., Papa, A. **The impact of the COVID-19 pandemic on college student mental health: A longitudinal examination of risk and protective factors**. Retrieved from <https://psyarxiv.com/2y7hu/>. 2020.
- [16] Zoumpourlis, V, Goulielmaki M, Rizos, E, Baliou, S, Spandidos, D.A. The COVID-19 pandemic as a scientific and social challenge in the 21st century. **Molecular Medicine Reports**, 22 (4), 2020, 3035–3048.

Virtual Meeting as Didactic Strategy and Teaching Archive in Health Residencies: An Integrative Review

Carolina MARTINS

Federal University of Pernambuco - UFPE
Faculdade Pernambucana de Saúde - FPS
Recife, PE, 50000, Brazil

Antonio MARTINS

Faculdade Pernambucana de Saúde - FPS
Recife, PE, 50000, Brazil

Camila PIMENTEL

Recife, PE, 50000, Brazil

Marilda SIRIANI OLIVEIRA

Faculdade de Medicina de Indaiatuba/São Paulo - UniMAX - UniEduK
São Paulo, SP, 10000, Brazil

Otília Maria Lúcia BARBOSA SEIFFERT

Federal University of São Paulo - UNIFESP
São Paulo, SP, 10000, Brazil

ABSTRACT

Specialization of hospitals has been gradually incorporated in the health field since post-WWII period. It brought challenges for in-hospital educational model characteristic of health professions, to such a degree that Residency Programs allocated in Specialized Units have problems providing for in-depth learning experiences outside their primary profile of care. There are few native solutions to mitigate this didactic limitation, and is a challenge faced by generations of residents now and into the future. This study evaluated the use of Virtual Meetings as Didactic Strategy and Teaching Archive in Health Residencies and its current representation in literature. A parametrized search was done between March/30th and April/6th, 2022. Eighteen articles fulfilled inclusion criteria. Of these, fourteen articles were published during COVID-19 pandemic; fifteen, focus on implementation of Virtual Meetings; eleven articles emphasized recording Meetings as a Virtual Archive. During the pandemic, concerns grew about curatorship, technical aspects, and uses beyond streaming-on-demand. No article lay emphasis on retention of knowledge, abilities, competencies, or impact on performance of residents. Eleven articles evaluated the virtual tool but to the extent of recording participants reactions. Although the professional development in health professions can be faced as a continuous, integrated process, marked by interdisciplinarity, there are differences distinguishing learning that occurs during residency. Virtual Meetings enhance the range of didactic interactions beyond time/space, but methodological differences between modalities call for stringent analysis criteria. At the other end, there is the outcome of interest. Is in the theoretical or applied knowledge, abilities, pre-clinical readiness, or clinical performance that a given strategy exerts impact? Technology has revolutionized teaching/learning, but the literature, currently, lacks evidence on effective tools to adequately train health professionals during residency. COVID-19 pandemic has forced acceleration on uptake of teaching technologies, thus exacerbating the need for guiding evidence. This integrative review, compiles data of interest, particularly to Residency Programs in Specialized Units that intend on taking

up these tools as alternatives for didactical constrains derived from their pre-determined profile-of-care.

Keywords: Online Education, Virtual Classes, Didactic Digital Collection, Synchronous Meetings, Live Web Meetings, Residency

1. INTRODUCTION

Health residency programs (HRP) are educational spaces demanding continuous assessment and requiring didactic adjustments based on evidence. Although the professional development in health-professions can be faced as a continuous, integrated process, marked by interdisciplinarity, there are differences according to the timing, motivation, influences, perspective, and focus that distinguish the learning that occurs during residency, from those happening during the graduation course, or later, during the continuous practice of health professionals (HP) that have fulfilled their basic training.

Specialized units (SU) harboring HRPs - even when assisting patients of other profiles beyond their primary focus - share the common problem of disparity of frequency, quality and depth of the learning experiences that can be derived from such cases, by their residents, when compared with those derived from cases under their primary-profile. This problem is systemic and bound to be felt repeatedly, by generations of residents, currently and in the future.

Although external rotations of residents in other units can mitigate inherent differences in patient profile and complement residents' education, how this will happen for a specific resident in a given moment is unpredictable and beyond governance of the native HRP in which the resident is enrolled. In this sense, there are few native solutions HRPs running on SU have to mitigate - in a consistent, systematic way - this type of didactic limitation, for actual, as well as future residents.

This has motivated a review of the current literature to evaluate how Virtual Scientific Meetings - as didactic strategy in HRPs - and their transformation into a Didactic Archive, have been used in such programs and which conclusions can be drawn of

their use, in this scenario, at this time.

2. METHODS

Literature search through Ovid MEDLINE, on Scientific Virtual Meetings at HRP in Brazil and abroad, anterior to the start of COVID-19 pandemic (before Dez/2019) and posterior to that (Jan/2020 and beyond) was accomplished. The nuclei of interest were a) format of the Meeting (Clinical case discussion, Journal club, Topic presentation, Technique discussion session, etc.); b) aspects of implementation; c) preservation as Virtual Archive; and/or d) impact of this didactic tool (on knowledge, attitudes, or performance of residents).

Presence of any of the search terms on the title, abstract or keywords was the initial step, followed by perusal for the nuclei of content previously defined (Fig. 1).

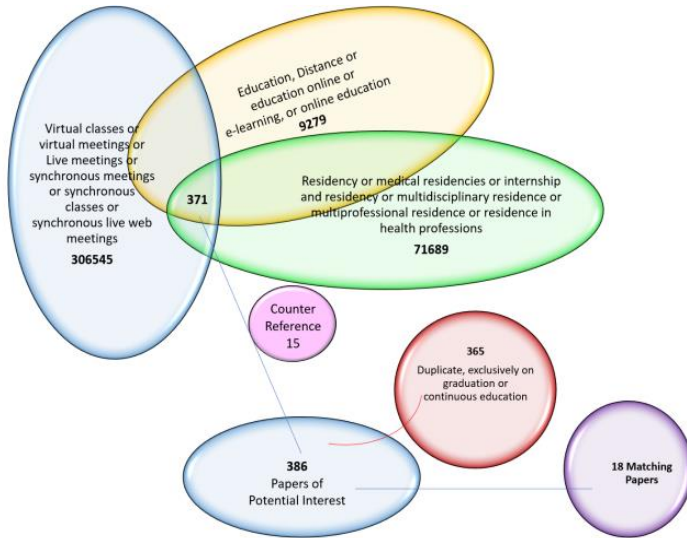


Fig. 1. Search strategy and terms applied.

Initial search resulted in a total of 371 papers, whose abstract was used for further refinement. Duplicated papers; those lacking enough description of the virtual strategy used; dealing only with asynchronous strategies; and those describing strategies exclusively for 1) Graduating students, 2) Residents selection process or 3) Continuous education of HP were excluded. Eight papers remained. Fifteen additional papers were listed by counter-reference and submitted to the same triage process, remaining 10 papers.

Therefore, between 30th/March and 06th/April 2022 a search using the parameters defined above retrieved 386 papers. Of these, 18 papers matching the defined criteria were analyzed in full and are the subject of this review.

3. RESULTS

Analysis of the search results are summarized on Table 1 (1-18).

Of the 18 papers that matched pre-defined criteria, two were undertaken in Brazil (10,18). Four papers were published before the COVID-19 pandemic (2-5). The description of the format of the Virtual Meeting was detailed in seven papers. Fifteen papers mentioned aspects of the implementation of the Virtual Meetings, but only one involved technological detail.

About the permanence as a Digital Archive, 11 papers emphasized its advantages. During the pandemic concerns about the curatorial and technical aspects arise as well as about the

varied use of this archived material beyond streaming-on-demand.

No paper presented details about retention of knowledge, competences, or the impact of such a didactic tool on residents' performance. Of the eleven papers that evaluated the Virtual Meeting, all analyzed them within other virtual didactic strategies and up to registering users' reactions.

4. DISCUSSION

“Webside teaching” is a movement in Health Education, designed to meet the growing demands derived from incorporation of a competence-based curriculum (19, 20), and received a new impulse with COVID-19 pandemic.

This “virtual acceleration” had been previewed by the World Health Organization (WHO) which, two decades ago, has recommended, among the characteristics of an Ideal Health Professional (21), familiarity with technology and use of its tools.

The path of virtual education is embedded within the concept of readiness, the prepared state (physical, mental, etc.) for an experience or action (20). Readiness for virtual education seem to involve five dimensions: a) access to technology; b) technological abilities and competences; c) capability for self-driven study; d) other pre-requisites (communication, capacity for group work, assertiveness, self-confidence); and e) motivation. Although the combination of the five dimensions seem to determine success in this didactic modality, the three last ones are easily correlated from their counterparts in traditional teaching methods and easily recognized by educators and HPs. The two initial dimensions, on the other hand, involve having access and efficiently sorting common problems associated with the daily use of computers and smart devices. In this realm, minimal requirements for e-learning involve the use of 1 GHz processors and 256 MB of RAM, as well as to have an internet connection of a minimum of 56 Kbps for asynchronous activities and above 1 Mbps wide range connection for synchronous activities involving audio and video. African studies have shown (20) that while, in 2015, only 15,7% of physicians had a personal connection able to allow for synchronous activities; by 2021, 75% were able to download over 10MB from their connections, demonstrating that technological readiness advanced markedly with time.

Again, it is a fact that all aspects of readiness for virtual education have evolved with COVID-19 pandemic (20), nevertheless audio and video problems have been reported by 36-42% of Chilean residents during e-learning activities during pandemic (9). Chile, a member of Organization for Cooperation and Development (OECD2020), has the America's highest mean internet connection velocity (23° and 15° on the world rank 2021-2022 – Brazil being 49°, on the same ranking) (22, 23); therefore, technological readiness remains an issue, even in the best scenarios. It is paramount that education planners and coordinators become fluent in this understanding, to be able to use it strategically.

Some authors (19, 24) have tried to establish which specific competences can be developed by virtual education. It seems to help development of general and specific examination techniques, clinical reasoning, analytic abilities, communication, and use of evidence-based practices. Furthermore, professionalism and virtual etiquette (*netiquette*) have also seemed to improve (19,20,24).

Strategies for virtual evaluation and feedback, considering the desired competence are summarized in Box 1.

It is a fact that diversified strategies used in virtual education have a special appeal for the new generations of HPs,

Table 1. Aspects of Matching Papers Included in the Review

| Year | Residency Program | Setting | Use prior to pandemic? | Format | Advantages | Observations | Concerns | Intent to use after pandemic? |
|-------------------------------------|------------------------------------|--------------------|------------------------|---|--|---|---|--|
| Fortin IV ¹ | Primary care and internal medicine | Institution | Y | Creation of Virtual Learning and Communication Platform, joining different <i>campi</i> of a Residency Program | Reduction of costs and working hours When compared to traditional presental system. High levels of satisfaction of users (Residents, Tutors, and Staff), that reported a "sense of connectivity" | Details on technological tools (hardware and software) used for creation of a virtual environment for communicating aiming at learning and daily routine of a Multisite Residency Program | Process initiated with evaluation of users' needs and <i>in loco</i> follow up of the presental support to demands. "Customized" Platform created for this Department and its specific needs are the explanation presented for the high level of users' satisfaction. | Does not apply |
| Chu <i>et al.</i> ² | Anesthesia | Institution | Y | Ten virtual modules combining <i>podcasts</i> , synchronous lectures, and asynchronous exercises (pre and post module) for leveling first year Residents. | Improved confidence of participants at beginning of Program, reduced anxiety, and improved Institution's perception. | Considered doable and of practical interest | Control group formed by Residents of the Program before the intervention, complicates analysis about the didactic contents <i>per se</i> . | Does not apply |
| Garrison <i>et al.</i> ³ | Pharmacy | Institution | Y | Introduction of asynchronous activities in a training module for Pharmacy Residents instead of a previous synchronous module | Experience of previous years facilitated creation of an asynchronous, gradual, self-applicable module that prepared Residents for presental teaching activities | 25% of participants preferred the previous synchronous module of activities based on lack of interaction and personalized feedback characteristic of the new model of exclusive asynchronous activities | Authors debate the properties of a balanced virtual teaching program and planned on reinserction of synchronous activities in the future. | Does not apply |
| Wittich <i>et al.</i> ⁴ | Internal medicine | Mult-Institutional | Y | National online research among Residency Program Coordinators (58% answering rate) on the use of synchronous and asynchronous activities and their impression about its didactic effectiveness | In US, before pandemic, those Residencies used synchronous strategies at a rate of 39,7% and 71,5% used asynchronous activities | Female Coordinators had a more positive view on e-learning strategies (only significant difference between groups). This perception was of 3-3,9 in a 5-point scale. | Only 11% of those Programs had financial support for e-learning. There was a correlation between financial support and use of synchronous activities | Proposals to increase use of this tools in the future. |
| Bilal & Shammugam ⁵ | Rheumatology | Institutional | N | Weekly rotations of activities including online consultations and case discussions. Asynchronous lectures (Reviewed by two Tutors before inclusion on the Department's Archive). Virtual games at beginning of weekly activities. Virtual consultation for standard patients in mini-virtual-rooms. Virtual analysis of exams (multidisciplinary). Virtual interviews on historic landmarks of the specialty. Virtual journal club and case discussion presented by Residents | Video archive on specific subjects | Archive used as <i>flipped virtual classroom</i> in preparation for case discussions | Highlighted weaknesses of Virtual Platforms and their policies on patients' data protection. Emphasized the need for cohesion of Tutor's group. Planned to sequence the study with evaluation of Residents metrics | Y. Authors understand virtual strategies as pillar of Medical Education. |

| | | | | | | | | | |
|--------------------------------------|------|-------------------|---------------------|---|---|--|--|---|--|
| Chertoff <i>et al.</i> ⁶ | 2020 | Radiology | National | Y | General view of the changes at daily practice of Residents and Tutors | Consistent with preferences of Millennial doctors. In dermatology means acceleration of ongoing practices | Mentions need for archived contents curatorship | Need of technical support and specific functionalities for virtual instruction in radiology. Changes in Residents selection process and specialist' evaluation imply didactic training of Tutors in Virtual Education Strategies | Ongoing change in instruction methods are making traditional methods obsolete and new methods standard |
| Svoboda <i>et al.</i> ⁷ | 2020 | Dermatology | Multi-Institutional | Y | Increasing use of asynchronous activities, archiving them for asynchronous use, teledermatology and evaluation of Residents practice using virtual presence tools | Report of Program's experience in 4 spheres: (a) care and Patients' Safety, (b) Safety and Residents' Well-Being, (c) Communication e (d) Education | Emphasizes impossibility of virtual activities replacing presentational ones. Mentions isolation and blurring of personal/professional life limits as disadvantages. | Y. Emphasizes need for future search for effectivity data | |
| Manson <i>et al.</i> ⁸ | 2020 | Internal medicine | Institutional | Y | Enhancement of current virtual activities including webinars (synchronous), asynchronous lectures, virtual supervision of virtual consultation (telemedicine) in several Chilean Programs | Introduction of synchronous activities allowed leveling of teams on subjects related COVID-19, reflecting on abbreviated time between practice incorporation of theory. | Virtual synchronous activities were the only means through which educational aspects of the Program could proceed during pandemic | Y. With necessary adaptations and based on future evidence | |
| Figuerola <i>et al.</i> ⁹ | 2020 | Orthopaedics | Multi-Institutional | Y | Virtual activities as: Case discussion (68%) / Rounds (60%) / asynchronous lectures & podcasts (56%) / Journal club (55%) / Synchronous lectures (41%) / Online courses (17%). | Satisfaction evaluation rated synchronous meetings higher than other strategies | 36-43% of Residents reported technical problems | Y. 82% of Chilean Residents intended on participating of virtual synchronous meetings after pandemic | |
| Prezotti <i>et al.</i> ¹⁰ | 2020 | Urology | National | N | Synchronous program of activities in subjects related to knee and hip, offered by renown specialists of 20 American institutions. Initiative undertaken between 31st/March and 25th/June 2020 | Compensated for lack of presentational activities | Lectures and Courses (48%) rated higher than Case discussions (38%), that rated better than podcasts (15%). | Not mentioned | |
| Hamilton <i>et al.</i> ¹¹ | 2021 | Orthopaedics | Multi-Institutional | N | Presential lectures recorded for virtual asynchronous use. Physical examination videos and virtual anamnesis. Virtual practice in simulation models previously mailed. Virtual games of surgical instruments. Robotic based simulation. Virtual bedside teaching. | Sessions recorded and uploaded to American Association of Knee & Hip. Format that interested the most was Case discussions. (86%) & Clinical topics (66.4%). Participants had contact with different surgical techniques, expanding experience | Evaluation: 27% of response, not done immediately after activity, 38% were Residents. Analysis segmented synchronous from asynchronous participation | Synchronous attendance dropped after two months, coinciding with return of elective surgeries. There was an associated increase in streaming-on-demand after this period. No evaluation of retention, impact on competence, performance, or burden of native Program Tutors | 92% of participants expressed the desire to continue with implemented activities |
| Mehta <i>et al.</i> ¹¹ | 2021 | Surgery | Multi-Institutional | Y | Virtual strategies seen as acceleration of ongoing practices | Need to train Tutors and define evaluation methodology that includes soft skills | Disparities in internet access, enhancing social isolation, disparity between training of concrete and abstract (soft skills) competences | Y. Considered inevitable | |

| | | | | | | | | | |
|--|------|-----------------------------|----------------------|---|---|--|---|---|--|
| Kojek <i>et al.</i> ¹³ | 2021 | Dermatology | Math-Institutional | N | Interchange Program for Tutors of Synchronous Virtual Activities | High levels of satisfaction of Residents. | Cost reduction and environmental preservation | Need to integrate interacting functionalities: chat, poll, games | Y |
| Alayywid <i>et al.</i> ¹⁴ | 2021 | Governmental (Saudi Arabia) | Math-Institutional | Y | <i>e-learning</i> (no details on format but mentioning Virtual Meetings) | Supplements presental activities. Can, in emergency situations, guarantee didactical activities of Residency Programs | | Platform capabilities, technical support, didactic and virtual curriculum, and satisfaction as required metrics to be followed | Y. Presents plan for implementation and maturation of e-learning activities for Residents |
| Martinelli <i>et al.</i> ¹⁵ | 2021 | Anesthesia | Situational Analysis | Y | Increased use of Educational Platforms including synchronous activities: In-class sessions of flipped-classroom activities become virtual meetings. Virtual evaluation and discussion of simulated scenarios. Virtual feedback in training and monitored practices. OSCE using video-conference | Pandemic turned universal existing practices, not previously ubiquitous. Mention to a) facilitated access and presence in virtual training activities, b) easy follow-up of metrics, c) possibility of reviewing recorded sessions kept in accessible archive, d) cooperation between Programs in creation of quality material in specific areas | In depth analysis of changes imposed by pandemic, particularly the didactic steps that became virtual and existing didactic knowledge that can be of service at this stage | Limited social interaction, burnout possibility, increased care costs associated with pandemics (and potential repercussion on Education as potentials risks for "virtualization". Emphasize need for future research as generator of knowledge that helps define course of action | Y. Emphasize need for education research once strategies included universalize d |
| Gabr <i>et al.</i> ¹⁶ | 2021 | | | Y | Before pandemic Residents had 8 ± 0.8h/week of theoretical activities. With pandemic it turned to 12.8 ± 1.6h/week. Virtual activities included Case-discussion (case of the day with didactic points stored in didactic archive), synchronous lectures (recorded for <i>streaming-on-demand</i>), Virtual journal club, M&M virtual sessions and virtual mock-certification test. | Emphasized storage of didactic activities for posterior use, interchange of virtual material between institutions and possibility of supplementing curriculum in the future with material recorded, as well as expertise gained. | Radiology is a field of knowledge that easily adapts to virtual didactical tools, particularly diagnostic modalities, needing only to consolidate and enhance the existing didactical databanks | A significant decrease was recorded in diagnostic and therapeutic activities seen and done by Residents in the same period, when compared with the previous 5-years. This reduction ranged between 39 to 75% in diagnostic subspecialties as neuro and female pelvis, to a global reduction of 52% of all interventions | Y. Authors emphasize importance of curatorial approach to didactic archives aiming its purposeful use in the attempt to mitigate reduction of cases in diagnostic subspecialties |
| Nagaraj <i>et al.</i> ¹⁷ | 2021 | General surgery | Institutional | Y | Increased use (in hours) of synchronous activities) | Challenge to maintain and guarantee presence of Residents & Tutors in these activities | Recording synchronous meetings for posterior viewing as basic tenet of virtual curriculum after pandemic | Emphasizes need for theoretical virtual activities labelled as "reserved times" to allow participation of junior Residents | Y. 61% of Residents and 84% of Tutors elected to continue using the tool after pandemic |
| Falcão <i>et al.</i> ¹⁸ | 2021 | Neonatology | Institutional | N | Case discussion used to initiate consolidation of specific knowledge at the specialty | Quick implementation. Broad range. Reuse and permanence of produced material. Enhanced frequency of participation. Able to engage interest of younger Tutors. Low-cost format | Ideal combination of presental and virtual (hybrid). | Requires longer spans for content assimilation. There is a need of dialogical interchange. Implies more effort and time in preparation | Y |

| | Knowledge | Topographical Diagnosis & Clinical Reasoning | Self-guided Specific Learning | Professionalism | Communication Skills |
|------------|---|--|--|---|---|
| Evaluation | Virtual Quiz. Standard examination | Virtual case discussions, Topic presentation. Oral or written evaluation of standard cases or simulation scenarios | Virtual presentation of individual learning projects | Punctuality in accessing virtual meetings, participation in virtual discussions, timing of delivery of requested answers, learning products and e-mail answering. Virtual etiquette (<i>Netiquette</i>) | Patient's consultation supervised virtually. Virtual provision of health education and hygiene-dietetic-medication counselling and follow up |
| Feedback | Automatic presentation of answers at end of test. Tutor's comments presented | Tutors' comments in real time using interactive software Post session debriefing | Real time tutors' comments using interactive software. Post session debriefing | Follow up of individual metrics by dashboard in a Didactic Platform | Individual access to appropriate answers to scenario and/or session. Real time tutors' comments using interactive software. Post session debriefing |

Box 1: Virtual evaluation and feedback strategy by competence

the “digital natives” and those who share this entelechy (25) and have evolved beyond didactic tools to become forms of institutional recognition (26-28).

According to time, content can be virtually presented in a synchronous, asynchronous, or combined mode (4, 15, 19, 20) and this last seem to help keep students engaged and reduce tutor's burden.

Synchronous sessions may enroll residents and interns of several hospitals and departments, reducing barriers of space and time, and optimizing the use of resources. In countries like Brazil, this is particularly valuable for specialties not included among the internship obligatory rotations, and HRP's less sought for and defined among national priority health areas (29, 30).

Pending on its format, Virtual Meetings - especially when based on clinical cases - can be of interest to different levels within the network of health assistance and to professionals of different backgrounds, supporting interdisciplinarity. Because they can be recorded, and stored into a Virtual Archive, they can benefit generations of residents, interns, and other professionals.

The choice of format seemed to vary according to the group of residents consulted. Orthopaedic residents in Chile and US elected virtual case discussions as preferred format (9, 11), but Urology residents preferred synchronous lectures and online courses as their virtual activity of choice (10).

Virtual Platforms and Meetings discussing clinical cases can also involve external tutors (19), with different background and experiences and, in this way, broaden the range of tutors, that residents have contact with. Such interactions can foster partnerships and other conjoined initiatives.

Challenges and limitations (15,19, 20, 21) include (a) recruitment of tutors interested in webside teaching; (b) training of tutors and residents in technological tools of live interaction; (c) formation of an institutional team involved in assisting events,

recording, editing, and making content available for posterior uses; and (d) retribution for the time spent in preparation and post-processing of this material. Besides, (e) network connections can limit live interactions, its recording and even its distribution, given the “technological inequality” (a term to denote varied levels of access to hardware and broad range connection needed for such interactions among different groups and areas). Swords et al (31) also point out the need for minimal equipment, including phones with universal serial bus (USB) entry and echo-suppression microphones – an initial investment to be considered.

It is also possible to expect skepticism and lack of support from higher (commanding and supervising) levels, as - at present - there is a lack of evidence on the results of this type of initiative in any area, including the residencies (19, 31).

Although in use by several HRP's and recently assimilated or emphasized with the advent of COVID-19 pandemic, it was precisely the need to enlist objective data on the utility of Virtual Meetings for training Health Residents, as well as their preservation as a Digital Archive that motivated this review.

On the other hand, the main intent of Virtual Meetings within a Program is to supplement - not replace or shorten - the presential curriculum. Considering the pandemic hindered and even dismantled several routines in health departments and their Residencies, caution must be exercised in dealing with such didactic tools.

Gabr e cols. (18) observed that, before the pandemic, radiology residents received $8 \pm 0.8\text{h/week}$ of theoretical activities. It increased to $12.8 \pm 1.6\text{h/week}$ virtual activities. There was a significant reduction in the number of cases of diagnostic and interventional radiology seen and done by residents, in comparison with the same period in the last 5-years.

Case reduction varied from 39,3-75,5% in diagnostic subspecialties like neuro and female pelvis and a global reduction of 51,9% of interventions. Although the number of hours has also increased in other specialties (13), residents mentioned not to learn virtually at the same pace when compared to presential interactions (13), re-igniting the notion that - in normal situations, Virtual Meetings are used best as complements to presential learning opportunities.

It is crucial to note (18) that in some areas, virtual activities are easily implemented and used, requiring only minor adjustments to the traditional teaching/learning experience. As happens in radiology, dermatology, and pathology.

The flexibility to review the whole or its parts, pause, fast forward or rewind a virtual content – once recorded - is the main feature supporting the affirmation that asynchronous materials enhance the effectivity of this teaching/learning process. However, this can only happen if the content is really accessed. If we can extrapolate from books to virtual content - and data suggests that 60% of books acquired are never opened (32, 33) - it is reasonable to expect that a percentage of didactic virtual content will never be used. Finding this percentage has implications on the choices for resources allocation, as on the format through which content will be offered to the public that will most benefit of its use.

In 2002, the internal medicine department at Yale University published an article on the development of a Virtual Platform to allow connectivity between their Residency Programs (4). They found a cost reduction related to administrative tasks and high levels of satisfaction amongst users including residents, tutors, supervisors, and coordinators, in geographically distinct sites. Authors (4) also emphasized that customized Virtual Platforms have a higher chance to reach high levels of satisfaction, once implanted and less difficulties in achieving buy-in from different groups. This finding, in the realm of a multisite Residency Program, is akin to data reported for a didactic virtual platform customized to the needs of a SU, that was rapidly incorporated internally, also receiving external recognition (34-37). Such Didactic Platforms may include Virtual Rooms in which Meetings can be recorded and posteriorly made available, streamlining the dealings with the virtual content into the didactic process, while registering the daily routines and progresses of different Residency Programs. Choice for systems that allow curatorship and auditing is, therefore, logical (10).

Automatic firing, requesting teaching module repetition (as a feature of spaced education) or the auto-determined repetition (the review undertaken by the participant at a moment when content is felt in need) (16, 38-40) are only two examples of uses of archived content that is amenable to planning edition.

Once more the COVID-19 pandemic – and the new potential situations requiring social withdraw – has made obvious the importance of didactic virtual archives and the benefits of its curatorship. Gabr et al (16) emphasized the interchangeability of material between institutions, their use to enhance Didactic Archives of specialty societies and other agencies involved with quality training of health residents. This emphasizes can be extended and seem particularly strategic for HRP native to SUs.

There is a paucity of studies and a marked inhomogeneity in methods in the ones published on this subject, namely Virtual education in the scenario of Post Graduation *latu sensu*. In fact, even in other scenarios, building evidence that supports didactical choices is not easy: a systematic review of technology assisted learning within a continuous education

program for HPs showed that only 64% of 417 studies included some validation (19, 31, 38-41).

Notwithstanding the fact that learning that happens during Residency cannot be extrapolated from data produced within other scenarios (graduation and continuous education), within the field itself there are Programs where virtual strategies seems an intuitive step - and the evaluation of its introduction, redundant - while the same strategy can be perceived as ineffective or superfluous in another. The same can be said for the need to segregate comparisons within groups by time of interaction, by outcome of interest, and avoiding common biases (17, 31, 41). In the search of the literature itself, difficulties are added by the broad definition of “virtual learning” as any educational program using electronic systems (42, 43). For long Medical Subjects Heading Vocabulary (MeSH) did not offer a specific term if the didactic program has been offered by mail, television, radio, or by the internet and, only recently, the term “e-learning” has been reserved for those strategies using the internet (42).

5. CONCLUSION

Technology has revolutionized teaching/learning, and Virtual Meetings enhance the range of didactic interactions beyond time/space, but methodological differences between modalities must be accounted for so that literature, can present evidence on effective tools to adequately train HPs during Residency. From nomenclature to methodological rigor, several enhancements have to be brought to this field of knowledge in order to accumulate efforts in favor of rational advances.

6. REFERENCES

- [1] Fortin IV, Luzzi, Galaty, Wong, Huot. Developing an Internet-Based Communication System for Residency Training Program. **J Gen Intern Med.** 2002; 17:278-282.
- [2] Chu, Ngai, Young, Pearl, Macario, Harrison. Preparing Interns for Anesthesiology Residency Training: Development and Assessment of the Successful Transition to Anesthesia Residency Training Learning Curriculum. **J of Grad Med Education.** 2013. Available at: <http://dx.doi.org/10.4300/JGME-D-12-00121.1>. Access: 01 aug. 2023
- [3] Garrison, Baia, Canning, Strang. An Asynchronous Learning Approach for the Instructional Component of a Dual-Campus Pharmacy Resident Teaching Program. **Am J of Pharm Education.** 2015;79(2): Art.29.
- [4] Wittich, Agrawal, Cook, Halvorsen, Mandrekar *et al.* E-learning in Graduate Medical Education: A Survey of Residency Program Directors. **BMC Med Education.** 2017; 17:114. doi: 10.1186/s12909-017-0953-9.
- [5] Bilal, Shanmugan. Enhancing Rheumatology Education during COVID-19 pandemic. **Rheum International.**2020.<https://doi.org/10.1007/s00296-020-04769-0>.
- [6] Chertoff, Zarzour, Morgan, Lewis, Canon, Harvey. The Early Influence and Effects of the Coronavirus Disease 2019 Pandemic on Resident Education and Adaptations. **J of the Am College of Radiology.** 2020. <http://doi.org/10.1016/j.acr.2020.07.0.22>.
- [7] Svoboda, Swigert, Nielson, Motaparathi. Inspired by COVID-19 Isolation: Evolving Educational Techniques in Dermatology Residency Programs. **Clin in Dermatology,** 2020. <https://doi.org/10.1016/j.clindermatol.2020.12.021>
- [8] Manson, Shen, Lavelle, Lumish, Chong *et al.* Reorganizing a Medicine Residency Program in Response to the COVID-19 Pandemic in New York. **Academ Medicine.** 2020. doi: 10.1097/ACM.00000000000003548
- [9] Figueroa, Figueroa, Calvo-Mena, Narvaez, Medina, Prieto. Orthopedic Surgery Residents' Perception of Online Education in

- their Programs during the COVID-19 Pandemic: Should It Be Maintained After the Crisis? *Acta Orthopaedica*. 2020;91 (5): 543–546.
- [10] Prezotti, Henriques, Favorito, Canalini, Machado, Thulio *et al.* Impact of COVID-19 on Education, Health, and Lifestyle Behaviour of Brazilian Urology Residents. *IBJU*. 2021;47 (4): 753-776. doi: 10.1590/S1677-5538.IBJU.2021.99.09.
- [11] Hamilton, Loper, Matthew, Springer, Chen. Adult Hip and Knee Reconstruction Education during the COVID-19 Pandemic. *The J of Arthroplasty*. 2021;36: S395eS399.
- [12] Mehta, Oppenheim, Wooster. Distance Learning in Surgical Education. *Curr Surg Rep*. 2021; 9:23-27. <https://doi.org/10.1007/s40137-021-00300-x>
- [13] Rojek, Madiga, Seminario-Vidal, Atwater, Fett, Milani-Nejad *et al.* A virtual faculty exchange program enhances dermatology resident education in the COVID-19 era: a survey study. *Dermatol O. J.* 2021;27(3):3-6. <http://escholarship.org/uc/item/1zt0q59g>.
- [14] Alsaywid, Lytra, Abuzenada, Lytra, Sultan, Badawoud *et al.* Effectiveness and Preparedness of Institutions' E-Learning Methods During the COVID-19 Pandemic for Residents' Medical Training in Saudi Arabia: A Pilot Study. *Frontiers in Public Health*. 2021. doi: 10.3389/fpubh.2021.707833.
- [15] Martinelli, Chen, Isaak, Huffmyer, Neves, Mitchell. Educating Anesthesiologists During the Coronavirus Disease 2019 Pandemic and Beyond. *Intern Anest Res Soc*. 2021;132(3): 585-593.
- [16] Gabr, Li, Schenning, Elbarbary, Anderson, Kaufman, *et al.* Diagnostic and Interventional Radiology Case Volume and Education in the Age of Pandemics: Impact Analysis and Potential Future Directions. *Academ Radiol* 2020;27(10): 1481-1488.
- [17] Nagaraj, Weis, Weis, Cook, Bailey, Shoultz *et al.* The Impact of COVID-19 on Surgical Education. *J Surg Res*. 2021;267: 366–373.
- [18] Falcão, Fonseca, Danti. Ensino na Residência Médica em Tempos de COVID-19. *Rev Paul Pediatr*. 2020;38: e2020334.
- [19] Govindarajan, Vu, Salas, Miller, Sandness, Said, *et al.* Accelerated Implementation of a Virtual Neurology Clerkship Amid a Global Crisis. *Neurology* Publish Ahead of Print. 2021 DOI: 10.1212/WNL.00000000000013222.
- [20] Asana, Irabor, Seppo, Jean, Ngoma, Elzawawy *et al.* Using Advanced Information and Communication Technologies to Advance Oncology Education in Africa. *Ecancer*. 2021; 15:1211-20. www.ecancer.org; doi: <https://doi.org/10.3332/ecancer.2021.1211>.
- [21] Institute of Medicine, Board on Health Care Services, Committee on Planning a Continuing Health Care Professional Education Institute. *Redesigning Continuing Education in the Health Professions*, 1. ed., National Academies Press; 2010.
- [22] FASTMETRICS. **Average internet speeds by country**. Available at <https://www.fastmetrics.com/internet-connection-speed-by-country.php> 2020. Access 02 mai. 2022.
- [23] WIKIPEDIA. **List of Countries by Internet Connection Speeds**. Available at: [List of countries by Internet connection speeds - Wikipedia](https://en.wikipedia.org/wiki/List_of_countries_by_Internet_connection_speeds). Access 02 mai. 2022.
- [24] HTRC. **Telehealth Etiquette Checklist**. Available at <https://telehealthresourcecenter.org/resources/toolkits/htrc-telehealth-etiquette-checklist/>. Access: 20 jan. 2022.
- [25] Prensky. **Digital Natives, Digital Immigrants**. MCB University Press. 2001; 9(5): 1-6.
- [26] Martins, Martins, Acioly, Maciel, Fragoso, Melo *et al.* Educational Strategies in a Neuro Facility: Virtual Course in Encephalic Vascularization. 2022. Available at: <http://www1.hps.imip.org.br/cms/opencvms/hps/pt/pdf/2021/FINALPaperVirtualCourseEncephalicVascularizationIMCIC2022.pdf>. Access: 23 fev. 2022.
- [27] Slanetz, Cooke E, Jambhekar K, Chong A. Branding Your Radiology Residency and Fellowship Programs in the COVID-19 Era. *J Am Coll Radiol*. 2020;17(12): 1673-1675.
- [28] Chezlock, Jaquette. Concentrated or Fragmented? The U.S. Market for Online Higher Education. *Res Higher Education*. 2021. <https://doi.org/10.1007/s11162-021-09639-7>.
- [29] BRASIL. Ministério da Saúde. **Editais Pró-Residência Médica. Edital 06 de 28/10/2021**. Available at <https://www.in.gov.br/web/dou/-/edital-n-6-de-28-de-outubro-de-2021-356095356>. Access: 29 jan.2022
- [30] BRASIL. Ministério da Saúde. **Editais Pró-Residência em Área Profissional da Saúde. Edital 05 de 28/10/2021**. Available at: <https://www.in.gov.br/web/dou/-/edital-n-6-de-28-de-outubro-de-2021-356095356>. Access 29 jan. 2022.
- [31] Swords, Bergman, Wilson-Jeffers, Randall, Morris, Brenner, *et al.* Multidisciplinary Tracheostomy Quality Improvement in the COVID-19 Pandemic: Building a Global Learning Community. *Ann Otol, Rhinol & Laryngology*. 2021;130(3): 262–272.
- [32] CNN Brasil. **Consumo de Livros em 2021 foi cerca de 30% Maior do que em 2020**. Available at: <https://www.cnnbrasil.com.br/nacional/consumo-de-livros-em-2021-foi-cerca-de-30-maior-do-que-em-2020-diz-pesquisa/>. Access 18 may. 2022.
- [33] GOOD E READER. **People Are Not Reading the e-Books They Buy Anymore**. Available at: <http://goodereader.com>. Access 18 mai. 2022
- [34] DIRETORIA DE ENSINO E PESQUISA, Hospital Pelópidas Silveira. **Plataforma Educativa Pelópidas Digital**. 2013. Available at: <https://pelopidasdigital.imip.org.br>. Access 29 jan. 2022.
- [35] Maciel, Acioly, Fragoso, Santos, Martins. Tutorial Continuing Education: Innovative Strategy in a Tertiary Specialized Health Unit. *Journal of Systemics, Cybernetics and Informatics JSCI*, 15(3): 16-21, 2017. Available at: ISSN: 1690-4524. <http://www.iiisci.org/journal/sci/issue.asp?is=ISS1703>
- [36] Martins, Acioly, Fragoso, Maciel, Melo, Martins *et al.* Educational Strategies in a Neuro Facility: Virtual Course in Encephalic Vascularization. *Journal of Systemics, Cybernetics and Informatics JSCI*, 20(4): 66-75. 2022. Available at: <http://www.iiisci.org/journal/sci/issue.asp?is=ISS2204>. Access: 01 aug. 2023
- [37] Martins, Acioly, Fragoso, Maciel, Melo, Martins *et al.* **Educational Strategies in a Neuro Facility: Virtual Course in Encephalic Vascularization**. Congress of Brazilian Society of Neurosurgery 2022. Best Paper Award. João Pessoa, 2022
- [38] Shaw, Pernar, Peyre, Helfrick, Vogelgesang, Graydon-Baker *et al.* Impact of online education on intern behaviour around Joint Commission National Patient Safety Goals: A randomised trial. *BMJ Qual Saf*. 2012;21(10):819–825. doi:10.1136/bmjqs-2011-000702.
- [39] Pashler, Rohrer, Cepeda, Carpenter. Enhancing Learning and Retarding Forgetting: Choices and Consequences. *Psych Bull Rev*. 2007;14(2):187–93.
- [40] Darr, Mughal, Siddiq, Spinou. Development, and evaluation of an interprofessional simulation workshop on assessment and management of tracheostomy and laryngectomy emergencies. *J Surg Simul*. 2016; 3:13-22.
- [41] Kirkpatrick. Revisiting Kirkpatrick's Four-Level-Model. Training & Development. 1996; 1:54-7.
- [42] Vaona, Banzi, Kwag, Rigon, Cereda, Pecoraro *et al.* e-Learning for Health Professionals (Review). *Cochrane Database of Systematic Reviews*. 2018; Issue 1. Art. No.: CD011736.
- [43] BIBLIOTECA VIRTUAL EM SAÚDE (BVS). **Descritores em Saúde: DeCS/MeSH**. Available at: <https://decs.bvsalud.org/> Access: 29 jan. 2022.

A Sign Language Learning Application for Children with Hearing Difficulties

Kuniomi SHIBATA

Faculty of Arts and Sciences, Tsuda University
Kodaira-shi, Tokyo, Japan

Akira HATTORI

Faculty of Global Media Studies, Komazawa University
Setagaya-ku, Tokyo, Japan

Sayaka MATSUMOTO

Faculty of Social Informatics, Otsuma Women's University
Chiyoda-ku, Tokyo, Japan

ABSTRACT

The purpose of this paper is to devise a mobile application to support both sign language and literacy skills among children with Hearing Difficulties as part of rehabilitation engineering and to implement its basic functionality. This study will make it possible to support children with Hearing Difficulties in learning written language in combination with sign language, thus helping to emphasize the importance of the latter, and in learning and communicating with their parents who use spoken language. This application has the following functions: (1) to register sign language clips acquired from a mobile device's camera by attaching tags to them, (2) to save multiple sign language clips using sets and tags, and (3) to reproduce and play back sequences of the saved sign language clips. Because of a preliminary evaluation experiment, the application was highly evaluated by the collaborators, and most of the negative comments were attributed to the small amount of registered data and its inability to support use in complex situations. Based on this, we believe that this application's basic concept has been achieved.

Keywords: Sign Language Learning, Speech Recognition and Mobile Applications.

1. INTRODUCTION

Hearing impairment is commonly referred to as a "communication disability." There is no doubt that hearing impairments such as deafness and Hearing Difficulties present a distinct disadvantage for accessing and transmitting information. In particular, for deaf and hearing-impaired children who will acquire language skills in the future, provision of continuous intervention support right from the early stages and over a long period of time is essential.

Language skills can only be supported through such intervention techniques. For this reason, the medical and rehabilitation fields have been aiming to develop technologies to support language acquisition. This paper aims to utilize technology from such a standpoint.

As background in Japanese society, the "Act on Promotion, Acquisition, Use, and Communication of Information by Persons with Disabilities" (Act on Promotion of In-formation Accessibility and Communication Policies for Persons with Disabilities) is to be enacted this year (that is, 2022). The supplementary resolution states, "In the light of the fact that all

47 prefectures and all 141 municipalities have submitted written opinions to the government requesting the enactment of the Act, further consideration should be given to the further enhancement of measures related to sign language, including legislation of a Sign Language Act" [1]. Thus, in recent years, the need to support the existence of sign language as a language and the communication conducted through it has become increasingly important.

The "Japanese Sign Language Bill" drafted by the Japanese Federation of the Deaf emphasizes the importance of education through sign language [2]. However, even to-day, there are still many cases of deaf people and some hearing-impaired people not receiving sufficient support for learning sign language or facing difficulties in learning it.

The current authors' research aims to support children's learning of written characters and communication and learning with parents that use spoken language—especially, for children with Hearing Difficulties—as well as the importance of sign language education in combination with it. In particular, this paper proposes and tries to develop a mobile application to support the sign language and literacy skills learning of children with Hearing Difficulties. The authors have previously developed mobile applications for assisting children with Hearing Difficulties and developmental disabilities in communicating and planning for the future [3][4]. By extending these applications, this paper aims to devise a mobile application for supporting the sign language and literacy skills learning of children with Hearing Difficulties and to implement its basic functionality.

2. RELATED RESEARCH

One of the earliest attempts to digitize the learning of Japanese Sign Language was the sign language learning system "Mascot" [5]. Since then, several further attempts have been made, including the development of "Mimehand II" (Mimehand Two), which is an animated version of sign language.

To cite an overseas example, El-Seoud et al. proposed a system to support communication and sign language learning for the hearing impaired [6]. This is a server-client type system with mobile devices as the client, in which users can browse words, phonemes, and numerals using photos and video. Joshi et al. developed an application to help deaf people learn the basic signs used in Indian Sign Language and communicate with hearing people [7]. The application's learning function includes signs for the alphabet, numbers, and greetings. The communication feature

displays a sign language video corresponding to the text entered by the listener. These efforts certainly focused on sign language and were aimed at constructing a support system for it, and while the inclusion of video was a feature, it did not go so far as to enable it to compose sentences and support communication.

Al Ameiri et al. have developed an application for teaching and communicating in Arabic Sign Language [8]. By selecting a word from a list, users of this application can view a sign language video corresponding to that word. The application also allows users to communicate by converting text into Arabic Sign Language, chat using Arabic Sign Language, and capture their own sign language and send it to others. Emad E. Abdallah et al. have developed applications for learning sign language and communicating with deaf people [9]. Although these were developed from the perspective of emphasizing communication, the sign language display is limited to images and is not fully capable of displaying video. Considering that sign language is a spatial language that involves movement, it is difficult to evaluate whether these applications make full use of this feature.

In terms of sign language learning in Japan, Ishihara et al. proposed a “sign language word retrieval system” for sign language learning [10]. Although there have been some scattered attempts at establishing databases storing sign language words and expressions such as these, there have not been enough attempts to support communication or to express sentences and meaning through them.

3. A SIGN LANGUAGE LEARNING APPLICATION

3.1. Proposal

Sign language is composed of hand actions and non-hand actions (non-manual markers) such as facial expressions and head movements [11]. There are two main types of signs in Japan: Japanese Sign Language and Japanese Correspondence Sign Language, and a mixed type of both, which is called Hybrid Sign Language [12][13]. Japanese Sign Language is a language with its own system that differs from that of Japanese, and Japanese Correspondence Sign Language arranges signed words in Japanese word order.

In the case of sign languages that involve hand actions and facial expressions, it is considered easier to learn by viewing videos rather than reading illustrations, photographs, or written explanations. Furthermore, since there are three types of sign languages, instead of the application provider specifying the type, the learners themselves should decide what they want to learn. Therefore, it is necessary to allow the learners and their parents to register sign language clips in the application.

Currently, various books are available as learning materials for sign language (e.g., [11][12][14]). In many of these books, illustrations or pictures showing the words or phrases in sign language are accompanied by the corresponding words or phrases in the spoken language—in the case of Japanese Sign Language, the Japanese words or phrases. Furthermore, sign language learning contents on DVDs and video sharing sites often display words and phrases corresponding to the signs like subtitles in TV programs. Therefore, in this application, the words and phrases in the spoken language corresponding to the words and phrases in the sign language will also be indicated together. However, in order to support both sign language and literacy, the learners themselves can register the sign language clips and the words and phrases corresponding to the signs and search for them.

We have developed a mobile application to support communication primarily for children with Hearing Difficulties [3][4]. This application is characterized by the following

features: (1) short words and phrases (we called them tags) are connected to illustrations and photos in the tablet device and stored and (2) depending on the communication setting, illustrations and photos are retrieved through speech recognition and displayed along with the tags as if they were sentences, thereby supporting communication for children with Hearing Difficulties. These features are considered effective for the requirements of a sign language learning-support mobile application that supports both sign language and literacy, as described above. Therefore, in this paper, we propose and implement an application that follows these features and has the following functions.

1. Function to associate tags with sign language clips acquired from mobile device cameras and register them;
2. Function to save multiple sign language clips in a row with tags and sets;
3. Function to reproduce and play back sequences of saved sign language clips

1. Function to associate tags with sign language clips acquired from mobile device cameras and register them

Sign language clips that have been captured in advance or captured by starting the device camera from this application are displayed on the device screen, and the phrases and words corresponding to the signs are assigned as tags and registered in the database of the application.

2. Function to save multiple sign language clips in a row with tags and sets

Sign language clips are retrieved through speech recognition or keyword search and displayed side by side with their tags. Then, their sequence is added to the database. If none of the sign language clips are found, the system searches for any illustrations or photographs to which the tag is attached. In this study, sign language clips and so on along with the sequence of their tags are referred to as a sequence.

3. Function to reproduce and play back saved sign language clips and tag sequences

The sequence of sign language clips and tags added to the database—that is, sequence—is reproduced, and each sign language clip is played back. When playing back the sign language clips, two methods can be used: one allows the user to specify the clip he/she wishes to play back, and the other allows the user to play back the sign language clips in synchronization with the sequence of the sign language clips—that is, each clip is played back in order.

3.2. Implementation

Sign language is composed of hand actions and non-hand actions (non-manual markers) such as facial expressions and head movements [11]. There are two main types of signs in Japan: Japanese Sign Language and Japanese Correspondence Sign Language.

3.2.1. Tagging sign language clips

To register a new sign language clip, first, either record a new sign language clip or select a clip that has already been recorded. To record a new sign language clip, start the camera application installed on the tablet device and take a video of the sign language using the application. When the user is recording a new sign language clip or selecting an existing one, the sign language clip is displayed on the screen, and the user can enter a word or short phrase that indicates the sign language content while

viewing the clip (Figure 1). When those clips and tags are saved, information about the sign language clip, which is described in the next section, is added to the database, completing the registration of the sign language clip.



Figure 1. Tagging and registration of sign language clips (in Japanese)

3.2.2. Searching for sign language clips and saving and playing back sequences

This application searches for sign language clips by using speech recognition or keywords, and displays the sign language clips together with their tags (Figure 2). The application manages the sequence of sign language clips and tags by maintaining a list of sign language clip file names, types, tags, and other information about individual sign language clips (sign language clip information). The sign language clip type indicates the type of clip that is preinstalled in the application or the type of clip that was captured by the mobile device's camera application, and this application switches the method of displaying the clip in the video view according to its value. Therefore, in the future, by increasing the number of types, it will be possible to use videos from websites.

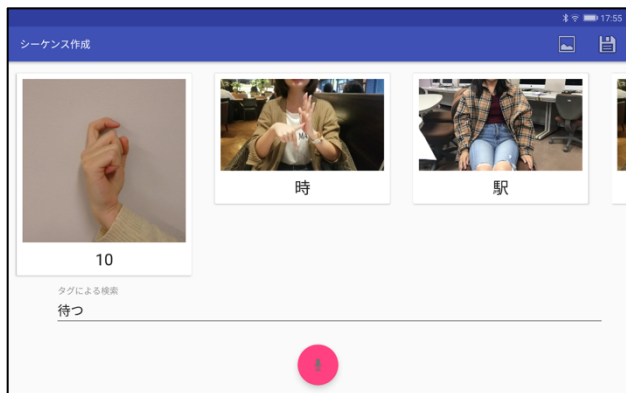


Figure 2. Achieving Sentence representation by searching and sequencing sign language clips (in Japanese)

If none of the sign language clips are found through the search, the application will search for any illustrations or photographs to which the tag is assigned. Furthermore, if there are multiple clips or illustrations/photos with the same tag, the user can select which one to add to the sequence.

When playing back a saved sequence, a list of sequences is first displayed (Figure 3), and by selecting one of them, the sequence is reproduced, and the respective sign language clip is played back as shown in Figure 4. When playing back a saved sequence,

the sequence is also managed through the list detailing the sign language clip information.

There are two ways to play back a sequence of sign language clips: by tapping each sign language clip individually, or by having each sign language clip play automatically in the order of the sequence after the first sign language clip in the sequence is played.



Figure 3. List of sequences (in Japanese)



Figure 3. List of sequences (in Japanese)



Figure 4. Reproducing and playing back sequences (in Japanese)

4. PRELIMINARY EVALUATION EXPERIMENT

4.1. Experiment Overview

Using the application described in the previous chapter, an experiment was conducted for future development.

The experiment was conducted by lending a tablet containing this application to users for two weeks. The participants were students, who were briefed on the application in advance and

confirmed with the experimenter that there were no problems with the tablet or the application. The participants conducted a “quest,” in which they communicated in a specified situation by using the app in pairs and wrote the results on a specified sheet. The application was preloaded with 260 sign language clips. Experiment participants: 13 groups of students attending the 2019 Tsuda College course “Introduction to Media Practice” Period: November 6-20, 2019.

Quest 1: Compose and save a sequence for “What I did in school yesterday (or the day before)” by using sign language clips, fingerspelling, and clip registration. The experimenter refers to this as the “classroom display.”

Quest 2: Compose and save a sequence for “What I did outside of school yesterday” by using sign language clips, fingerspelling, and clip registration. The experimenter refers to this as the “social display.”

Quest 3: Register sign language clips and combine them to create a free sequence (three per person). The experimenter refers to this as “free display.”

The answer sheet asked the following questions for each quest: 1. The sequence created, 2. Whether the content was considered sufficient, 3. Good and bad points, 4. Words that could not be displayed well and words or functions they wanted to include and 5. Words that were newly recorded and registered in the video. The participants were asked to rate their understanding of Item 1 on a 5-point scale: 5. Well done, 4. Mostly well done, 3. Undecided, 2. Not well done, 1. Not at all well done.

They were also asked to use a 100-point scale to rate what was good and bad about the operability, sign language comprehension promotion, usefulness of video communication, and expectations. They were also asked to report any bugs they found.

4.2. Experiment Results

4.2.1. Results of each quest

All participants in the experiment completed all quests and submitted completed evaluation sheets. The comments below summarize the main points (omitting trivial differences in textual expression and so on).

The results of Quest 1, “Classroom Display,” were as follows. The sentences created in response to the quest were short sentences such as “I read a book in school yesterday.” The contents were actions such as eating, studying, and dropping a smartphone.

The average rating on the 5-point scale was 3.2 for whether the contents were adequately displayed. The good points included comments such as “Almost everything was displayed,” “I think that I could understand it,” “The speech recognition performance was better than I expected,” “When there is no corresponding word, I can quickly add it by taking a video,” and “The use of video registration makes it concrete and easy to understand.” As for the bad points, there were comments such as “After making a sentence, it is not possible to add it in the middle,” “There is no past tense” “Speech recognition does not work well, and it is slow,” and “Japanese has many verb patterns, and more data is needed.”

The results of Quest 2, “Social Display,” were as follows. The content included actions such as shopping, talking on the phone with a friend, and taking a picture with a camera. The sentences created in response to the quest were short sentences such as “I played volleyball yesterday.”

Regarding whether the content was adequately displayed, the average rating on the 5-point scale was 3.1. As for the good

points, there were similar comments to those of Quest 1 as well as “I was impressed when I found the corresponding words.” The bad points included comments such as “It is difficult to use (or select) the registered words because there are so many,” “I wish it would recognize verb conjugations,” “Conjunctions do not work,” “Words I want to use are not registered,” and “I cannot distinguish which ‘take’ is ‘take’” (meaning that it could not distinguish between homonyms).

The results of Quest 3, “Free Display,” were as follows.

The sentences produced in response to the quests were short sentences that contained more complex elements than Quests 1 and 2 (for example, “I have a cat” and “I went to Korea with my friends”).

Regarding whether the contents were adequately displayed, the average 5-point rating was 3.0. Good points included comments such as “It has the ability to search by text if it does not appear in the audio” and “The sequence list page is easy to read.” As for the bad points, there were comments such as “I did not know how to express auxiliary verbs,” “The part that can be displayed on an actual smartphone (when showing a smartphone),” “I do not know how to express the verb ‘to do,’” and “There is not enough data (to express what I want to say).”

The results of the operability evaluation throughout the quest were as follows.

4.2.2. Evaluation through all quests

The evaluation of operability throughout the entire quest was as follows.

The average rating on the 100-point scale was 53.5, with a minimum score of 30 and a maximum score of 80. For the good points, most of the comments were about voice recognition and its ease of use and comprehensibility in operation, such as “Voice search is possible and easy to understand,” “What is not recognized as a sentence is recognized as a word,” “The design is simple,” and “There are almost no complicated operations, and it is easy to create sequences and take videos.” Most of the comments were about the “simplicity of the design” and “the fact that there are almost no complicated operations and it is easy to create sequences and take videos. As for the bad points, they concerned issues with input such as “I was surprised when the video played by itself,” “I had to speak slowly to be heard,” “It is slow,” “Sometimes, it is difficult to recognize the speech, and the videos are not played clearly,” “(Certain words) were not recognized no matter how many times I tried,” and “Words are recognized, but sentences are not recognized through speech recognition or the keyboard (no input functionality).” Words are recognized, but sentences do not work (cannot be input) either by voice recognition or by keyboard. There were two user comments that stated, “I want to edit part of a sequence, but I have to re-enter the whole text.” One person commented on the operability issues with the video, saying, “There were many sign language videos that stated, ‘This video cannot be played.’”

The evaluation of the promotion of sign language understanding throughout the entire quest was as follows.

The average rating on the 100-point scale was 62.3, with a minimum score of 30 and a maximum score of 90. The most common positive points concerned the basic concept of this application and its potential; see, for example, “Interpretation with people who use sign language is possible” (4 persons), “Any conversation is possible,” “There are interesting points and possibilities even if I do not use sign language” (2 persons), and “I can talk regardless of age and nationality.” One common bad point was expressed in “I do not need to use it to talk” (2). The most common negative points included functional problems such as “Sign language corresponding to trivial changes such as

adverbs and past tenses does not appear” (2 persons) and photography issues such as “The sign language database makes it difficult to see unless the angle of the view is adjusted” (2 persons). Furthermore, there were also comments that may be of concern to those who do not use sign language such as “It is difficult to tell whether the sign language is a mirror image or not,” “It is difficult to tell whether the sign language displayed is really appropriate for the content,” and “Unnecessary movements may make it difficult to convey the message” (1 person).

The evaluation of video communication throughout the entire quest was as follows.

The average rating out of 100 was 66.9, with a minimum score of 30 and a maximum score of 100. Good points included evaluations of specific functions such as “The ability to save videos that I entered myself” (3 persons), “The sense of accomplishment in being able to do it makes it fun,” and “Being able to use videos is interesting, and I never get bored” (2 persons).

The most common comments on the bad points were about portrait issues such as “It is hard to concentrate when the faces of various people who created the signs are shown” (2 persons), “I am worried about misuse because my face is shown,” and “It is not exactly fun to see the faces of people I do not know.” There were three comments about the registered vocabulary: “If there are not enough words, I end up typing in letters (more data would be good)” and “I cannot express what I want to express adequately.” Other comments included “It is difficult to use” (2 persons), “It may be confusing if gestures using sign language are mixed in,” “Displaying the number of times the video has been played is unnecessary,” “I want to give titles to sequences,” and “I might get bored if I cannot share the videos I have created with others.”

The average expectation score was 73, with a minimum score of 50 and a maximum score of 100. Although they overlapped with the previous items, many comments were concerned with the basic concept of this application. These were comments such as “It can be used to communicate with people who use sign language” and “It can be used for learning sign language.” There were also comments on specific operations and requests for improvement. Furthermore, many other possibilities for use beyond hearing-impaired children were indicated, such as communication with people who speak different languages, use as an illustrated book application, and use with young children.

4.3. Discussion of Survey Results

Overall, the experiment collaborators rated the application highly, and most of the negative comments were attributed to the small amount of registered data and the inability of the application to withstand use in complex situations. Based on this, we believe that the basic concept of this application has been achieved.

The score-based evaluations varied depending on the quests at the time of the experiment; the more limited the situation, the higher the evaluation. When the situation was more flexible, there were more negative comments about the small number of registered vocabulary words, lack of abundance of expressions (e.g., past tense), and increased slowness during operation. This indicates that it is necessary to first limit the situations in which this application is used to some extent, augment the registered data related to those situations, and create a manual that includes the purpose and situations in which the application is to be used. Furthermore, although the application was evaluated as being easy to operate in this experiment with students, it is necessary to continue verifying whether there are any problems for actual users, including children.

The application showed a high level of expectation and many potential applications. It can be said that there is room to develop various versions of this application as a prototype.

5. CONCLUSION

Regarding language acquisition technology, this paper aimed to develop an application that can support language acquisition by utilizing sign language videos.

In particular, this paper provides a concrete implementation and preliminary verification of the basic functions of the application including sign language clip registration and retrieval. This paper also confirms that these functions work properly and are useful. However, we are also aware that several features are still insufficient for users who want to actually learn a sign language or for assisting users who want to use it in communication. First, the standard vocabulary that can be stored does not allow for sufficient organization of its variations.

Sign language consists of sentences made up of a series of movements, and many of these movements are difficult to isolate as words. The same word can have a variety of “conjugations” where the meaning is emphasized or reduced depending on the movement, but it is difficult to store these in this application. A typical challenge will concern how to resolve such changes and variations in sign words. Another challenge, again, concerns the use of a large-scale use experiment to test how far it can respond in practice.

Although a certain degree of effectiveness can be expected at this stage, the true value of the system will not be known until it is actually used in a variety of communication situations. We believe that the next task is to conduct use experiments with the cooperation of actual deaf and hearing-impaired people.

6. FUNDING

This research was supported by JSPS Grant-in-Aid for Scientific Research JP18K11994 and 20K12550.

7. REFERENCES

- [1] House of Representatives. **Supplementary Resolution to the Proposed Act on Promotion of Measures Pertaining to Acquisition and Use of Information and Communication by Persons with Disabilities**. 2022 (<https://www8.cao.go.jp/shougai/suishin/jouhousyutoku/futai.html>, retrieved November 30, 2022).
- [2] Japanese Federation of the Deaf. **Japan Sign Language Bill**. 2018. (<https://www.jfd.or.jp/sgh>, retrieved November 30, 2022).
- [3] Hattori, A., Shibata, K. and Matsumoto, S. **A TABLET APPLICATION TO SUPPORT COMMUNICATION FOR PEOPLE WITH DISABILITIES**. Proceedings of the International Conference on Interfaces and Human Computer Interaction 2017, 2017, pp. 167-176.
- [4] Hattori A., Shibata K. **Development of an Android Application to Support Communication for Children and People with Hearing Impairment**. GN Workshop 2014 Bulletin, 2014, pp. 1-6.
- [5] Yan, B., Onishi, S., and Fujimoto, T. **Development of a Sign Language Learning Support System "Mascot Drill" Using HORB**. 21st Annual Meeting of the Japanese Society for Educational Informatics Bulletin, 2005.
- [6] Samir Abou El-Seoud, S. A., Taj-Eddin, I., Nosseir, A., El-Sofany, H., Rumman, N. A. **A Proposed Pedagogical Mobile Application for Learning Sign Language**.

- International Journal of Interactive Mobile Technologies. 2013, Vol. 7, No. 3, 2013, Vol. 7, No. 3, pp. 46-55.
- [7] Joshi, A., Homeminiha, M. D., Pavithra, P., Srilakshmi, B. **Assistive Android Application For Hearing Impaired People Us-ing Sign Language**. Advances in Natural and Applied Sciences. 2017, Vol. 11, No. 7, pp. 166- 171.
- [8] Al Ameiri, F., Mohamed Jamal Zemerly, M. J., Al Marzouqi, M. **M-Learning and Chatting using Indexed Arabic Sign Lan-guage**. International Journal for Infonomics. 2012, Vol. 5, No. 1/2, pp. 575-582.
- [9] Abdallah, E. E., Fayyoumi, E. **Assistive Technology for Deaf People Based on Android Platform**. Procedia Computer Science. 2016, Vol. 94, pp. 295-301.
- [10] Ishihara, Y., Miyoshi, S., Ito, M. et al. **A Study on Sign Language Learning Methods Part 1 -Development of a Sign Language Word Retrieval System-**. Tsukuba College of Technology Techno Report, 2002, Vol. 9.
- [11] Kimura, H., Ichida, Y. (Revised edition) **Sign Language for Beginners**. Seikatsu Shoin, 2015.
- [12] NPO Sign Language Proficiency Test Association (supervisor). **A Practical Sign Language Dictionary at a Glance**. Shinsei Shuppansha, 2002.
- [13] 13. Saito, K. (Ed.). **The Challenge of the Liberal Arts University through Sign Language**. Minerva Shobo, 2017.
- [14] NPO Bilingual and Bicultural, **Deaf Education Center** (ed.), Oka, N., Akabori, H. (Eds.).
- [15] Japanese Sign Language: **From the Basics of Grammar to the Structure**. Taishukan Shoten, 2011.

Metadigital Skills Development For Foreign Languages Education In Wartime Digitization

Rusudan MAKHACHASHVILI

Germanic Philology Department
Borys Grinchenko Kyiv University, Bulvarno-Kudryavska-st., 18/2,
Kyiv, Ukraine

Ivan SEMENIST

Oriental Studies Department
Borys Grinchenko Kyiv University, Bulvarno-Kudryavska-st., 18/2,
Kyiv, Ukraine

ABSTRACT

The wartime emergency induced amplified digitalization measures in the higher education sphere, informed by the need to take quick comprehensive action in order to achieve the overarching result to transform educational scenarios into interdisciplinary digital, blended, and hybrid frameworks. Taking into account the context of the erupted military intervention on Ukraine in February 2022, and the ensuing information warfare in various digital environments (social media, news coverage, digital communications), the specific value of the learning outcomes and outputs is allocated to the digitally enhanced foreign languages education as a tool of the internationally broadcast strife of Ukraine for freedom and sovereignty. The study results disclose the comprehensive review of dynamics of the metadigital skills development and application to construe interdisciplinary competencies of students of European (English, Spanish, French, Italian, German) and Asian (Mandarin Chinese, Japanese) Languages major programs in Ukraine through the span of educational activities in the time-frame of wartime emergency digitization measures of 2022-2023 in Ukraine.

Keywords: metadigital skills, digital literacy, dynamics, foreign languages education (FLE), emergency digitization

1. INTRODUCTION

Transformative shifts in the knowledge economy of the XXI century, Industry 4.0 development [17] and elaboration of networked society, emergency digitization due to quarantine measures has imposed pressing revisions onto interdisciplinary and cross-sectorial job market demands of Liberal Arts university graduates' skillsets, upon entering the workforce. This, in turn, stipulates reevaluation of the interdisciplinary approaches to comprehensive professional competences in foreign languages acquisition, education, and application [15].

First the global pandemic and later the active phase of the warfare induced amplified digitalization measures in the higher education sphere [13; 14; 16], informed by the need to take quick comprehensive action in order to achieve the overarching result to transform educational scenarios into interdisciplinary digital, blended, and hybrid frameworks.

Taking into account the context of the erupted military intervention on Ukraine in February 2022, and the ensuing

information warfare in varying digital environments (social media, news coverage, digital communications), the specific value of the learning outcomes and outputs is allocated to the digitally enhanced foreign languages education as a tool of the internationally broadcast strife of Ukraine for freedom and sovereignty.

The consequent functional tasks to meet this challenge in the educational sphere are estimated as 1) adapt the existent educational scenarios to digital, remote and hybrid formats; 2) to upgrade ICT competence and digital literacy of all participants of the educational process under extreme duress; 3) to activate complex interdisciplinary (soft and hard) skillsets, otherwise latent or underutilized in the educational process.

The study objective is to diagnose and critically review the dynamics of metadigital skills development and application to construe interdisciplinary competencies of students of European (English, Spanish, French, Italian, German) and Asian (Mandarin Chinese, Japanese) Languages major programs in Ukraine through the span of educational activities in the time-frame of wartime emergency digitization measures of 2022-2023 in Ukraine.

2. METHODOLOGY

The study methodological design includes the following steps:

- 1) The modelling of interoperability between various competency principles, derivative of twenty-first-century skills [1; 3; 4; 22] and projected digital literacy requirements for Foreign Languages Education (FLE) across core digital literacy frameworks (European e-Competence Framework [7], UNESCO ICT Competence framework for educators [20] and European Commission Digital Competence Framework: DigComp 2020 [6]);
- 2) The survey method application for diagnostic analysis of different digital literacy [5] components and dimensions, as well as digital skills implementation, used to assess the parameters of efficiency of transforming real-life linguistic education practices into the emergency digital and hybrid format.

The identification of the correlation between various groups of applied digital skills and soft skills, instrumental to develop interdisciplinary professional competence of FLE students.

¹ Peer-editor: Olena Tupakhina, PhD, Zaporizhzhya National University, Ukraine, Coordinator of Erasmus+ JMM Project "European Values in Literary Arts" (EUVOLIA, 599918-EPP-1-2018-1-UA-EPPJMO-MODULE)

3. FINDINGS

Metadigital skills development modelling

The following grid of groundwork concepts is applied to profile the Foreign Languages Education (FLE) in the study:

- INTERDISCIPLINARITY;
- INTEROPERABILITY;
- META SKILLS;
- VIRAL DIGITAL SKILLS.

The meaning of INTERDISCIPLINARITY is synthesized for the purpose of this study as an agglomeration of two or more fields of knowledge into one scope/goal of study, inquiry or activity [2; 8; 9; 12; 13].

The concept of INTEROPERABILITY is disclosed across different lens [11; 18] as a characteristic of an object, product or system, that allows its interface to be comprehensible, to work with other objects, products or systems.

As applied to Foreign Languages Education, the concept of interoperability represents the property of functional, dynamic interconnectivity between the source and target domains of linguistic content, linguistic theory content, related areas of scientific and universal knowledge, and domains of professional and social application.

Interoperability for FLE skills is ensured by the communicative nature [1] of interdisciplinary skills. The core cross-sectorial domain that is referential for primary skills (social skills, emotional intellect, collaboration, communication, ICT-literacy), necessary for educational goals achievement, is estimated to be COMMUNICATION.

A METASKILL is defined as a skill requiring to process lots of information across different knowledge domains and make complex interoperable decisions simultaneously [21].

VIRAL DIGITAL SKILLS for the purpose of this study are defined as rhisomatic capabilities of interoperable manipulation of digital data, tools, and communication formats, acquired institutionally, intuitively or on the peer-to-peer basis.

Given the nature of increasingly digitalized context of foreign languages education and communicative application (“the Technospheric shift” [16], it is suggested to consider the different types of information source and information destination (human and machine/computer/program, accordingly) in the structure of the groundwork Communication Model [19], when communication is approached as the core factor of interoperability of source and target knowledge and application domains in FLE.

Subsequently, a model of soft skills paradigms and digital literacy frameworks INTEROPERABILITY in FLE is suggested:

- 1) European E-competence Framework Guideline (European Commission, 2020 [7]), customized according to European Professional Competence Framework, accommodates the following soft skills in terms of digital competence requirements for vocational activity in FLE: service orientation; attention to detail, learning strategies, leadership and social influence, cognitive creativity and flexibility, coordination and time-management; human resources management;
- 2) UNESCO ICT Competence framework (UNESCO, 2018 [20]), customized for pre-service teachers of foreign languages, accommodates the following types of soft skills in terms of digital competence requirements: collaboration, team-work, problem-solving, reasoning and ideation.
- 3) Digital Competence 2020 framework (European Commission, 2020 [6]) for general public, accommodates

the following soft skills in terms of digital competence requirements for efficient digital citizenship: Communication and collaboration, creativity and adaptability, learning and innovation, trustworthiness, emotional intelligence, complex problem solving.

E-skills dynamics in Foreign Languages Education: Survey results

The survey analysis is further applied for in-depth, comprehensive diagnostics of interoperable digital literacy components, used to assess the parameters of efficiency of transforming real-life FLE education practices into the digital and hybrid format in the active wartime timeframe in Ukraine (February 2022 – April 2023) for students of Asian languages and European languages major programs.

The survey sample consists of 457 respondents of 7 Foreign Languages Programs (Italian, Spanish, French, English, German, Mandarin Chinese and Japanese) across 3 tiers of FLE study (Bachelor’s, Master’s, Graduate) in the universities of the capital city (Kyiv, Ukraine) in the timeframe of wartime emergency digitization measures of 2022-2023 in Ukraine.

The survey structure comprised of 16 complex diagnostic questions (multiple choice, criteria comparison and Likert scale score types), divided into the following categories:

1) questions on overall assessment of digital literacy level in the framework of wartime digitization for university programs of Asian and European languages;

2) questions on diagnostics of future specialists in FLE according to the established frameworks of digital competencies in the professional field;

3) questions on diagnostics of interoperability of linguistic / communicative / soft professional and e-skills for university programs of European and Asian languages

The study results disclose the following interoperable dimensions of dynamic e-skills development, instrumental for the efficiency of Foreign Languages Education:

- I. Estimation of overall digital literacy level in the framework of emergency digitization for university programs of Asian and European languages;
 - Comparative evaluation of individual digital literacy level for university programs of Asian and European languages during and prior to the framework of emergency digitization measures (in peacetime and in wartime);
- II. Diagnostics of future specialists in FLE according to European e-Competence Framework and estimation of digital skills of FLE for professional application:
 - The evaluation of the dominant professional e-competence dimensions for FLE students being to PLAN; to RUN; to ENABLE professional processes in FLE.
 - The corresponding dominant professional goals for FLE students are measured to be: Planning of professional processes (in the field of foreign languages); Monitoring of professional activity (in the field of foreign languages); Provision (facilitation) of professional activity (in the field of foreign languages).
 - General types of dominant digital skills for professional application of FLE students according to the European e-competence framework - ICT practitioner skills and ICT user skills
 - Comparative assessment of general types of digital skills for professional application of FLE students (pre- and Covid-19 timeframe).

III. Diagnostics of digital skills of FLE for pre-service and in-service teachers according to UNESCO ICT Competence Framework:

Priority professional activity goals of FLE pre-service teachers for digital skills application are estimated as:

- 1) to develop curricula using digital tools;
- 2) to develop learning materials using digital tools;
- 3) to understand the role of digital technologies in language education;
- 4) to organize and administer the learning process using digital tools;
- 5) to improve your own teaching skills with digital tools.

Priority student oriented goals of FLE pre-service teachers for digital skills application are estimated as:

- 1) Teach to implement different types of speech activities (oral, written, listening, dialogue, monologue);
- 2) Teach to work in a team / organize collaboration;
- 3) Teach to think critically using digital tools;
- 4) Teach to solve problems with digital tools;
- 5) Help learn independently via digital tools;
- 6) Help to become effective participants in civil society through digital tools.

IV. Diagnostics of future specialists in FLE according to European Commission DigComp 2020 Framework ensured assessment of digital skills of FLE for digital citizenship:

Key digital competence dimensions for digital citizenship, enhanced by FLE (foreign languages education) are estimated as:

- 1) Information and data literacy;
- 2) Communication and collaboration;
- 3) Problem solving;

Digital activities mastery in FLE, enhanced through emergency digitization timeframe: to articulate information needs, to locate and retrieve digital data, information and content; to judge the relevance of the source and its content; to store, manage, and organize digital data, information and content; to interact, communicate and collaborate through digital technologies while being aware of cultural and generational diversity; to keep up-to-date with the digital evolution.

V. Diagnostics of interoperability of linguistic / communicative / soft professional and digital skills for university programs of FLE:

Dominant combinations of digital communication elements, instrumental for professional linguistic competence formation are estimated as follows (Fig.1):

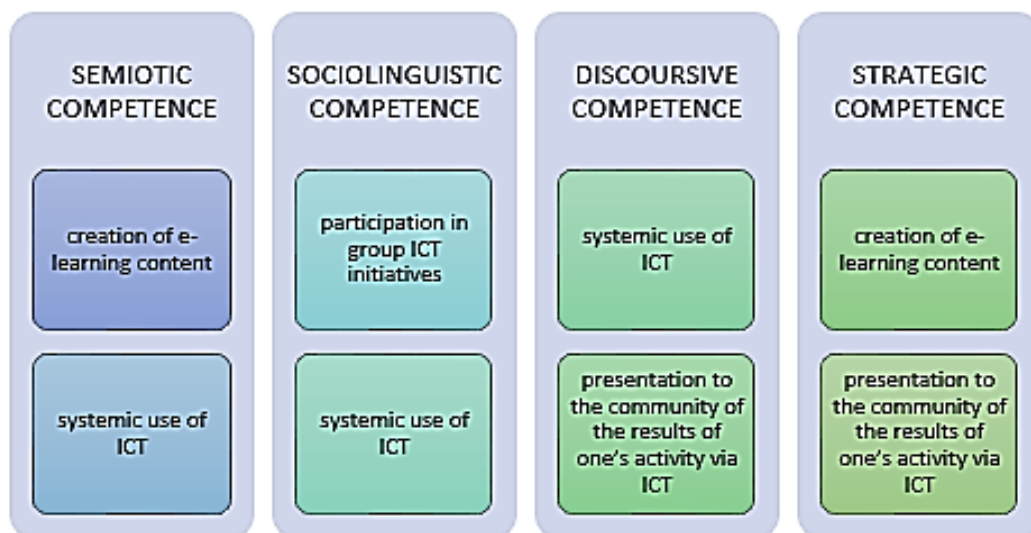


Figure 1. Digital communication elements, instrumental for linguistic competence formation.

1) semiotic competence is enhanced by such elements of digital communication as creation of e-learning content, systemic use of ICT;

2) sociolinguistic competence is enhanced by such elements of digital communication as participation in group ICT initiatives, systemic use of ICT;

3) discursive competence is enhanced by such elements of digital communication as systemic use of ICT, presentation to the community of the results of one's activity via ICT;

4) strategic competence is enhanced by such elements of digital communication as creation of e-learning content, presentation to the community of the results of one's activity via ICT.

- Dominant linguistic competence elements, instrumental for digital communication are evaluated as follows (Fig.2):

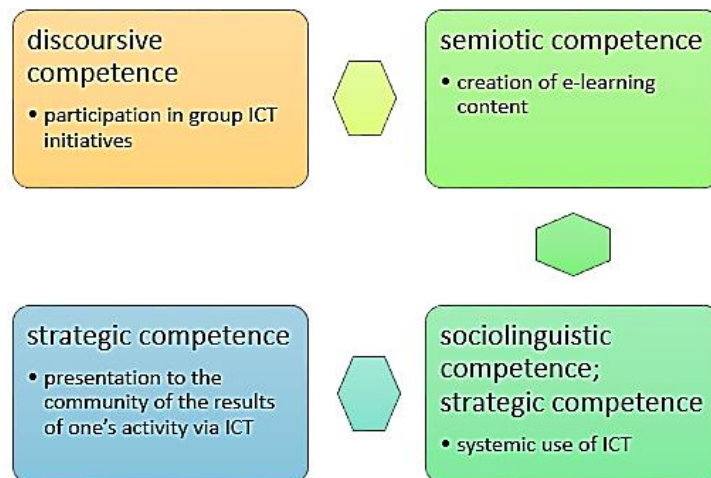


Figure 2. Linguistic competence elements, instrumental for digital communication.

- 1) discursive competence is estimated as dominant for participation in group ICT initiatives;
- 2) semiotic competence is estimated as dominant for creation of e-learning content;
- 3) sociolinguistic competence and strategic competence are estimated as dominant for systemic use of ICT;
- 4) strategic competence is estimated as dominant for presentation to the community of the results of one's activity via ICT.

Key digital competencies, effective for the implementation of foreign language acquisition activities are evaluated and estimated as follows:

- 1) for Oral speech activities the dominant digital competences are Information and data literacy, Communication and collaboration;
- 2) for Written speech activities the dominant digital competences are Communication and collaboration, Digital content creation, Safety;
- 3) For Audial activities the dominant digital competences are Information and data literacy, Communication and collaboration, Digital content creation;
- 4) For Vocabulary acquisition activities the dominant digital competences are Information and data literacy, Digital content creation, Communication and collaboration;
- 5) for Stylistic acquisition activities the dominant digital competences in equal measures are Information and data literacy, Communication and collaboration, Digital content creation, Problem solving.

4. CONCLUSIONS

The study findings allow to estimate as well the interoperability of soft skills and digital competence dimensions in Foreign Languages Education, and to detect challenges for actual and underdeveloped skills (hard, technical, and soft), that stakeholders of the European and Asian languages education encountered through digital format adaptation in the emergency digitization timeframes in peacetime and in wartime. These challenges include the following types:

- 1) Digital literacy challenges: Lack of proficiency in the use of LMS tools for specific purposes (tests, test results export, essay question randomizer); Lack of proficiency in use of specific communicative interface options (for e.g. screen sharing, separate rooms division, individual and public chats); Lack of proficiency in use of Google Suite tools; Lack of proficiency in

the use of mobile versions and Android/iOS app versions of platforms, tools and services, used in FLE workflow;

- 2) Digital divide in accessibility of computer and Web technologies, necessary for all stages of Foreign Languages Education: Internet bandwidth and stability of connection; Update of PC hardware and software for all participants of the FLE process (out of date software impaired videoconferencing possibilities, for e.g.); Access to back-up smart devices to carry out the FLE procedures.

- 3) Soft skills and emotional challenges: Learning and innovation (professional activity outside of the comfort zone); Entrepreneurial outlook; Time-management; Collaboration and networking via digital media in the lockdown framework; Emotional intelligence and awareness; Critical thinking and decision making;

The comprehensive study results inform the derivation of the following recommendations for Foreign Languages Education in emergency digitization paradigms:

- to critical review of the curriculum content to accommodate the dynamics of multi-disciplinary digital input expectations of the FLE stakeholders;
- to review and update of the FLE curriculum content interconnectivity and learning outcomes to accommodate the interoperable interface of skills, customized to facilitate professional activity and language application in the intensely digitized world (especially under extreme duress);
- to devise a flexible model of FLE content upgrade to meet the dynamic transdisciplinary requirements of the job market in the digital economy of the post-pandemic / post-war timespans and to enhance universal employability of professional application for foreign languages majors in the digital age.

The study results have a potential to be furthered and elaborated in assessment of interdisciplinary and interoperable digital skills adaptability for separate groups FLE stakeholders, according to according to roles and tasks performed in the language acquisition workflow, as well as according to age and entry digital literacy level. The perspective of the study is in scaling the inquiry to estimate the parameters of digital literacy formation for separate groups of source and target languages acquired, as well as to diagnose interdisciplinary digitization trends of FLE across countries of Asia and countries of Europe.

5. ACKNOWLEDGEMENT

The paper has been reviewed by Hanna Prykhodko, Hab. Doc., Zaporizhzhya National University, Ukraine. Empirical findings and survey procedures have been conducted under the auspices of Integrated Research framework of Germanic Philology Chair *Digital Transformative Linguistics and Cross-cultural Communication in Romance and Germanic Languages (0123 U 102796)* and Integrated Research framework of Oriental Studies Chair of Borys Grinchenko Kyiv University *Oriental Studies development in the framework of Higher Education Internationalization (0116 U 007073)*. The authors extend special acknowledgement to the Armed Forces of Ukraine for providing safety to complete this work.

6. REFERENCES

- [1] Abbott S., **The Glossary of Education Reform**. Retrieved from: <http://edglossary.org/hidden-curriculum> (accessed July 2020), 2013.
- [2] Callaos N., Marlowe T., “Inter-Disciplinary Communication Rigor”. **Rigor and Inter-Disciplinary Communication: Intellectual Perspectives from Different Disciplinary and Inter-Disciplinary Fields**. TIDC, LLC, 2020, pp. 4-29.
- [3] Davies A., Fidler D. et al, **Future Work Skills 2020**, Institute for the Future for University of Phoenix Research Institute. Retrieved from: https://www.iftf.org/uploads/media/SR-1382A_UPRI_future_work_skills_sm.pdf, 2011.
- [4] Dos Reis A., “To Be a (Blended) Teacher in the 21st Century - Some Reflections”, **International Journal of Research in E-learning**, 1(1), 2015, pp. 11-24.
- [5] DQ Global Standards Report, **World’s first global standard for digital literacy, skills and readiness launched by the Coalition for Digital Intelligence**. Retrieved from: <https://www.dqinstitute.org/>, 2019.
- [6] European Commission, **Digital Competence 2020**. Retrieved from: <https://ec.europa.eu/jrc/en/digcomp/digital-competence-framework>, 2020.
- [7] European Commission, **European E-Competence Framework Guideline**. Retrieved from: <https://www.ecompetences.eu/>, 2020.
- [8] Frodeman R. (ed). **The Oxford Handbook of Interdisciplinarity (2 ed.)**, OUP, 2017.
- [9] **Holbrook, J. Britt (2013)**. “What is interdisciplinary communication. Reflections on the very idea of disciplinary integration”, **Synthese**, Vol. 190 (11), 2013, pp. 1865–1879.
- [10] Hymes, Dell H., “Communicative competence”, **Sociolinguistics: selected readings**, Harmondsworth: Penguin., 1972, pp. 269–293.
- [11] Interoperability Working Group, **Definition of Interoperability**. Retrieved from: <http://interoperability-definition.info/en/>, 2020.
- [12] Jacobs, J.A. & S. Frickel, “Interdisciplinarity: a critical assessment”, **Annual Review of Sociology**, Vol. 35, 2009, pp. 43–65.
- [13] J. Peterlin, V. Dimovski, M. Meško, V. Roblek. “Cultivating Management Education Based on the Awareness of Students’ Multiple Intelligences”, **SAGE Open**. vol. 11, issue 1, 2021.
- [14] Kulinich, T. Y. Lisnievska, Y. Zimbalevska, T. Trubnik, and S. Obikhod, “Digitalization of economies of low and middle income countries in the context of digital transformation”, **Amazonia Investiga**, vol. 11, no. 51, pp. 300-311, Apr. 2022.
- [15] Makhachashvili, R., Semenist, I., “Innovative Educational Communication in the Global Digital Environment: Trans-Disciplinary Models, Tools, and Mechanisms”, **Proceedings of the 13th International Multi-Conference on Complexity, Informatics and Cybernetics**, IIS, 2022, pp.134-140.
- [16] Makhachashvili, R., Semenist, I., “Transdisciplinary Communication as a Meta-Framework of Digital Education”, **Proceedings of the 26th World Multi-Conference on Systemics, Cybernetics and Informatics, WMSCI 2022**, IIS, 2022, pp. 151-156.
- [17] R. Debopriyo “Media Design and Technical Writing with Industry 4.0 Towards Developing Entrepreneurial Thinking in EFL Learners: A Pilot Study”, **Proceedings of 9th International Conference on Information and Education Technology, ICIET 2021**, 1. pp. 98-109, 2021.
- [18] Shannon, C. E., "A Mathematical Theory of Communication", **Bell System Technical Journal**, Vol. 27 (3), 1948, pp. 379–423.
- [19] Slater, T. "Cross-Domain Interoperability", **Network Centric Operations Industry Consortium - NCOIC**. Retrieved from: <https://www.ncoic.org>, 2013.
- [20] Slater, T. "What is Interoperability?", **Network Centric Operations Industry Consortium – NCOIC**. Retrieved from: <https://www.ncoic.org>, 2012.
- [21] UNESCO, **ICT Competency Framework for Teachers**. Retrieved from: <https://unesdoc.unesco.org/ark:/48223/pf0000265721>, 2018.
- [22] Wulf, G., Shea, G. “Principles derived from the study of simple skills do not generalize to complex skill learning”, **Psychonomic Bulletin & Review**, 9, 2002, pp. 185–211.

Teacher digital' skills for online education in preschool and schools education careers

Sandra MONTENEGRO

Master program in Education with major in Information Communication Technology on Education, Faculty of Postgraduate Studies.
Department of Pedagogy, Faculty of Philosophy, Literature and Educational Science, Universidad Técnica de Manabí
Portoviejo, 130113, Ecuador

Karina MENDOZA

Department of Pedagogy. Faculty of Philosophy, Literature and Educational Science, Universidad Técnica de Manabí
Portoviejo, 130113, Ecuador

Carlos CHANCAY

Department of Foreign Language Pedagogy. Faculty of Philosophy, Literature and Educational Science, Universidad Técnica de Manabí
Portoviejo, 130113, Ecuador

Katty POSLIGUA

Department of Pedagogy. Faculty of Philosophy, Literature and Educational Science, Universidad Técnica de Manabí
Portoviejo, 130113, Ecuador

Jaime MEZA

Computacional Systems, Universidad Técnica de Manabí
Portoviejo, 130113, Ecuador

ABSTRACT

In order to cover the educational needs generated by the accelerated change in the rhythm of life of society, the creation of other study modalities arises that allow access from anywhere, in this sense, the online education modality emerge, it requiring teachers to evolve in their skills to be participants in this teaching-learning process. This research propose a pedagogical strategy based on the use of tools that allow the development of teachers' digital skills in the face of virtual learning environments in the online modality of the in preschool and schools education careers of the Technical University of Manabí. A descriptive level methodology is addressed, supported by a mixed approach. Early outcomes shown the importance of digital competences to face the educational need of today's society, and, the training needs of the teachers this environments. The training strategy based on the use of tools for the development of digital skills promotes significant learning in teachers, and allows them to satisfactorily face virtual learning environments, due to the high motivation that their use generates efficient in these environments.

Keywords: Digital skills, virtual environments, teachers, training strategy, online modality.

1. INTRODUCTION

In order to cover the educational needs generated by the accelerated change in the rhythm of life of society, the creation of other study modalities arises that allow access from anywhere. This need allowed the creation of virtual education and closely related distance education; In the same way, the online modality was born, among others, requiring teachers to evolve in their digital skills to be participants in this teaching-learning process.

According to Quintana [17], a teacher's digital competence is "the ability to master knowledge, skills, and attitudes to optimally use ICTs in both the teaching and learning process of the student." In this regard [16] states that the digital skills developed by the teacher allowed him to respond effectively and efficiently to the changes that occur, in a continuous and accelerated way, the technological advances of globalization. [6] in his study: "digital skills in upper secondary education teachers", (Master's Thesis) at the Instituto Tecnológico de Monterrey, Naucalpan, Mexico. With this investigation it was determined that the competences need to be consolidated by the teacher around the use of educational technologies axis.

In the Ecuadorian context, the Secretaría de Educación Superior, Ciencia, Tecnología e Innovación (Senescyt) has been expanding the coverage of the online academic offer at the national level, achieving that thousands of students from different places have access to higher education, strengthening in a pertinent and responsible manner to the teaching staff to successfully achieve its implementation and permanence.

It must be considered that virtual education is related to distance education, which was born as a result of the need for quality educational coverage for people who, due to distance and time, cannot travel to a training center. This need allowed the creation of online modalities, forcing teachers to be participants in this teaching-learning process.

The experience of the author of this work as a follow-up tutor in the initial and basic online careers of the Technical University of Manabí has made it possible to demonstrate the shortcomings of digital teaching skills compared to virtual learning environments. It was observed that teachers do not use technological tools adequately due to lack of knowledge, lack of skills to execute innovative strategies aimed at developing the pedagogical

process through digital resources, do not have knowledge regarding digital skills, are unaware of the use of virtual environments and lack of institutional support for training; among the most prevalent.

This problem leads to the following formulation of the problem: how to contribute to the development of teachers' digital skills in the face of virtual learning environments in the online modality? It is proposed as an objective to design a training strategy for the development of digital skills of teachers in the virtual learning environments in the online modality of the Initial and Basic careers of the Technical University of Manabí.

In order to fulfill the general objective, the following specific objectives are established: 1) To base the theoretical references that support the importance of digital teaching competences and virtual learning environments in online mode of the Initial and Basic Careers of the Technical University of Manabí ; 2) Diagnose the current state of digital teaching skills and the management of virtual learning environment tools in the online initial and basic careers of the Technical University of Manabí; 3) Prepare the structure and activities of the training strategy for the development of teachers' digital skills through the use of tools in virtual learning environments in online mode; and, 4) Validate the feasibility of applying the training strategy designed for the development of digital teaching skills.

2. DEVELOPMENT

The systematization of the case study carried out in the Initial Education and Basic Education careers, online modalities, of the Faculty of Philosophy, Letters and Educational Sciences, of the Technical University of Manabí is presented, starting with a theoretical methodological support.

Phase 1: theoretical systematization (Literature Review).

Virtual learning environments: The virtual environment is the set of means of different synchronous or asynchronous interaction that is carried out by means of software that complements interaction and collaboration in the classroom. The importance of the use of technological tools for learning has become much more remarkable, since the traditional model has been modified, therefore, education professionals have seen the need to acquire new pedagogical skills, which allow them to propose new methodologies and face new educational challenges [9].
 Digital Competences in teachers: [13] affirms that the teacher's competencies in the educational framework are established based on the needs or demands of the time, therefore, it is essential that the educator accommodate and develop capacities that seek to satisfy the new training needs of future professionals, which are mediated by the context of the time. "In the current context we find ourselves immersed in a society that is increasingly oriented towards the process of massive technification." (p. 537, 2018). The need to use them or their obligatory recurrence can be sustained in what was stated by [7] when mentioning that the "...technological revolution has reached the classrooms, either by the hand of the students, by the teachers themselves or as a claim of society, and therefore we cannot ignore it" (p.1, 2018). An important point for the university professor in correspondence with modern technologies is adapting to them, which in itself is not an easy task since, among other things, it will require them to adjust to digital literacy and everything that it demands. [7]; [14]. On the other

hand, [16] indicated that some studies have suggested that, if teachers use sufficiently concrete knowledge, they will be able to highlight the drawbacks that arise and thus integrate technology into their experience.

Virtual learning environments in the development of digital skills: Specifically, in higher education, the constant training of teachers should promote the autonomous learning of the student body, stimulate research and problem solving, through practical exercises and the use of tools. technological. In this way, competent students and professionals capable of effectively responding to the current demands of the country will be created [19]. On the other hand[5] it confirms that, despite the implementation of technological tools in education and the commitment of teachers to continue updating and imparting their knowledge with a good predisposition and positive attitude, the lack of interaction and social exchange that the student used to feel in face-to-face environments, on the other hand [20] indicates that the aspects of innovative teaching practice, emphasizing the importance of the teacher mastering his field of action, but also being a reflective entity that manages to achieve the different elements that allow you to transform; This is precisely what virtual environments allow in the learning process, learning and incorporating new contexts so that students develop digital skills, to the extent that their teachers lead them towards the benefits of technology.

Phase 2: materials and methods

The methodological approach comprises a type of descriptive research. A mixed approach design, parallel design, supported by a multiple case study was applied based on [10], [18]. This work was carried out at the Technical University of Manabí, Faculty of Philosophy, Sciences and Letters of Education in the Initial and Basic Careers of the online modality, where 99 teachers were research subjects, including authors and follow-up tutors and 2550 Initial Education students and 2750 Basic Education students. A random probabilistic sampling was applied, in which a sampling formula was applied to the total population of 5300, with a margin of error of 10%, yielding a total of 94 students at a reliability level of 95%.

The calculation used to draw the sample is proposed:

$p = q = 50\%$
 $N = \text{population size} = 5300$
 $e = \text{margin of error} = 10\%$
 $z = \text{confidence level} = 95\%$
 $\sigma = \text{confidence level constant} 1.96$

$$m = \frac{(N)}{1 + \frac{(e)^2(N-1)}{\sigma^2(p)(q)}} \quad m = 94$$

Regarding tutor teachers, authors and follow-up tutors, no sampling was carried out since 100% of the population was taken.

The techniques used to obtain information were the following:

| Techniques | Tools | Objective | Application |
|-------------|---------------------------------|--|--|
| Survey | List of questions | Diagnose teachers' digital skills | Teachers |
| Observation | Observation form | Conducted a classroom observation (RESEARCHER) | Authors, Tutors, Students in the process (monitoring tutors) |
| Survey | List of questions (Survey form) | Assess if the teacher possesses digital skills from the students' perspective | Students |
| Interview | Questionnaire | Conducted an interview to verify the teacher's digital skills | Monitoring tutors |
| Focus group | Interview guide | Conducted a group interview with a specific focus group, addressing questions related to the protocol's objectives | Authors and tutors (teachers) |

Phase 3: results

In the country, the valuation of technology for the development, appropriation and dissemination of knowledge determined that the National Plan for Science, Technology, Innovation and Ancestral Knowledge (2013-2017) in its policy 6 establishes "...incorporate new information technologies information and communication to the generation and dissemination of knowledge so that they contribute to boosting national production with the following improvement in the quality of life of the population". Said objective is attached to the technological advances that the degree must incorporate. The foregoing would involve that the professionals who are trained in the Basic and Initial Education career strengthen their capacities in the management of technological tools applied to the methodology of work in the classroom, aware that this represents promoting autonomous and collaborative learning, to facilitate investigative processes.

For the creation of the Basic and Initial Education careers in online modality, it was generated with the sum of the efforts of five public universities: Technical University of Manabí, Central University of Ecuador, State University of Milagro, Technical University of the North and Universidad of the Armed Forces-ESPE. An innovative proposal was presented that allowed access to quality teacher training, with the use of virtual media and overcoming mobility and geographic location barriers. Tutors and teachers had to use technology, materials and be a guide-mediator or facilitator of learning to contribute to the development of conceptual reasoning, strengthening continuity of thought and motivation of student interest. The five universities have technological support for comprehensive training. The virtual system of the Technical University of Manabí made it possible to manage, distribute and control the activities of the non-contact training learning management process, of the Learning Management System type, with a definition of a content management system of the Content Management System type that empowered the exchange of learning social tools, blogs, wikis, multimedia content, video chats, forums, 3D environments, video games, etc. All this allowed interaction with people and providing information

between users of the computer platform, the services contained in the electronic portals through policies regarding the operating time of the classrooms or the virtual campus, which determine availability 24 hours a day and access from all types of electronic devices, through the use of more advanced technological and communication elements within the process objects simulating situations real. This entire process was based on policies that allow users to provide relevant information on the technological and connectivity requirements necessary to study the degree in the online modality.

The questionnaire was used with the purpose of making a diagnosis and evaluating the level of preparation of teachers in digital skills. For this research, the questionnaire was extracted from the article entitled "questionnaire to assess teacher digital competence and the use of social networks by teachers in their initial training" from [8]. Said instrument was considered adequate to the needs of the researcher and some questions were adapted for its application. After this, the changes made were sent to experts to be validated and then a pilot test was applied to determine the reliability index by means of Cronbach's Alpha.

For the analysis of the results, the TPACK method was used, which includes the three types of knowledge in digital skills: knowledge, pedagogy and technology.

Once the information from the participants was obtained through the survey, the data analysis was carried out. During this process, the following could be identified in a general way: in terms of age, it was observed that the majority of the participants were in the 41-year-old or older group, followed by the 31-40-year-old group. There was a minority of participants aged between 20 and 30 years. In relation to gender, it was found that the majority of the participants were women. In addition, the opinions and perspectives of teachers regarding Information and Communication Technologies (ICT) were taken into consideration. The following significant advantages were highlighted: access to information, the diversity of methodologies and the possibility of publishing information. However, limitations were also identified in the use of ICT, such as technical failures, access to the network, teacher training and the prior knowledge that users should have.

DIMENSION A: CONTENT

In the initial diagnosis, it is evident that teachers consider they have moderate knowledge about the use of ICT tools. During the focus group with the tutor teachers and authors, when inquiring about their knowledge of the content to be taught. It was observed that they are almost always integrated into the tools used, addressing the contents with clear and structured conceptions, maintaining continuity in them. The students, when asked in the survey about the dimension of knowledge, corroborated that teachers always address content in accordance with the knowledge that is intended to be taught. For their part, the follow-up tutors expressed that the teachers almost always master the contents of the subjects. This information was also supported by the documentary analysis of the records of teaching activities carried out by them. Additionally, the researcher, as part of the group of follow-up tutors, carried out direct observation of the teaching-learning process in the online modality. During this observation, he collected first-hand information, evidencing that, in terms of knowledge, teachers tend to develop and organize the virtual learning platform effectively in most cases.

DIMENSION B: PEDAGOGY

In the initial diagnosis, it was evidenced that teachers consider accessibility for students with disabilities and constant support for learning to be important. The relevance of the use of resources by students was highlighted, as well as the ease of use of digital skills for teachers, regardless of socioeconomic situation, in order to facilitate access to digital resources and strengthen didactic innovation in the teaching-learning process. It sought to enhance knowledge in the classroom, motivating and encouraging the dedication of teachers, sharing concerns and using open content in virtual learning classrooms. In the focus group, when inquiring about the knowledge of general pedagogical activities and the processes and practices of the teaching method, the tutor teachers and authors indicated that they almost always integrate effective pedagogical techniques. However, only sometimes do they combine them with technological resources, almost always responding to the needs of the students. On the other hand, students have different opinions when asked about the pedagogical dimension, adding that teachers adequately manage the knowledge of the teaching and learning processes. The follow-up tutors expressed that almost always the teachers demonstrate pedagogical and significant competences in the management of their class and the contents they teach. This information was supported by the documentary analysis of the records of teaching activities carried out by them. In addition, the researcher, as part of the group of follow-up tutors, was able to directly observe the teaching-learning process in the online modality. During this process, first-hand information was collected, evidencing that, in terms of the pedagogical dimension, teachers always adequately manage the learning resources on the virtual platforms, they almost always adequately manage the qualification processes on the virtual platform of learning and sometimes proactively use the forums, chats and emails integrated into said platform.

DIMENSION C: TECHNOLOGY

In the initial diagnosis, it was evidenced that the teachers considered that the majority of them had a moderate knowledge of the basic concepts associated with ICT. They indicated that they had fair to moderate knowledge of the basic hardware and software components in the computer. They also noted that the optimal selection of resources was moderate and the ability to resolve incidents was regular. In addition, it was noted that autonomous learning by teachers was considerable due to the lack of institutional support. In the focus group, when inquiring about the operation of technologies and the modes of presentation to develop activities, the teacher authors and tutors indicated that they almost always knew, handled, integrated and applied technological tools in virtual environments to teach the subject. However, the students differed when asked about the technological dimension in the survey, highlighting those teachers always knew, managed, integrated and applied technological tools in virtual environments to teach the subject. The follow-up tutors expressed that sometimes they adequately used and integrated technological resources in their pedagogical practice, and almost always demonstrated knowledge and management of the same in the total teaching of the subject. This information was supported by the documentary analysis of the records of teaching activities carried out by them. In addition, the researcher, as part of the group of follow-up tutors, carried out direct observation of the teaching-learning process in the online modality. During this observation, he collected first-hand information, evidencing that, in terms of the technological

dimension, the teacher almost always adequately taught the synchronous class using virtual environments and digital resources.

In the diagnosis, it was observed that teachers have a moderate level of knowledge and frequently use some tools within the technological dimension, especially the habitual application of visual presentations and the frequent use of forums in their virtual learning classrooms. Likewise, there is evidence of a regular practice of collaborative networking and the moderate use of videoconferences to interact with students.

Phase 4. Proposal: Training strategy in digital skills to strengthen teacher performance in digital environments

This section deals with the design of a proposal based on the diagnostic study carried out in the online Initial and Basic careers of the Technical University of Manabí, and with the theoretical support of the consulted referents.

The theoretical foundation is based on the exhaustive analysis of the theoretical references consulted regarding the development of digital skills to strengthen teaching performance in digital environments. In this, it was obtained as main premises that digital competences are the skills and abilities to manage information technologies for a better execution of virtual learning environments. The teaching performance allows the use of different teaching-learning methodologies that strengthen the capacities and competences of each one of the students, the digital environments allow to complement the synchronous training given by the teacher since it integrates different tools, materials and resources, managing to interact through the media. virtual. The methodological foundation is based on the diagnostic study carried out through various methods, techniques and instruments applied to tutor teachers, authors, students and monitoring tutors of the Initial and Basic online careers of the Technical University of Manabí in which evidence that some teachers have a basic knowledge of digital skills in the virtual environments used in this modality, which due to ignorance or lack of motivation do not apply in their virtual classrooms, turning students into incompetent subjects in the modern world, since they do not develop their skills to improve teaching-learning processes, likewise the proposal will be flexible, adaptable since it allows interdisciplinary training by maintaining direct contact with the contents and applying knowledge directly in their classrooms.

Regarding the requirements for an efficient development of the training strategies, technological equipment (computer, tablet), connectivity, endorsement of the authority is demanded, it should be noted that our objective is to strengthen teaching performance in the face of virtual environments through a strategy training in digital skills in the online initial and basic careers of the Technical University of Manabí, for the fulfillment of this objective the following specific objectives were established: 1) Plan the methodical and sequential procedure of the training strategy; 2) Run training workshops in synchronous and asynchronous virtual environments; 3) Evaluate the strategy designed in its different moments.

This proposal is conceived in a design of three stages that are planning, executing, evaluating, each one with its different actions and recommendations. This is how its structure looks like:

| Formative Strategy | Planning | Immersion |
|--------------------|----------|---|
| | | Design |
| | | Socialization |
| Execution | | Workshop 1: Synchronous virtual environments |
| | | Workshop 2: Asynchronous virtual environments |
| | | Workshop 3: Other digital tools |
| Evaluation | | Initial |
| | | Process-oriented |
| | | Final |

Figure 1

STAGE 1 planning: the objective of this stage is to plan the process of immersion, design and socialization of the training strategy, within this the immersion, design and socialization stages were described, in this way it is detailed that in the immersion stage a call to all teachers of the online Initial Education and Basic Education careers requesting as the main requirement the predisposition to participate, learn and improve the knowledge of digital skills in the face of virtual learning environments, on the other hand, the design stage consisted of throughout the process carried out to achieve the training strategy that was designed as an alternative to improve digital skills, supported by user guides so that they can be applied in the different activities related to teaching-learning on virtual platforms, therefore the socialization stage was planned for two moments, to the scientific community through this article; and, to the academic community in a coordinated session with the respective authorities of online careers.

STAGE 2 execution, aims to: Execute training workshops in synchronous and asynchronous virtual environments applying a designed manual, allowing to describe the stages of the different workshops to be taught. That is why three training workshops were coordinated with the respective authorities of online careers where the following topics were focused:

Synchronous virtual environments: These environments allow a real-time interaction between teacher-student, managing to resolve different doubts at the precise moment, as well as being able to interact live with classmates in the different activities that are presented, it should be noted that for these meetings in the online careers of the Technical University of Manabí the Zoom platform is used, for this a workshop was created in which it will be possible to access to know in depth the operation of the Zoom platform, which is used for synchronous meetings in the online classes, it should be noted that the zoom platform is a tool that allows you to work online, make video calls, with a desktop sharing functionality, whiteboard, chat, record the conference, share documents and be able to access from anywhere and any device.

Asynchronous virtual environments: These environments achieve the independence of the student, encouraging them to organize their time since it allows access at any time to review the material, as for the tool used in these meetings is the Moodle platform, in fact it was developed a workshop which shows how to effectively manage the platform so that teachers can plan their

activities in asynchronous meetings in online classes, therefore, Moodle is an online learning and interaction platform between teachers and students, it presents an interface as simple and intuitive in which the course can be published in a dynamic and interactive way with the possibility of being able to access it from anywhere

Digital tools: digital educational tools are tools for content management, for interaction with students and gamification of learning, allowing the construction of knowledge and achieving digital skills in students, therefore the workshop has included tools that will allow favorable transformations to be obtained that motivate students through the interaction and manipulation of the different tools, facilitating student learning in online classes.

STAGE 3 evaluation, aims to: Verify the feasibility or results obtained from the various evaluations, so that the stages of initial, procedural and summative evaluations can be described. The initial evaluation begins in the immersion phase, which began with a call to deepen and improve the previous knowledge of teachers regarding virtual learning environments, evidencing in a certain way that knowledge is basic and requires a deep immersion in field. The formative evaluation promotes learning since it not only focuses on measuring results but also adds feedback as a characteristic element of this evaluation. In this case, this evaluation was developed during the training process of the workshop, using the main characteristic (feedback) of this evaluation system that allows attention and progressive improvement of learning. The summative evaluation gives us the opportunity to assess the learning obtained in the development of a process and determine if the objectives set were achieved. The degree of satisfaction test will be applied to the teachers involved, which will provide us with the effectiveness of the workshops carried out.

3. CONCLUSIONS

The theoretical references analyzed support the importance of digital skills to meet the educational need of today's society. With a diagnostic study, it was possible to demonstrate the training needs of the teachers of the Initial and Basic online careers with respect to digital skills. The inputs obtained allowed the efficient development of a training strategy aimed at improving digital skills.

4. REFERENCES

[1] Arias Gómez, M. A. (junio de 2018). Perfil y Competencias del docente universitario recomendados por la UNESCO y la OCDE. Atlante Cuadernos de Educación y Desarrollo

[2] Avalos, B. (2005). CPD Policies and Practices in the Latin American Region. En Day, C. y Sachs, J. (Eds.), International Handbook on the Continuing Professional Development of Teachers. Oxford: McGraw-Hill Education.

[3] Balarin, M., & Escudero, A. (2019). El acompañamiento pedagógico como estrategia de formación docente en servicio: reflexiones para el contexto peruano.

[4] Baque, P. G. C., & Marcillo, C. (2020). Estrategias pedagógicas innovadoras en entornos virtuales de aprendizaje. Dominio de las Ciencias, 6(3), 56-77.

[5] Becerra Rodríguez, D. F. (2020). Percepciones de los profesores y estudiantes sobre la enseñanza remota durante la pandemia COVID-19: Caso del Colegio Misael Pastrana.

Educación Química, 31 (5), 129 - 135.

[6] Bustos, H. (2014). Las competencias digitales en los docentes de educación media superior. (Tesis de maestría, Instituto Tecnológico de Monterrey, Naucalpan).

[7] Carrillo, M., Cascales, A., & Valero, A. (2018). Apps para el aprendizaje de idiomas en la Universidad de Murcia. *Revista de Educación a Distancia*, 58(13), 1-18. Recuperado de http://www.um.es/ead/red/58/carrillo_et_al.pdf

[8] Calderón-Garrido, D., Gil-Fernández, R., & León-Gómez, A. (2018). Cuestionario para evaluar la Competencia Digital Docente y el uso de las Redes Sociales de los docentes en su formación inicial.

[9] Cueva Gaibor, D. A. (2020). La tecnología educativa en tiempos de crisis. *Conrado*, 16(74), 341-348.

[10] Gross, M. (16 de Junio de 2010). Conozca 3 tipos de investigación: Descriptiva, Exploratoria y Explicativa.

[11] Macías Arias, E. J., López Pinargote, J. A., Ramos León, G. T., & Lozada Armendáriz, F. E. (2020). Los entornos virtuales como nuevos escenarios de aprendizaje: el manejo de plataformas online en el contexto académico. *Revista de Ciencias Humanísticas y Sociales (ReHuSo)*, 5(3), 72-81.

[12] María, V. (2014). Inventario 4x40x4 de competencias digitales de los docentes en el siglo XXI. *Revista Académica Conexión*. Obtenido de <http://www.aliatuniversidades.com.mx/conexxion/index.php/en/educacion/789-inventario-4x40x4-de-competencias-digitales-de-los-docentes-en-el-siglo-xxi-ano-3-numero-8>

[13] Martínez, M. C. (2020). Caracterización del perfil de las competencias laborales en el docente universitario. *Orbis: revista de Ciencias Humanas*, 15(45), 23-37.

[14] Ocaña, Y., Valenzuela, L., & Garro, L. (2019). Inteligencia artificial y sus implicaciones en la educación superior. *Propósitos y Representaciones*, 7(2), 536-568. doi: <https://doi.org/10.20511/pyr2019.v7n2.274>

[15] Ocaña-Fernández, Y., Valenzuela-Fernández, L., & Morillo-Flores, J. (2020). La competencia digital en el docente

[16] Ottenbreit, A., Liao, J., Sadik, O., & Ertmer, P. (2018). Evolution of Teachers' Technology Integration Knowledge, Beliefs, and Practices: How Can We Support Beginning Teachers Use of Technology? *Journal of Research on Technology in Education*, 1-23. doi: <https://doi.org/10.1080/15391523.2018.1487350>

[17] Quintana, J. (2000). Competencias en tecnologías de la información del profesorado de educación infantil y primaria. *Revista Interuniversitaria de Tecnología*.

[18] Stacciarini, J. M. R., & Cook, C. L. (2015). La aplicación efectiva de la investigación usando métodos mixtos. *Enfermería universitaria*, 12(3), 99-101.

[19] Suárez, N. (2020). Formación docente universitaria y crisis sanitaria COVID-19. *Ciencia América*, 9(2), 109-114.

[20] Urquijo, S. L. S., Álvarez, J. F., & Peláez, A. M. (2019). Las competencias digitales docentes y su importancia en ambientes virtuales de aprendizaje. *Revista Reflexiones y Saberes*, (10), 33-41.

[21] Vaillant, D. (2007). Mejorando la formación y el desarrollo profesional docente en Latinoamérica. *Revista Pensamiento Educativo*, 41(2), pp. 207-222.

[22] Vezub, L. (2010). El desarrollo profesional docente centrado en la escuela: concepciones, políticas y experiencias (1ra ed.). Buenos Aires: Instituto Internacional de Planeamiento de la Educación IIPPE - UNESCO.

Disclosure of Support Statement: Increasing student transparency about support from software like ChatGPT

James LIPUMA

Department of Humanities, NJIT, Newark, NJ, 07102-1982, U.S.A.

Cristo LEÓN*

Office of Research & Development, NJIT, Newark, NJ, 07102-1982, U.S.A.

ABSTRACT

This article presents the development and pilot testing of a Disclosure of Support Statement (DSS) tool to promote transparency and student engagement in academic writing. In an era where human and software supports play integral roles in completing written work, it is essential to consider the contributions of human sources and the impact of artificial intelligence software (AIS) tools. The DSS tool encourages students to reflect on how much they utilize human and software supports, including professors, peers, librarians, tutors, and AIS tools such as search engines and grammar-checking software. The ethical implications and boundaries of using these supports are explored through a series of reflective questions and class discussions. The pilot study involves a senior seminar class and utilizes the DSS alongside written reports and a literature review. The ultimate goal is to increase transparency in student work, encourage critical thinking about support options, and initiate conversations about academic integrity and the purpose of education. The data collected from the pilot tests will provide insights into student attitudes and pave the way for further analysis and refinement of the DSS tool. By embracing transparency and fostering open dialogue, educators can empower students to make informed choices in seeking support, thus enhancing their writing skills and ethical understanding within the academic environment.

Keywords: Disclosure of Support Statement, Transparency, Student engagement, Academic writing, Artificial intelligence software, Human support, Software support, Academic integrity, Ethical implications, and Educational process.

1. INTRODUCTION

Disruptive innovation, especially in education, is not new. The question becomes how quickly the change comes, how rapid the new adoption is, and what must be transformed in the wake of that change (Moore, 2014). Currently, disruptive innovation in education is Artificial Intelligence Systems (AIS or AI systems) that generate text through Natural Language Processing (NLP) and Natural Language Generation (NLG) methods. Content generators like Generative Pre-trained Transformer 3 (GPT-3) are only the most recent disruptions. Some Americans may remember the shift in mathematics education with the advent of calculators, and this debate continues to some extent despite the evidence of research (Banks, 2011). More recently, penmanship has disappeared from school curricula and has been replaced with keyboarding skills as an essential tool for modern life and schooling. Fifteen

years ago, in *Disrupting Class: How Disruptive Innovation Will Change the Way the World Learns* (Christensen et al., 2008), the authors proposed that technology-driven educational reforms will serve students better and bring the K-12 education system into the 21st century, emphasizing the need for disruptive innovation in learning and providing practical strategies and success stories for administrators, leaders, parents, and teachers.

This article presents perspectives on the newest debate over a disruptive innovation AIS and its impact on written communication. However, the challenge may be deciding where to draw the line with software rather than the battlelines between AIS as a beneficial force multiplier and its role as an insidious threat to academic integrity and writing in higher education. The researchers of this article would rather avoid the battleground perspective in which educators and students are in an arms race around integrity, authenticity, and the value of personal creations (Gluska, 2023; Hetler, 2023; Nanda, 2021; Schatten, 2022). Instead, the exploratory research detailed in this article relates to Curriculum and Instructional Designs (CID) that embrace AIS tools like ChatGPT and the use of an Acknowledgment Section that goes well beyond citations to credit the support a student writer received to create, revise, edit, and proofread their written work. This Acknowledgment Section aims to increase the transparency of the support utilized by the student and disclose the type and extent of each (Lamb, 2023).

Through this, the writing process is the end sought and not the artifact produced. This allows educators and learners to converse about the process and products of their intellectual endeavors rather than the easiest way to complete a task without getting caught.

The authors performed a Systematic Literature Review (SLR) by searching for books using the keywords "Artificial Intelligence," "Writing," and "Higher Education." This search yielded a total of 518 results. The books were published between 1987 and 2023, but for the purposes of the review, the authors focused on books published between 2020 and 2023.

The search yielded 63 books with four relevant titles (Arora, 2021; Bruce M McLaren et al., 2022; Churi et al., 2023; Daniela, 2020). The report of the SLR shows that the scholarly discussion is more general regarding disruptive innovation and its impact on academic integrity and CID. The debate about AIS has been growing over the past few years (Arora, 2021; Bruce M McLaren et al., 2022; Churi et al., 2023; Daniela, 2020; Dergaa et al., 2023; Nazari et al., 2021). With the advent of the newest versions of Large-Language-Model AIS, the concerns have grown to a fevered level. Faculty discussed transforming the CID to face this new paradigm shift during department meetings and online forums. The traditional way of crediting a

source of support or content is with a properly formatted citation. The APA and MLA both have guidance on how to cite AI-generated work (McAdoo, 2023; McNiff, 2023; Modern Language Association of America, 2023)

2. ENGAGING WITH CHATGPT

Question.- Is generative AI a force multiplier in education or an insidious threat to academic integrity and college writing?

Table 1 below contains the answer provided by ChatGPT to the above question.

Table 1.-Conversation with ChatGPT

| ChatGPT Answer |
|---|
| <p>Generative AI can be both a force multiplier in education and a potential threat to academic integrity and college writing.</p> <p>As a force multiplier, generative AI can enhance education by providing students with tools and resources to support their learning. It can generate educational content, such as tutorials, practice exercises, and interactive simulations, which can supplement traditional teaching methods. This technology can also facilitate personalized learning experiences, adapt to individual needs, and offer real-time feedback, thereby improving student engagement and outcomes.</p> <p>However, generative AI also poses challenges to academic integrity and college writing. With the advancement of language models like ChatGPT, it becomes easier for students to access pre-written essays or papers that can be passed off as their own work. This raises concerns about plagiarism and undermines the value of education. Institutions and educators need to stay vigilant and adopt measures to detect and discourage academic dishonesty.</p> <p>Ultimately, the impact of generative AI in education depends on how it is utilized and regulated. When properly integrated and monitored, it has the potential to be a valuable tool for educators and students. However, it is important to address the ethical implications and ensure that academic integrity remains a priority. (OpenAI, 2023 Personal Communication)</p> |

3. REFLECTING WITH CHATGPT

Would you have recognized the above text as AI-generated content? Could you determine to what extent AIS assisted in creating and proofing the text? The real question is how the value of the originality of what is written and the arguments put forth are the authors'. Today few people would ask us about the search engines or database tools used to access the scholarly information that underpins the writing of the work and the research that provides the background. However, not too long ago, crowd-sourced pages like Wikipedia or open-access content had a stigma attached to their value and reliability. This article does not want to take a stand for or against AIS or other supports that students might access. Instead, this article presents a

tool that has been created to allow students to have transparency in what they did to aid them in the processes of creating, revising, editing, and proofreading their written work.

This tool is currently being utilized in pilot tests to see how students react to their inclusion in assignments and to gather a baseline of possible responses when questions like these are asked.

At the time of this writing, the first exploratory ChatGPT assignments have been administered as the first step to building the Disclosure of Support Statement (DSS). Starting in June 2023, two sets of pilots with 20 students each will be run to see how students react and the types of responses the tool provides in the context of a senior seminar with required written reports and a literature review. An Institutional Review Board (IRB) is currently being reviewed for student feedback.

4. DISCLOSURE OF SUPPORT STATEMENT OF CONTRIBUTIONS BY HUMANS AND AIS

A significant aspect of being effective as an expert is using your expertise to judge when you need help or are not qualified to speak about a topic. Students often do not consider this due to poor time management, understanding, and self-assessment. In college, support is usually provided if sought, so many students cannot recognize when help is needed and how to reach out for support in a timely manner.

Putting aside all the technology needed to facilitate the construction and submission of work, such as word processing programs and Learning Management Systems, humans and software still play many different roles in supporting the completion of written work in higher education. Typically, everyone is trained to cite materials taken from outside sources to give credit to those that originated the content, whether ideas, data, images, programing code, or many others. However, with the rise of AIS, we must also consider those software tools that aided in the creation, revision, editing, and proofreading of the written work. First, let us consider the humans that might be consulted to assist:

- Professor
- Peers/classmates
- Friends
- Family
- Librarian
- Tutor/writing center staff
- Outside consultant/Expert/Paid professional

Software support has become more prominent with the advent of AIS (Murugesan, 2009) and the semantic Web or Web 3.0. Benito-Osorio et al. defines Web 3.0 as:

"Web 3.0 combines human and artificial intelligence to provide more relevant, opportune and accessible information.[...] Web 3.0 is a neologism used to describe the transformation of the Web into a database, a way of making content more accessible through multiple non-browser applications,

artificial intelligence technologies, the semantic Web, the geospatial Web and the 3DWeb" (2013, p. 277)

People reported that that AIS can be accessed anytime and they do not feel judged. Additionally, AIS can provide answers and support to students that seem to improve the work with less planning and effort than consulting a human. AIS is leveraged to accomplish some of the following:

- Searching
- Spelling, grammar, syntax proofing
- Vocabulary, word choice, and diction improvement
- Paraphrasing
- Automatic citing
- Editing of content
- Revising and reformatting
- Content generation
- Translation
- Ideation
- Collaboration

Conversations with students highlighted gray areas such as:

- To what extent are these different types of support acceptable, marginal, or a violation of ethics or academic integrity?
- Is paying for a private tutor to help you be a better writer and complete your essays and presentations' wrong'?
- Is using Grammarly to correct grammar, syntax, and spelling acceptable but wrong when it suggests how to make your paper more readable?

At some point, AIS tools will impact all of our work life overtly, so acknowledging the value and reliability of each is essential to practical outcomes. Therefore, in order to engage students and encourage them to reflect on options before using the DSS, I present a task that involves a summary of scholarly articles followed by consultation with reference librarians. Finally, I assigned them the following reflection questions:

"Please discuss to what extent, if any, you use any of the human and software supports listed above when completing academic writing tasks. Next, do you ever ask about or analyze the AI tools that support you when you use a search engine? How much do these tools assist you in completing your tasks: autofill, spellchecking, suggested search strings, presented results, what others have asked, and other search questions? Next, consider your use of a simple spelling/grammar-checking tool. If it recommends a change, to what extent do you question autosuggestion? Once you have finished the proofing on the computer, do you reread the work to see how it sounds? Does this activity ever raise the question if you are violating

academic integrity? Finally, if you ask a human to assist you in this proofreading process, do you feel they are more or less effective than the software?"

Then, the class discussion moves to one of the ethical concerns. They are prompted:

"You have been asked to use software to leverage AI and machine learning to augment your work. Do you think this is something that should be allowed? To what extent should this be restricted, regulated, or dictated at this university? Finally, how do you use AI tools in your text creation process?"

This sets the stage for a complete written report that the DSS accompanies. The authors hope this type of tool can be developed to increase the transparency of student work and support them in seeking all avenues of support resulting in effective writing. More generally, it reinforces a conversation about what is and is not permitted in assignments, along with the purpose of the educational endeavor. Hopefully, the tool's use initiates thinking about the types of value of what the student created and how it reflects on their work and personal ethics and value in the educational process.

5. DSS FOR THIS ARTICLE

To provide a tangible example, the following responses provide the completed DSS for this article.

1. Did you seek help or support from other humans to complete this task: Beyond the authors listed, we talked with two librarians participating in the pilot study, Jill Lagerstrom and Quinn I Morris-Pearson. Additionally, we use two non-blind peer editors as directed by the conference to review the manuscript before completing the submission.

2. What software help and support did you receive? The initial question was inserted into the Google search box which returned the general Google suggested items (see citations listed). The entire search string has to be broken into two different concepts to yield results unrelated to academic integrity since that term overwhelmed the search. To discover specific topics within the larger scope, such as *acknowledgment* or *disclosures*, the original search string had to be adjusted to yield the cited works related to transparency and disclosure statements, APA and MLA citations for AI, and other information. Finally, the authors followed the feedback section "People also ask" to examine potentially related searchers to this initial string.

To complete the SLR, the NJIT library database search was utilized.

The paper was edited and proofed with Microsoft Office LTSC Professional Plus 2021 using the "Spelling & Grammar" tool. In addition, the authors utilized Grammarly Premium to ensure correctness, clarity, engagement, delivery, and to detect any instances of plagiarism. Grammarly Premium was used to proofread and suggest edits for all content, including the text generated by ChatGPT May24Version (Free Research Preview). As noted in the prompt, we used ChatGPT to

generate the answer to the question. Interestingly, it mirrored the information provided in the Google searches for both sides of the initial question that Dr. Lipuma had generated.

ChatGPT was also used to generate the abstract for this article once the entire work was finished. Other than Grammarly Premium, no other edits were made to either contribution.

The authors used Zotero as a tool to collect, annotate, cite, and organize research.

Finally, VOSViewer and Power BI were used as data visualization tools for the SLR. At this point, there is not enough data to include a visualization.

3. Are there other sources of content, authority, and/or support you incorporated into this work beyond what is cited in the work (in-text and reference page) and the disclosure listed above?

To test the opening information about calculators and penmanship, I had a conversation with my twelve-year-old daughter about her experience in school and what she and her classmates said. She shared that the other math class could use calculators on a test just for the long division since they had less time due to scheduling. In her mind, the calculator was a tool to be used and did not provide any advantage nor negatively impact her math learning. Therefore, she was happy to do her long division with pencil and paper.

6. CONCLUSION

This article is only the first step to testing the use of a DSS tool for aiding students to be transparent about the support they access. The researchers plan to be able to report on data by the time of the conference to share some sense of student attitudes towards this topic. Additionally, using the DSS may provide unexpected results; as part of this exploratory pilot, the authors consider this an excellent first step toward an open conversation with students around AIS. The researchers do not want to be "academic integrity police" or suspicious of every word written. Of course, due diligence in CID is needed to make the lessons and assessments in class measure student progress and mastery as intended. The DSS is just another way to make visible the work of students and their thinking, and perhaps also give them options they did not realize they had for seeking help and support on the work they submit. It also has applications outside of classroom practice in scholarly and professional writing, as shown in this work. Moreover, the DSS may prove to be a good conversation starter and not just another checklist or obligation. Only time will tell as the pilots yield data to be analyzed.

7. ACKNOWLEDGEMENTS

Special thanks to the blind reviewers, whomever you may be, for your notes and observations that improved the final version.

Nonblind Peer-Reviewers

Bruce Bukiet, Professor of Mathematical Sciences, New Jersey Institute of Technology.

Quinn I Morris-Pearson, Research and Instruction Librarian, New Jersey Institute of Technology.
Catherine Siemann, Senior University Lecturer, Humanities & Social Sciences, New Jersey Institute of Technology.

Disclosure statement

No conflict of interest pertains to the research presented above.

ORCID

Cristo Leon <https://orcid.org/0000-0002-0930-0179>

James Lipuma <https://orcid.org/0000-0002-9778-3843>

8. SOURCES

- Arora, V. (2021). *Artificial Intelligence in Schools: A Guide for Teachers, Administrators, and Technology Leaders*. Taylor and Francis. <https://doi.org/10.4324/9781003183235>
- Banks, S. (2011). *A Historical Analysis of Attitudes Toward the Use of Calculators in Junior High and High School Math Classrooms in the United States Since 1975* [Masters of Education, Cedarville University]. [chrome-extension://efaidnbmnnnibpajpcglclefindmkaj/https://files.eric.ed.gov/fulltext/ED525547.pdf](https://files.eric.ed.gov/fulltext/ED525547.pdf)
- Benito-Osorio, D., Peris-Ortiz, M., Armengot, C. R., & Colino, A. (2013). Web 5.0: The future of emotional competences in higher education. *Global Business Perspectives*, 1(3), 274–287. <https://doi.org/10.1007/s40196-013-0016-5>
- Bruce M McLaren, Pengcheng Jiao, Amir H Alavi, & Fan Ouyang. (2022). *Artificial Intelligence in STEM Education: The Paradigmatic Shifts in Research, Education, and Technology*. CRC Press. <https://doi.org/10.1201/9781003181187>
- Christensen, C., Johnson, C. W., & Horn, M. B. (2008). *Disrupting Class: How Disruptive Innovation Will Change the Way the World Learns* (1st edition). McGraw-Hill.
- Churi, P. P., Joshi, S., Elhoseny, M., & Omrane, A. (2023). *Artificial Intelligence in Higher Education: A Practical Approach* (1st ed.). CRC Press. <https://doi.org/10.1201/9781003184157>
- Daniela, L. (2020). *Pedagogies of Digital Learning in Higher Education*. Taylor and Francis. <https://doi.org/10.4324/9781003019466>
- Dergaa, I., Chamari, K., Zmijewski, P., & Ben Saad, H. (2023). From human writing to artificial intelligence generated text: Examining the prospects and potential threats of ChatGPT in academic writing. *Biology of Sport*, 40(2), 615–622. <https://doi.org/10.5114/biolsport.2023.125623>
- Gluska, J. (2023, April 5). *How to Make AI Writing Undetectable: A Complete Guide* [..Org]. Gold Penguin. <https://goldpenguin.org/blog/make-ai-writing-undetectable/>
- Hetler, A. (2023, March 29). *Pros and Cons of AI-Generated Content* [..Com]. TechTarget WhatIs.Com.

- <https://www.techtarget.com/whatis/feature/Pros-and-cons-of-AI-generated-content>
- Lamb, S. (2023, January 27). How we're approaching AI-generated writing on Medium [..Com]. *Medium*. <https://blog.medium.com/how-were-approaching-ai-generated-writing-on-medium-16ee8cb3bc89>
- McAdoo, T. (2023, April 7). How to cite ChatGPT [..Org]. *APA Style*. <https://apastyle.apa.org/blog/how-to-cite-chatgpt>
- McNiff, L. (2023, March 24). *Citation Style Guide: Citing Artificial Intelligence (AI)*. Dalhousie University Libraries. <https://dal.ca.libguides.com/CitationStyleGuide/citing-ai>
- Modern Language Association of America. (2023, March 17). How do I cite generative AI in MLA style? *MLA Style Center*. <https://style.mla.org/citing-generative-ai/>
- Moore, G. A. (2014). *Crossing the Chasm, 3rd Edition: Marketing and Selling Disruptive Products to Mainstream Customers* (3rd ed.). Harper Business.
- Murugesan, S. (2009). Handbook of Research on Web 2.0, 3.0, and X.0: Technologies, Business, and Social Applications. In *Http://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/978-1-60566-384-5* (1ra ed., Vol. 2). IGI Global. www.igi-global.com/book/handbook-research-web/518
- Nanda, N. (2021, December 7). Is AI a threat to academic integrity? [..Com]. *The Ouriginal Blog*. <https://www.ouriginal.com/is-ai-a-threat-to-academic-integrity/>
- Nazari, N., Shabbir, M. S., & Setiawan, R. (2021). Application of Artificial Intelligence powered digital writing assistant in higher education: Randomized controlled trial. *Heliyon*, 7(5), e07014–e07014. <https://doi.org/10.1016/j.heliyon.2021.e07014>
- Schatten, J. (2022, September 14). *Will Artificial Intelligence Kill College Writing?* [..Com]. The Chronicle of Higher Education. <https://www.chronicle.com/article/will-artificial-intelligence-kill-college-writing>

A Markov Chain for the evaluation of completion rate in Engineering Technical and Vocational Education and Training Colleges of South Africa

Masikini LUGOMA

Department of Mining Engineering
University of South Africa
Pretoria, South Africa

Masengo ILUNGA

Department of Civil Engineering
University of South Africa
Pretoria, South Africa

ABSTRACT

The Markov chain (MC) approach is used in the evaluation of the completion rate for each engineering qualification offered in the technical and vocational education and training (TVET) colleges of South Africa. The data related to TVET is used to demonstrate the practical importance of this approach. An absorbing MC is used where enrolment class and exam illegibility state are transient states, whereas the exclusion and completion are absorbing states. The approach replicates the completion rates as determined by the Department of Higher Education and Training (DHET). The completion rate is defined as the ratio between students who completed and those eligible for examination. MC goes further in defining the rate at which the learner is excluded from completion as well as the rate of completion considering the learner starts from enrolment state. The average times are estimated between the transient states and the completion state. Generally, the probabilities of absorption into the completion state were relatively high as opposed to those of exclusion state.

Keywords: Absorbing state, non-absorbing state, uncertainty, technical colleges, graduation rate, higher education.

1. INTRODUCTION

The educational system of any country is highly regarded as a catalytic point for many aspects that include the economy, politics, religion, science and technology, knowledge generation and application. Education contributes to the generation of human capital and presents a means for life opportunities [1]. The technical and vocational education and training (TVET) colleges are generally post-secondary education phase [2] to help in the provision of hands-on category of the work force for South Africa. TVET colleges, private and public universities are regulated by the Department of Higher Education and Training (DHET). Generating technical people (artisans) for the engineering sector is pivotal to the contribution of the country development, particularly in developing countries. Completion and student intake phases are key elements in the assessment of the success of programmes and help different educational institutions to better plan and manage. These 2 phases may not be predicted accurately, hence they are usually associated with a degree of uncertainty. Random processes that characterise a range of uncertain variables can be handled with the application

of the Markov Chain (MC) technique [3]. In this study, the approach used is to deal with the uncertainty associated with the enrolments and completion rates per qualification of TVET qualifications of South Africa. These qualifications include N1, N2, N3, N4, N5 and N6 certificates, each of 6-month duration. They are standalone programmes for the same duration. However, the lower level is a pre-requisite to the next one. The number of students enrolled, students graduated are usually considered as random events and have been handled with MC, e.g. [3], [4]. There is no doubt that MC has gained immense popularity as a predictive tool, e.g. [5], [6]. In the educational sector, previous MC applications include among others the progression of secondary school learners using a group of schools [1]; the determination of retention/completion rates as well as the expected schooling duration of students before and after introduction of the free schooling education policy [7]; suggestion of a multi-level absorbing Markov chain for computing students' graduation rate, when dealing with small sample sizes [8]. However, little has been carried out on the national educational system that includes TVET part in engineering studies. Based on MC technique, the current study estimates mainly the completion rates for engineering certificates N4, N5 and N6 and compare them to those used by DHET. It does not investigate student progression on specific modules of a given certificate in a specific college. This is constrained by the data published by DHET and such data give the overall performance of TVET certificates at national level. Using the data related to the above-mentioned certificates and performing MC, the learner's progression from the initial state (enrolment class) to completion at a given time can be modelled/predicted. The completion rate for each certificate is understood as the number of students who wrote and completed successfully all modules versus the number of the students enrolled for the given programme [9]. This can be referred as the frequentist approach [8] for computing completion rate. The completion rate in the context of this study is similar to other parts of the world [8],[10] i.e. completion rates are understood as graduation rates, which serves as good proxies for throughput rates in determining the student cohorts [2].

The rest of the paper is structured as follows. Section 2 gives an overview of TVET programmes, including the notion of completion rate/graduation rate. In Section 3, the basics that underline MC is given. Section 4 presents the data used in line with the methodological approach of the MC model on completion rate. Results and discussion are conducted in Section

5 to illustrate the practical application of the MC simulation. Finally, the conclusion is presented, and recommendations are formulated in Section 6. In what follows, MC approach and MC technique will be used interchangeably. Similarly, student and learner will be used as the same concept. Completion rate and graduation rate will yield the same meaning. Non-absorbing state and transient state will be used interchangeably. TVET colleges will imply in most cases, colleges offering N4, N5 and N6 engineering qualifications. Halting, absorbing, and stopping stage will be used synonymously. Certificates and programmes will be meant to describe the same concept.

2. OVERVIEW OF TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING CERTIFICATES

The details on these certificates can be found in [15]. Nonetheless selected relevant aspects to the current study are given briefly in this section. The TVET colleges are education providers for technical and vocational education and training programmes and enroll students who have passed at least Grade 9 or equivalent. In general, TVET colleges provide three broad categories of qualifications:

- a. The National Certificate (Vocational) [NC(V)] which has three qualification levels, namely, Levels 2, 3 and 4 of the National Qualifications Framework [NQF].
- b. The “Report 190/191 National Technical Education (NATED)” programmes are offered at 6 different levels (N1 to N6) for Engineering Studies programmes, and three levels (N4-N6) for Business and General Studies programmes. Engineering programmes or certificates require trimester enrolment. The N1 to N6 part-qualifications culminate in a National Diploma on condition that students meet the requirements for work experience. In particular, the “Report 190/191 (NATED)” N4-N6 Programmes in Engineering covers field such as Civil, Mechanical, Automotive and Electrical career fields. The recent amendment to the TVET colleges programmes suggested that, from 2022 N4-N6 be run on a semester basis and N1-N3 be phased out [15]. Nonetheless, the data used in Section 4 are based on trimester certificates.

Completion rates

The following are considerations for the completion rates calculations for an intake, e.g. 2019 [2]:

“Completion rate” refers to the number of students who successfully completed a Report 190/1 N4-N-6 part-qualification in the 2019 academic year, expressed as a percentage of the number of students who were eligible to complete the Report 190/1 N4-N6 part-qualifications and wrote the examinations (the latter is defined above) in 2019.

If number of students registered is represented by NR1, the number of students who wrote by NR2 and those who completed by NC and Completion rate by CR, hence

$$CR = NC/NR2 \quad (1)$$

The “Number Registered” is the number of students registered for the 2019 Report 190/1 N4-N6 examinations for Engineering Studies and eligible to complete a Report 190/1 N4-N6 part-qualification during the 2019 academic year.

“Number Wrote” is the number of students who wrote the 2019 Report 190/1 N4-N6 examinations for Engineering Studies and eligible to complete a Report 190/1 N4-N6 part-qualification during the 2019 academic year.

“Number Completed” is the number of learners eligible to complete and successfully completed the Report 190/1 N-4-N-6 part-qualifications in the 2019 academic year.

The number registered and the number wrote both exclude students who wrote individual subjects but who were not eligible to complete the Report 190/1 N4-N6 part-qualifications in 2019, whereas number completed students who may have passed individual subjects but were not eligible to complete the Report 190/1 N4-N6 part-qualifications in 2019.

3. BASICS OF MARKOV CHAIN MODEL

The MC deals with stochastic processes known as random events such that the probability of the future state of a system is not a function of the previous states but of the present state [11]. The considerations in this section have similarities with previous studies, e.g. [7], [12]. Most equations in this section have been adapted from these authors. Given a state space $S = 1, 2, \dots, n$, the MC is defined by a series of random variables $Y_k \in S$ where $k = 1, 2, \dots, n$

$$\begin{aligned} \Pr [Y_{k+1} = y_{k+1} / Y_1 = y_1, \dots, Y_k = y_k] &= \text{Prob} [Y_{k+1} = y_{k+1} / Y_1 = y_1, \dots, Y_k = y_k] \\ &= \Pr [Y_{k+1} / Y_k] \end{aligned} \quad (2)$$

The above mathematical expression holds for homogeneous MC. It implies that given $Y_1, Y_2, Y_3, \dots, Y_k, Y_{k+1}$, the conditional distribution of Y_{k+1} is only a function of the value of Y_k , not a function of the previous values Y_1, \dots, Y_{k-1} . This form of conditional probability is derived from the memorylessness principle. The probability matrix of the MC corresponding to the finite space state is of dimension $n \times n$ and is called the transition matrix. The transition matrix summarises all probabilities p_{ij} obtained from Equation (1), into the following matrix.

$$B = [p_{ij}] \quad (3)$$

Where p_{ij} is the transition probability from state S_i to state S_j , $i, j = 1, 2, \dots, n$.

The transition matrix is a key characteristic of MC model and plays an important role during analysis of the model. The matrix enables also the system to move from one state to the other. It is the one-step matrix of transition probabilities between states [12]. The Markov chain is said to be an absorbing chain if it has one or more absorbing states, meaning that once a subject enters an absorbing state, it remains trapped. An absorbing state is characterised by a maximum probability of the occurrence. A state different from absorbing states is said to be transient or non-absorbing state. From a non-absorbing state, it is possible to reach absorbing states in one step or several steps.

3.1. Canonical transition probability matrix

The canonical form of the transition matrix of an absorbing MC with q non-absorbing/transient states and h absorbing states, is as follows:

$$B = \begin{bmatrix} Q & R \\ O & I \end{bmatrix} \quad (4)$$

Where Q is a matrix of dimension $q \times q$ with q non-absorbing states, R is a non-zero matrix of dimension $q \times h$, with h non-absorbing states (R shows the move from the non-absorbing states to the absorbing state) and O is a null matrix of dimension $h \times q$

I is an identity matrix of dimension $h \times h$.

There are 2 important matrices of the absorbing MC model, i.e. the fundamental matrix and the absorbing probability matrix [13].

3.2. Fundamental matrix

The expected/average times the MC attains the non-absorbing states can be estimated by the fundamental matrix [11]. Before reaching the absorbing state, the time of cycles that a learner resides in the non-absorbing state is determined by this matrix. Mathematically speaking the fundamental matrix F is given by the following equation:

$$F = (I - Q)^{-1} \tag{5}$$

Matrix F is the inverse of $(I - Q)$, hence the determinant of the matrix $(I - Q)$ must be different from 0. The components of the fundamental matrix help define the expected times for the different non-absorbing states before the role player reaches the absorbing states. However, in a case of learning a subject matter in the classroom, the time available for teaching and learning process for a course is usually predetermined, hence the components of the fundamental matrix could be considered as the level of difficulty that learners face [13], [14] during the course.

3.3. Matrix of probabilities of absorption

This matrix gives the probabilities of absorption to reach the absorbing states. The limiting values of probabilities of the absorbing states as components of matrix A can be computed using the following equation:

$$A = (I - Q)^{-1} * R \tag{6}$$

4. DATA USED AND METHODS

4.1. Data used

The data provided in Table 1 are the performance of the overall TVET colleges across all 3 trimesters of the academic year 2019.

Table 1. Number of students for the completed Report 190/1 N4 to N6 part-qualifications for Engineering Studies, 2019 [9].

| Qualification | Number registered | Number wrote | Number completed | Completion rate (%) |
|-----------------|-------------------|---------------|------------------|---------------------|
| Report 190/1 N4 | 27 818 | 25 252 | 22 278 | 88.2 |
| Report 190/1 N5 | 19 063 | 17 860 | 16 390 | 91.8 |
| Report 190/1 N6 | 16 433 | 15 510 | 14 061 | 90.7 |
| Total | 63 314 | 58 622 | 52 729 | 89.9 |

4.2. MC model formulation

For each certificate that takes a trimester, 4 states can be defined reasonably. S₁: the enrolment state called the starting state; S₂: the inclusion/admission state where the learner is eligible for examination, S₃: stopping/halting/exclusion state where the student is not eligible for examination, S₄: the completion state where the learner graduates. Based on the data, on one hand it is implied that the number of students ineligible for examination is

NR1-NR2. These students go into the stopping state. On the other hand, the number of students who wrote but failed the examination are assumed to go into the stopping state. Completion state as well as the halting state are usually considered to be absorbing states [1], [8]. In these states, the learner does not go back to any of the non-absorbing states once he/she has completed (has been halted). Hence the learner cannot exit from the stopping state or completion state for the duration of the programme. Since the TVET college engineering certificates are designed as trimester programmes, students who were not eligible for examination, failing the exam and those dropping out have been assumed to remain in the stopping stage for that specific trimester. Hence, they cannot graduate for the duration of the certificate. In line with [8], practically speaking, a student could re-enroll the following trimester or later. The enrolment class and the inclusion/admission state to examination are considered as transient states since the learner cannot remain there for the whole duration of the certificate. From the enrolment state, students will be split into the halting state or the inclusion state. Once the student is eligible for examination, or has been halted, he is not going back to the enrolment state. Figure 1 below illustrates the above considerations for the MC model.

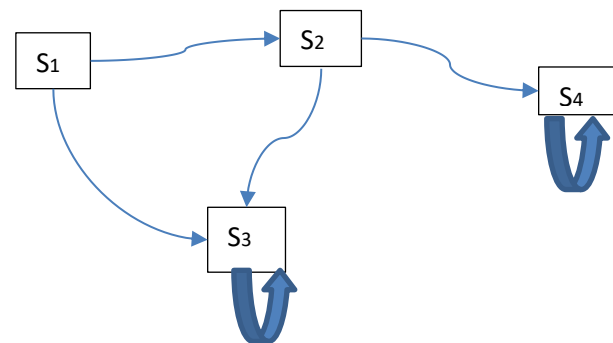


Figure 1. Proposed Markov Chain Model

This model applies to each of the TVET Engineering qualifications N4, N5 and N6.

Probability values are approximated by using the frequency values in each state. Therefore, the probability of remaining in the enrolment state is assumed to be null, i.e. $p_{11} = 0$. Similarly, $p_{22} = 0$. The probability of moving from state 1 to the halting state 3 is p_{13} , which is a non-zero value. The probabilities of transiting from non-absorbing state 1 to non-absorbing state 2 and vice versa are p_{12} (non-zero value) and 0 respectively. The probability of transiting from non-absorbing state 2 to halting state and completion state are p_{23} and p_{24} respectively. In any absorbing state, the following applies, i.e. $p_{33} = p_{44} = 1$. Once the student enters any of the absorbing states, he/she cannot go back again to the initial state. From the above, the following sums of probabilities are satisfied

$$p_{12} + p_{13} = 1 \tag{7}$$

$$p_{23} + p_{24} = 1 \tag{8}$$

This yield to matrix B in its canonical form as shown below:

$$B = \begin{bmatrix} 0 & p_{12} & p_{13} & 0 \\ 0 & 0 & p_{23} & p_{24} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The components of matrix B are $I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$; $O = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$; $Q = \begin{bmatrix} 0 & p_{12} \\ 0 & 0 \end{bmatrix}$ and $R = \begin{bmatrix} p_{13} & 0 \\ p_{23} & p_{24} \end{bmatrix}$

4.3. Fundamental matrix and absorption probability matrix

From the previous section, $I - Q$ is a diagonal matrix with non-zero entries. Hence, algebraically the matrix is invertible, and its inverse is obtained as follows

$$I - Q = \begin{bmatrix} 1 & -p_{12} \\ 0 & 1 \end{bmatrix}$$

$$F = (I - Q)^{-1} = \begin{bmatrix} 1 & p_{12} \\ 0 & 1 \end{bmatrix}$$

The absorption probability matrix is

$$A = F * R = \begin{bmatrix} 1 & p_{12} \\ 0 & 1 \end{bmatrix} * \begin{bmatrix} p_{13} & 0 \\ p_{23} & p_{24} \end{bmatrix} = \begin{bmatrix} p_{13} + p_{12}p_{23} & p_{12}p_{24} \\ p_{23} & p_{24} \end{bmatrix}$$

5. RESULTS AND DISCUSSION

5.1. Determination of the transition probability matrix

The data in Table 1 from the 3 certificates N4, N5 and N6 of the TVET colleges yielded to the results presented in Tables 2, 3 and 4 respectively. Each of these tables displays a 4 x 4 matrix, which gives the estimated transition probabilities of the MC.

Table 2. Probabilities of transition between states for N4

| | S1 | S2 | S3 | S4 |
|----|----|-------|-------|-------|
| S1 | 0 | 0.908 | 0.092 | 0 |
| S2 | 0 | 0 | 0.118 | 0.882 |
| S3 | 0 | 0 | 1 | 0 |
| S4 | 0 | 0 | 0 | 1 |

Table 3. Probabilities of transition between states for N5

| | S1 | S2 | S3 | S4 |
|----|----|-------|-------|-------|
| S1 | 0 | 0.937 | 0.063 | 0 |
| S2 | 0 | 0 | 0.082 | 0.918 |
| S3 | 0 | 0 | 1 | 0 |
| S4 | 0 | 0 | 0 | 1 |

Table 4. Probabilities of transition between states for N6

| | S1 | S2 | S3 | S4 |
|----|----|-------|-------|-------|
| S1 | 0 | 0.944 | 0.056 | 0 |
| S2 | 0 | 0 | 0.093 | 0.907 |
| S3 | 0 | 0 | 1 | 0 |
| S4 | 0 | 0 | 0 | 1 |

The one step transition probability matrices for the respective programmes are as follows

$$B_{N4} = \begin{bmatrix} 0 & 0.908 & 0.092 & 0 \\ 0 & 0 & 0.118 & 0.882 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix};$$

$$B_{N5} = \begin{bmatrix} 0 & 0.937 & 0.063 & 0 \\ 0 & 0 & 0.082 & 0.918 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix};$$

$$B_{N6} = \begin{bmatrix} 0 & 0.944 & 0.056 & 0 \\ 0 & 0 & 0.093 & 0.907 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

5.2. Determination of canonical form of probability matrices

The matrices in the previous section yields to the following submatrices

$$I_{N4} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}; O_{N4} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}; Q_{N4} = \begin{bmatrix} 0 & 0.908 \\ 0 & 0 \end{bmatrix} \text{ and}$$

$$R_{N4} = \begin{bmatrix} 0.092 & 0 \\ 0.118 & 0.882 \end{bmatrix}$$

$$I_{N5} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}; O_{N5} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}; Q_{N5} = \begin{bmatrix} 0 & 0.937 \\ 0 & 0 \end{bmatrix} \text{ and}$$

$$R_{N5} = \begin{bmatrix} 0.063 & 0 \\ 0.082 & 0.918 \end{bmatrix}$$

$$I_{N6} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}; O_{N6} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}; Q_{N6} = \begin{bmatrix} 0 & 0.944 \\ 0 & 0 \end{bmatrix} \text{ and}$$

$$R_{N6} = \begin{bmatrix} 0.056 & 0 \\ 0.093 & 0.907 \end{bmatrix}$$

5.3. Calculation of fundamental matrices

$$F_{N4} = \begin{bmatrix} 1 & 0.908 \\ 0 & 1 \end{bmatrix}; F_{N5} = \begin{bmatrix} 1 & 0.937 \\ 0 & 1 \end{bmatrix} \text{ and } F_{N6} = \begin{bmatrix} 1 & 0.944 \\ 0 & 1 \end{bmatrix}$$

The calculation of matrix inverse was also validated using an online matrix calculator (<https://matrix.reshish.com/inverCalculation.php>).

The average time from non-absorbing states to the absorbing states are as follows for the 3 qualifications

$$t_4 = \begin{bmatrix} 1 & 0.908 \\ 0 & 1 \end{bmatrix} * \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1.908 \\ 1 \end{bmatrix}; t_5 = \begin{bmatrix} 1.937 \\ 1 \end{bmatrix};$$

$$t_6 = \begin{bmatrix} 1.944 \\ 1 \end{bmatrix};$$

The above-calculated matrices display the mean number of times between the initial state and the completion state for the certificate to reach the absorption state. The elements in the first row correspond to the time it takes to move from enrolment class to the completion state, whereas the second element is associated with time the learner moving from the eligibility/inclusion state to be in the absorption state, i.e. either in the stopping state or completion state. The predetermined time is approximately one trimester, whereas the first components are 1.908, 1.937 and 1.944 for the fundamental matrices. Mean time has been also used as an expression of the student difficulties in a specific class [12], [13], specifically when the estimate time goes beyond the predetermine time of the programme. Hence, in addition to the normal duration of the certificate, the level of difficulty faced by the student when he starts from enrolment class to reach the completion state. The second component of fundamental matrices is 1, which is equivalent to the trimester and corresponds

to the expected time when learner moves from state 2 to the absorbing states. From these results, it could be predicted that the level of the learner's difficulty is increasing with the level of certificate, i.e. from N4 to N6. However, the differences in levels of difficulty across certificates are not huge. Hence, for example an N4 graduate who decides to further his studies in terms of N5, may not face drastic difficulties since it is believed that he is used already to the environment of the engineering studies offered in TVET colleges.

5.4. Computation of absorption probabilities

$$A_{N4} = \begin{bmatrix} 1 & 0.908 \\ 0 & 1 \end{bmatrix} * \begin{bmatrix} 0.092 & 0 \\ 0.118 & 0.882 \end{bmatrix} = \begin{bmatrix} 0.20 & 0.80 \\ 0.118 & 0.882 \end{bmatrix}; A_{N5} = \begin{bmatrix} 0.14 & 0.860 \\ 0.082 & 0.918 \end{bmatrix}; A_{N6} = \begin{bmatrix} 0.144 & 0.856 \\ 0.093 & 0.907 \end{bmatrix}$$

For each certificate, the first row of the above matrix and second row are the absorption probability for the learner to reach the halting state and completion state respectively when the learner starts from the enrolment class. The absorption probability to reach the exclusion state is relatively higher for N4 certificate as compared with N5 and N6 certificates. Academic staff and the TVET managers may investigate teaching and learning approaches to assist students to reduce further the exclusion rate. The second row shows the absorption probabilities for the learner to reach the halting state and completion state respectively when he/she starts from the inclusion/eligibility state. For each matrix, the element/probability on the second column and second row shows exactly the completion rate computed by DHET. Hence the probability of being absorbed in the completion state is increasing with the level of certificate. From the results displayed for N4, N5 and N6, more information is given by the MC and goes beyond just the computation of completion rate by DHET. Besides the completion rate between state 2 and the final completion state, the halting rates have been also computed. These results did not feature explicitly in the DHET completion rate. Of course, the case above is simplified in the sense that it does not take into consideration the progress of the students as per module. For each certificate, all modules are taken once and should be completed in principle in the given trimester. The occurrence of any module is not conditioned statistically by any other module for the same certificate. Other random factors such as health or current indisposition may affect the completion of the certificate [1] as well as the exclusion state. In addition to these factors, financial difficulty can also be a major problem for disadvantaged students who may not complete successfully the certificate during the required time. The simplified MC developed in this case could help educational managers to wisely strategise around the issue of learner intakes, resources distributions such as finances, educational materials, teaching and learning strategies. In this way improvements in throughput rates could be sought to, especially for N6 with the relatively highest mean time, i.e., the relatively lower completion rate.

6. CONCLUSIONS

The current paper has introduced the MC approach with a special case where non-absorbing states do not interact. The approach has been in line with the strategy that the DHET uses to compute the completion rate of the certificates for TVET colleges in South Africa. MC formulation and implementation for certificate completion yield to a way of understanding elegantly the level of

difficulties that the student faces during the programmes. An estimation of the probabilities of being absorbed into the completion and exclusion states were determined. MC mimicked exactly the certificate completion rates calculated by DHET. Additionally, MC helped to determine the rate at which learners is excluded from completion as well as the rate of completion when the enrolment state is the entry point for the learner. The expected times between transient states and graduation state were also determined. MC technique showed also that the output model may send a signal to the educational sector role-players around their resources planning by putting forward quality education, especially when dealing with enrolments and improvement in completion strategies. Equally the model does assume that the cases of dropout are included in the exclusion state. The approach does not take into consideration of the transfer (transition) of students between the different colleges for the same certificate. Other reasons should be also investigated such as dropout in the middle of the trimester that could also add some tone to the level of difficulty of the certificate. This will require the acquisition of relevant data to conduct such an investigation.

7. REFERENCES

- [1] Nyandwaki, M.J., Akelo, O.E., Samson, O.O., Fredrick, O., 2014. Application of Markov Chain Model in Studying progression Of Secondary School Students by Sex During The Free Secondary Education: A Case Study of Kisii Central District. **Mathematical Theory and Modeling**, Vol.4, No.4, 2014, 73-84.
- [2] Department of Higher Education and Training (DoHET), 2021. Statistics on Post-School Education and Training in South Africa: 2019. Available at https://cdn.lgseta.co.za/resources/research_and_reports/Statistic%20on%20Post-School%20Education%20and%20Training%20in%20South%20Africa.%202019.pdf
- [3] Walde, G.S., 2019. "Triple absorbing Markov chain model to study the flow of higher education students." **Journal of Physics: Conference Series** 1176 042066, pp.1-8.
- [4] Gagne, L., 2015. Modeling the progress and retention of international students using Markov Chains. https://ideaexchange.uakron.edu/honors_research_projects/3
- [5] Brown, E.L., Petersen, K. D., Leshner, C.E., 2020. "Markov chain Monte Carlo inversion of mantle temperature and source composition, with application to Reykjanes Peninsula, Iceland". **Earth and Planetary Science Letters**, Vol. 532, pp.1-15.
- [6] Dey, N.N., Al. Rakib, A., Kafy, A.A., Raikwar, V., 2021. "Geospatial modelling of changes in land use/land cover dynamics using Multi-layer perception Markov chain model in Rajshahi City, Bangladesh". **Environmental Challenge**, pp.2-11.
- [7] Gikie, S.W., Karoki, S. and Kinyanjui, S., 2020. "Evaluation of the impact of the free secondary education on students' progression using Markov chain model: a case study of Kiambaa sub-county, Kiambu county". **Bulletin of Mathematics and Statistics research**, Vol.8, Issue 2, pp. 17-31.
- [8] Boumi, S. and Vela, A.E., 2020. "Improving Graduation Rate Estimates Using Regularly Updating Multi-Level Absorbing Markov Chains". **Education Sciences**, Vol.10, No. 377, pp.1-18.
- [9] Department of Higher Education and Training (DoHET), 2019. 2017 examination data: South African technical and vocational education and training, community education and

training, and private colleges. Available at <https://www.dhet.gov.za/DHET%20Statistics%20Publication/2017%20Examination%20Data%20-%20South%20African%20TVET,%20CET%20and%20Private%20Colleges-%20Released%20November%202019.pdf>

[10] Sneyers, E. and De Witte, K., 2016. The interaction between dropout, graduation rates and quality ratings in universities. **Journal of the Operational Research Society**, pp.1–15.

[11] Nyandwaki, M.J. and Kennedy, G., 2016. “Statistical Modeling of the Kenyan Secondary School Students Enrollment: An Application of the Markov Chain Model”. **IOSR Journal of Mathematics**, Vol. 12, Issue 2 Ver. II, pp. 11-18..

[12] Voskoglou, M.G., 2021. “Smart Learning Systems: A Markov Chain Approach”. **Egyptian Computer Science Journal** Vol. 45 (2), pp. 24-29.

[13] Voskoglou, M.G., 2019. “A Markov Chain Application on the Levels of the Bloom’s Taxonomy of Learning Objectives”. **American Journal of Educational Research**, Vol. 7, (3), 294-298.

[14] Eledum, H. and Idriss, E.I.M., 2019. “An undergraduate student flow model: Semester system in university of Tabuk (KSA)”. **International Journal of Statics and Applied Mathematics** Vol. 4, pp. 11–19.

[15] Government gazette, 6 November 2020, No. 43872, Department of Higher Education and Training. Available at https://www.merseta.org.za/wp-content/uploads/2021/04/Government-Gazette-43872-TVET-Colleges_DUE-DATE-5-MARCH-2021.pdf

Assessing knowledge areas of Advanced Certificate in Engineering Technology using Analytic Hierarchy Process (AHP)

Lusiwe MADUNA

Department of Civil Engineering, University of South Africa
Pretoria, Gauteng, South Africa

Masengo ILUNGA

Department of Civil Engineering, University of South Africa,
Pretoria, Gauteng, South Africa

ABSTRACT

Consistency among knowledge areas of the Advanced Certificate in Engineering (AdvCertEng) as proposed by the Engineering Council of South Africa (ECSA) is evaluated using Analytic Hierarchy Process (AHP) model. The certificate is part of the new programmes offered in universities of technology and comprehensive universities in South Africa. The AHP model compares the credit weight of each knowledge area with the existing weights in the programme as suggested by ECSA. The model has its foundations on pairwise comparisons of knowledge areas. The findings of the present study showed that an acceptable level of consistency in credit allocation among knowledge areas of AdvCertEng was achieved. AHP was shown to be a validation tool of the existing preference order of credits allocated to the different knowledge areas. Nonetheless, very small differences in credit weights between AHP and ECSA's were noticed.

Keywords: Analytic hierarchy, model, engineering qualification, credit allocation

1. INTRODUCTION

Teaching and learning of engineering programmes in South African universities is founded on knowledge areas (KAs). KAs are comprised of 6 elements, i.e. mathematical sciences, natural sciences, engineering sciences, design and synthesis, complementary studies and for relocation [1]. These KAs are associated with credit allocation set by the Higher Education Framework [3]. A credit is 10 notional hours of learning for the student to achieve learning outcomes. Hence it is imperative for ECSA to make sure programmes are aligned with the National Qualifications Framework (NQF) of South Africa.

The Engineering Council of South Africa (ECSA) as an accreditation body of engineering qualifications is mandated by the Department of Higher Education (DHET) to conduct accreditation in different universities offering engineering programmes. All new programmes are aligned with the minimum credit qualification set by the Higher Education Qualification Framework (HEQF) [3]. The Advanced Certificate in Engineering, as a new engineering programme is at NQF level 6 Level 6 NQF is A minimum of 140 credits must be completed for the certification program, with at least 120 of those credits being at NQF level 6 and including integrated projects worth at least 70 credits. [2]. The distribution of minimum credits among KAs is decided by a team of ECSA

members, who deal with education matters. Moreover, each institution of higher learning package modules in a programme based on the minimum credit distribution of KAs. In deciding on credit distribution, it is almost impossible to exclude a level of subjectivity. The literature on evaluating KAs degree of consistency based in terms of their weights is very rare, except recent studies undertaken on Advanced Diploma in engineering qualification dealing with KAs, e.g. [4]. In this respect, multi-criteria decision making (MCDM) such as the family of Analytic Hierarchy Process (AHP) techniques were used. These techniques enable to rank the different KAs derived from the weight calculation. The KAs were approached as criteria in AHP formulation and implementation. It is worth noting AHP in its standard form and its variants have been popular in several fields, e.g. risk assessment in the transportation of hazardous material [5], fire and explosion in process industry [6], traffic accessibility of suburban areas [7] implementation of new communication technology for education [8]. MCDM is a systematic and multidimensional procedure established to unravel decision-making problems in several different fields and search for the most logical and reasonable alternative with consideration of all relevant criteria [13]. There is no unanimity of using a specific MCDM method to evaluate criteria [4]. MCDM deals with several criteria that can present some contraction or conflict. It was proven recently that the decision to be made on credit allocation of KAs of Advanced Diploma in engineering may be reveal some complexity and may reveal some subjectivity [4]. Since AHP is suitable for articulating complex/subjective problems, it is therefore extended to the current study. Generally, the level of accommodating subjectivity is that judgements of the decision-makers called experts should not reflect the degree of inconsistency of more than 10 %. This paper uses the standard AHP and the scale 1 to 9 as crisp values [9]. The scale enables to determine the computation of the consistency degree of the elements, summarized in a pairwise comparison/decision matrix. This matrix yields to the determination of criteria weights.

It is reiterated that this study presently takes opportunity to formulate and implement the standard AHP around KAs, which are adopted in universities of technologies and comprehensive universities. Universities of technologies offer mainly technology-based programmes while comprehensive universities offer a combination of technology based and science-based programmes. In this paper, "method", "technique", "tool", will mean the same when used in combination with AHP. In a similar way, "decision matrix" and "pairwise comparison matrix" will be used interchangeably.

Programme will refer often to “engineering” programme. “Qualification”, “programme” and “certificate” will be used synonymously. AHP will mean standard conventional technique.

The study is structured as follows. Section 2 focuses on a brief foundation of AHP and its application to knowledge areas of engineering programmes. The data availability and the essential steps for credit determination during AHP are discussed in Section 3. The results and discussion from the application of AHP to AdvCertEng are given. Lastly, conclusions and suggestions are presented in Section 5.

2. FOUNDATION OF AHP AND KNOWLEDGE AREAS OF ENGINEERING PROGRAMMES

The introduction of the AHP method in years around 1980 [9], was remarkable and yielded to various applications involving multi-attributes decision problems [8], that reflect complexity. The standard AHP has been instrumental in this respect, despite of being criticized for addressing problems characterised with imprecision, fuzziness, etc. Several variants have been introduced in attempt to deal with such problems [5], [7]. However, the application of AHP to problems dealing knowledge areas of engineering programmes remains very sparse. The advantage of AHP is in splitting elegantly a complex problem into a simplified problem. AHP relies on the collection of opinions expressed by experts/decision-makers in the form of an interview or written questionnaire and targets in selecting the best alternatives as solutions to a problem. The standard AHP is usually in the form of a hierarchical structure as shown in Figure 1 below. It has basically 3 stages or levels of decision-making process, namely: objective, criteria, sub-criteria and alternatives.

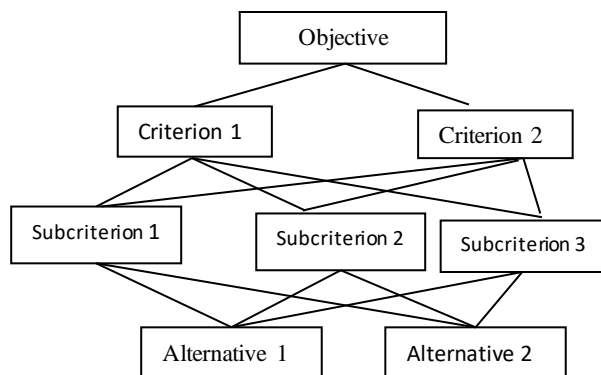


Figure 1. Hierarchical presentation of AHP

- The top stage is the objective pursued in aligning the programmes with the National Qualifications Framework by ranking the different KAs consistently and then selecting the best alternatives.
- The criteria and sub-criteria constitute the intermediate stage that enable finding the solution(s). They are used as means in the ranking of the different alternatives. Criteria can be divided into sub-criteria, where applicable. Sub-criteria are catalytic in ranking the criteria and determination of weight criteria. They help to establish the comparisons among criteria.
- Alternatives constitute the last stage of the hierarchical structure and their ranking and weights

can determined through criteria. Hence, indirectly alternatives are influenced by sub-criteria.

The ranking of criteria and that of sub-criteria can be carried in the process. As mentioned previously, pairwise comparisons are performed (by experts) among entities as shown Table 1. These comparisons are an expression of the judgements that experts made in deciding on alternatives. Depend on the problem at hand, a problem may not contain sub-criteria or it could be simply to rank and find weights of criteria. Below is the scoring approach in the AHP technique.

A score of 1 is used if 2 elements are equally perceived in terms of level of preference. The pairwise comparison scores 1 if 2 elements are of equal importance. The pairwise comparison is given a score of 3 if one entity is moderately important than the other. When one entity is strongly important over the other, a score of 5 should be allocated. If one entity has very strong importance over the other one, a score of 7 is given. When one element is extremely more important than the other one, a score of 9 is allocated. The scores 2, 4, 6 and 8 are intermediate scores. The scores of all pairwise comparisons are normally summarized in a matrix called decision matrix or pairwise comparison matrix. There different kinds of decision matrix established at the level of criteria, sub-criteria and alternatives. This matrix plays a pivotal role in the computation of the weights for the different stages.

Table 1. Likert scale (1-9) for level of importance of AHP model

| Level of preference | Description | Reciprocals of levels of preference |
|---------------------|---|-------------------------------------|
| 1 | Two entities are equally important | 1 |
| 3 | One entity is moderately important over the other | 1/3 |
| 5 | One entity is strongly more important over the other | 1/5 |
| 7 | One entity is very strongly more important over the other | 1/7 |
| 9 | One entity is extremely more important over the other | 1/9 |
| 2,4,6,8 | Intermediate values between the above preferences | 1/2,1/4,1/6,1/8 |

3. DATA AVAILABILITY AND METHODS

The data pertaining to the KAs of AdvCertEng was extracted from ECSA publication and adapted in Table 2 below. This is a programme of a minimum total of 140 credits allocated throughout the KAs as displayed in the same Table 2. The last column in the table represents the weights derived by the author, based on the minimum credits; i.e. 1400 notional hours. Credit allocation by ECSA team was a result from a consultative process and an alignment of best practices with the different accords where ECSA belong to. In line with AHP

formulation KAs were used as criteria in the evaluation of the qualification [10]. There is no official publication describing a scientific procedure or proven methodology undertaken in credit allocation on the ECSA website.

Table 2. Knowledge areas minimum credits of Advanced Certificate in Engineering as adapted from ECSA

| | Knowledge area | Minimum credits | Calculated weights from minimum credits |
|---|-----------------------|-----------------|---|
| C | Mathematical sciences | 7 | 0.05 |
| D | Natural sciences | 7 | 0.05 |
| E | Engineering sciences | 35 | 0.25 |
| F | Design and synthesis | 35 | 0.25 |
| G | Complementary studies | 7 | 0.05 |
| H | For Relocation | 49 | 0.35 |
| | Total | 140 | 1 |

Based on the minimum credit allocation as shown above, the formulation and implementation of AHP was carried out briefly as follows [4]:

-The objective was focused on ranking the different KAs (criteria) consistently.

- The strategy of credits ratios between knowledge areas was used to conduct pairwise comparisons among criteria. The strategy ensured the conversion of credits were converted into the qualitative likert scale 1 to 9. For instance, C and D have respectively 7 credits. The ratio of 1:1 is selected for pairwise comparisons and this could mean that these 2 criterias were perceived to be equally important. Comparing H with C, the ratio is 7:1, therefore 7 was used. In this case, its reciprocal is 1:7, i.e. when comparing C with H, 1/7 was used. In the case of E and H a ratio of 1:1.4 was approximated to 1:2 because of the existence of intermediate value according to the likert scale. The rest of pairwise comparisons were carried out in a similar manner.

-The decision matrix was constructed from all pairwise comparisons and their reciprocals.

-The validity of the judgment matrix was tested by computing the consistency ratio (CR) as the ratio between the consistency index (CI) and random index (RI), using Eq. (1) and Eq. (2), below

$$CI = \frac{\lambda_{MAX} - n}{n - 1} \tag{1}$$

$$CR = \frac{CI}{RI} \tag{2}$$

The maximum eigen value λ_{MAX} and the size n of the matrix can be used as a measure of inconsistency [11], i.e. the difference between these parameters is relatively big. The mistake in the evaluation of pairwise comparison process can be acceptable if CR is equal to 0.1 (or slightly more) [4], [5]. Table 3 is usually used for consistency index values for different sizes of the judgment matrix, which is a square matrix of order n.

Table 3. Random index representing different sizes of pairwise comparison matrix.

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|----|---|---|------|------|------|------|------|------|
| RI | 0 | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 |

If the consistency test does not pass, it could be an indication of the inconsistency in the experts' judgments. Hence the weight determination in the next step cannot be carried out. If done, the weights could be a result of inconsistency and invalidity. In case of invalidity, since the decision-making team cannot be asked to review credit allocation in this point of time, consistency could be forced. One would refer then to synthetic consistency.

-The weights were computed by considering the priority vector which represents algebraically the eigen vector. Based on AHP, this vector normally corresponds to the highest eigen value. The priority vector is obtained by calculating the sum of entries of the decision matrix in each column. Then divide each entry by the above-calculated sum (respectively) to obtain a new matrix with entries less than 1. Then the weight for each criterion is obtained by averaging the sum of each row of the new matrix.

-The validation of weights was carried out by comparing the differences in weight allocation by ECSA and the weight determined through AHP. The smaller the differences, the better the results.

The methodology introduced in this study is a double validation process, i.e. test the consistency of credit allocation from the strategy of credit ratios, then estimate the differences between AHP credits and ECSA credits and decide on the magnitude of the differences.

4. RESULTS AND DISCUSSION

Decision matrix and consistency test

The pairwise comparisons among the knowledge areas were used to derive the judgment matrix for AHP, which is given in Table 4. The matrix order is 6. This was derived from AHP process as the result of ECSA team's judgments in the credit allocation process.

Table 4. Pairwise comparison matrix of criteria

| | C | D | E | F | G | H |
|---|---|---|-----|-----|---|-----|
| C | 1 | 1 | 1/5 | 1/5 | 1 | 1/7 |
| D | 1 | 1 | 1/5 | 1/5 | 1 | 1/7 |
| E | 5 | 5 | 1 | 1 | 5 | 1/2 |
| F | 5 | 5 | 1 | 1 | 5 | 1/2 |
| G | 1 | 1 | 1/5 | 1/5 | 1 | 1/7 |
| H | 7 | 7 | 2 | 2 | 7 | 1 |

The computed maximum eigen value was 6.1. Since the size of the matrix is 6 corresponding to a random index of 1.24, the calculated CR was 0.016 (1.6%). Hence CR < 10 % and confirmed that the judgments involved in the decision matrix were consistency as far as Kas are concerned. ECSA team could associated with 98.4 % confidence in the process of establishing credits among KAs, based on AHP technique formulation.

Calculation of weights of knowledge areas

In the process of calculating weight of the different KAs that represent the criteria in AHP method, Tables 5 was first determined by summing up all entries of each column. In this table, the last row is very important to be used in Table 6.

Table 5. Matrix showing the last row as sum of entries for each column.

| | | | | | | |
|-----|----|----|-----|-----|----|-------|
| | C | D | E | F | G | H |
| C | 1 | 1 | 0.2 | 0.2 | 1 | 0.143 |
| D | 1 | 1 | 0.2 | 0.2 | 1 | 0.143 |
| E | 5 | 5 | 1 | 1 | 5 | 0.5 |
| F | 5 | 5 | 1 | 1 | 5 | 0.5 |
| G | 1 | 1 | 0.2 | 0.2 | 1 | 0.143 |
| H | 7 | 7 | 2 | 2 | 7 | 1 |
| sum | 20 | 20 | 4.6 | 4.6 | 20 | 2.429 |

Table 6. Matrix obtained by dividing each entry by the respective sum of entries for each column.

| | | | | | | |
|---|-------|-------|-------|-------|-------|-------|
| | C | D | E | F | G | H |
| C | 0.050 | 0.050 | 0.043 | 0.043 | 0.050 | 0.059 |
| D | 0.050 | 0.050 | 0.043 | 0.043 | 0.050 | 0.059 |
| E | 0.250 | 0.250 | 0.217 | 0.217 | 0.250 | 0.206 |
| F | 0.250 | 0.250 | 0.217 | 0.217 | 0.250 | 0.206 |
| G | 0.050 | 0.050 | 0.043 | 0.043 | 0.050 | 0.059 |
| H | 0.350 | 0.350 | 0.435 | 0.435 | 0.350 | 0.412 |
| | 1 | 1 | 1 | 1 | 1 | 1 |

Table 7. Knowledge area weights

| Criterion | Weights |
|-----------|---------|
| C | 0.049 |
| D | 0.049 |
| E | 0.232 |
| F | 0.232 |
| G | 0.049 |
| H | 0.389 |

Then each column entry was divided by its respective sum as computed previously. This led to Table 6, where entries in each row were averaged to obtain the weights of criteria. The weights were summarised in Table 7. The weights pertaining to Mathematical sciences (C), Natural sciences (D), Engineering Sciences (E), Design and synthesis (F), complementary studies (G) and for relocation (H) were 4.9, 4.9, 23.2, 23.2, 4.9 and 38.9 % respectively. These results showed that H had the highest importance from experts’ point of view, followed by (E)/(F). These were followed by (C)/(D)/(G), which were the least in terms of importance order. This showed the decreasing ranking order of Kas, based on AHP technique. The highest weight attached with the redistribution (relocation) of credits could be

an opportunity for universities to include courses of their choice to make the AdvCertEng attractive. At the same time, the course selection should be aligned with industry requirements and respond adequately to the societal aspirations. The credits for relocation could play a major role in the mobility and credit transfer between institutions of higher learning. In the next section, a comparison is conducted between the KA weights obtained from AHP and existing weights from ECSA. This is used to validate or triangulate the accuracy of ECSA’s weight

Evaluation of validity of knowledge area weights

In the validation process, comparison was carried out by computing the absolute differences between ECSA weights and AHP weights, as shown in Table 8. Considering ECSA’s weights as benchmark, the absolute differences in percentage showed there was no significant difference between the 2 categories of weights. This was possible by assuming a threshold of 10%. Hence AHP method could be used as tool to validate weights derived from ECSA. The choice of threshold value is crucial in the validation process and could be subjective.

Table 8. Comparison between ECSA and AHP weights

| | | | | |
|---|-------------|---------------|---------------------|----------------------------------|
| | AHP weights | ECSA Weight s | Absolute difference | Relative absolute difference (%) |
| C | 0.049 | 0.05 | 0.01 | 1.39 |
| D | 0.049 | 0.05 | 0.01 | 1.39 |
| E | 0.232 | 0.25 | 0.018 | 7.29 |
| F | 0.232 | 0.25 | 0.018 | 7.29 |
| G | 0.049 | 0.05 | 0.01 | 1.39 |
| H | 0.389 | 0.35 | 0.039 | 11.0 |

From the above exercise, the application of MCDM tools such the standard AHP has shown a level of transparency in the determination of weight allocation to the different criteria. This could be a guiding tool for ECSA in the future allocation of minimum credits of engineering programmes. Besides, qualifications should be aligned with graduate attributes, to increase employability for students [12].

5. CONCLUSIONS

The present study has shown that AHP is a versatile technique that can be used to rank transparently and simply the knowledge areas of Advanced Certificate in Engineering. The consistency in the judgements of ECSA’s experts was proven to be acceptable. The ranking of knowledge areas of the programme was carried out consistently through AHP, which was finally used as a validation tool of the existing credit allocation to the different KAs. Credit for relocation part was showed to have the highest preference. The significance of the present study is to have used innovatively ratios between credits to estimate the preferences of ECSA’s experts’ judgements, translated into the likert scale between 1 and 9. For curriculum development in institutions of higher learning offering engineering programmes, instructional practitioners could explore AHP as one of the MCDM techniques. ECSA could also make use of the same transparent strategy, should a need arise to review or develop new qualifications. Further research could include the application of the method presented in this study, to engineering programmes other than AdvCertEng.

6. REFERENCES

- [1] Engineering Council of South Africa: Engineering Qualifications in the Higher Education Qualifications Sub-framework E-23-P Revision No. 1: 17 April 2019. Available: <https://www.ecsa.co.za/education/EducationDocs/E-23-P%20Engineering%20Qualifications%20in%20the%20Higher%20Education%20Qualifications.pdf>. [Accessed: May 24, 2023].
- [2] Qualification Standard for Advanced Diploma in Engineering: NQF Level 7 E-05-PT REVISION No. 5: 01 September 2020. Available: <https://www.ecsa.co.za/ECSADocuments/Shared%20Documents/E05PT%20Qualification%20Standard%20for%20Advanced%20Diploma%20in%20Engineering%20NQF%20Level%207%2020>.
- [3] Council on Higher Education (CHE), **Qualification Standard for Bachelor of Engineering Technology**, Pretoria, 2017.
- [4] M. Ilunga, An assessment of knowledge areas for advanced diploma in Engineering using Fuzzy Analytic Hierarchy Process (FAHP). **Proceedings of the 25th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2021)**, pp.34-38.
- [5]. E. Ayyildiz, A.T. Gumus, "Pythagorean fuzzy AHP based risk assessment methodology for hazardous material transportation: an application in Istanbul", **Environmental Science and Pollution Research**, vol. 28, pp. 35798-35810, 2021, <https://doi.org/10.1007/s11356-021-13223-y>.
- [6] M. Yazdi, O. Korhan, and S. Daneshvar, "Application of fuzzy fault tree analysis based on modified fuzzy AHP and fuzzy TOPSIS for fire and explosion in the process industry", **International Journal of Occupational Safety and Ergonomics**, vol. 26, no. 2, pp. 319-335, 2020, DOI: 10.1080/10803548.2018.1454636.
- [7] M. Stanković, P. Gladović and V. Popović, "Determining the importance of the criteria of traffic accessibility using fuzzy AHP and rough AHP method", **Decision Making: Applications in Management and Engineering**, vol. 2, no.1, pp. 86-104, 2019.
- [8] X. Wang, G. Li, J. Tu, N.T.T. Khuyen, C.Chang., "Sustainable Education Using New Communication Technology: Assessment with Analytical Hierarchy Process (AHP)", **Sustainability**, vol 13(17), no. 9640, pp.1-12, 2021.
- [9] T.L. Saaty, L.G. Vargas, **Models, Methods, Concepts and Applications of the Analytic Hierarchy Process**, Springer New York, NY., 2012.
- [10] M. Ilunga, Analytic hierarchy process (AHP) for evaluating knowledge areas of advanced diploma in Engineering taught in South African universities. **Proceedings of the 25th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2021)**, pp. 30-33
- [11] R. Amarullah, R.M. Simanjorang, "Planning Decision Support System Using Building Mall AHP (Analytical Hierarchy Process)", **Jurnal Teknik Informatika C.I.T**, vol.12, no.1, pp. 26-33, 2020.
- [12] O. Humberto, K.Loretta, and H. Samuel, "Does university prepare students for employment? Alignment between graduate attributes, accreditation requirements and industry employability criteria ", **Journal of Teaching and Learning for Graduate Employability**, vol.10(1), pp. 173-194, 2019.
- [13] F. Eltarabishi, O.M. Omar, L. Alsyouf, M. Bettayeb. Multi-criteria decision making methods and their applications-A literature Review. **Proceedings of the International Conference on Industrial Engineering and Operations Management Dubai, UAE**, March 10-12, 2020, pp. 2654-2663.

Measuring entropy associated with first time undergraduate students' enrolments in South African public universities

Samukelisiwe MATHENJWA

Department of Civil Engineering, University of South Africa
Pretoria, Gauteng, South Africa

Masengo ILUNGA

Department of Civil Engineering, University of South Africa
Pretoria, Gauteng, South Africa

ABSTRACT

Students' enrolment plans in South African institutions of higher learning system are associated with a degree of uncertainty, which is measured by entropy index, under Shannon entropy expression. Twenty-six universities have been considered as contributing to the university system entropy on yearly basis. The entropy of the system was found to be relatively higher, with a quasi-constant trend. The University of South Africa (UNISA) was the main contributor to the university system entropy. Universities depicted a unique characteristic of enrolments being statistically independent such that the system entropy and joint entropy of enrolments were equivalent. It was found that there is a strong correlation between relative changes in enrolments and relative changes in entropy. Three zones of uncertainty with enrolments were finally suggested, i.e. zone of low enrolments, zone of sustainable enrolments and zone of chaotic enrolments.

Keywords: Uncertainty, enrolment, higher education

entropy dealing with enrolments in universities is almost nonexistent. The notion of entropy index has been derived from Shannon entropy to assess the variable uncertainty [11] in terms of spatial distribution for land use, e.g. [9], [10], mean annual runoff distribution [12], urban sprawl and fractal analysis [13]. In this case, the uniformity or concentration of variable in a region has been of importance. The concept of entropy index is extended to the South African public universities. The purpose of the study is to determine the uncertainty associated with the level of enrolment spread across public universities within the IHE sector. Hence the study mainly investigates whether the enrolments are dominantly concentrated in few specific institutions or distributed uniformly across the IHE sector. The data of students' enrolments covers the period from 2009 to 2019. In what follows, enrolment will mean student enrolment. Institution, institution of higher learning and institution of higher education will be used interchangeably. Entropy index, entropy and marginal entropy will be used interchangeably. University sector, university system, IHE sector will mean the same.

1. INTRODUCTION

Institutions of higher learning such as universities face often more applications of first-time learners than the places available. The South African educational sector has twenty-six public universities, which are regulated by the Department of Higher Education and Training (DHET). Student enrolment plans in public universities are subsidised by DHET. In the last two decades, the number of new matriculants produced in high school outweigh the place availability in these universities. This is one of the trends of massification and open access to higher education [1]. The situation is exacerbated by the accumulated number of matriculants who completed in the previous years. Universities find themselves compelled to uptake more students than what they would accommodate. One reason for this uptake is that universities need to tackle issues around transformation in addressing the imbalances of the past (apartheid) era, in cohort of African students [2], hence the least advantaged should be brought to the level of those advantaged in the past in targeting equal participation in institutions of higher education (IHE) [3]. The deviation from the enrolment plans in IHE is common practice, however the costs associated with the deviation from approved enrolments plans by DHET is incurred by universities. Consequently, these institutions are uncertain to stick to enrolment plans. Hence there is a need to assess the uncertainty of enrolments in the South African higher education sector. Shannon's entropy is immensely used to assess the degree of uncertainty or chaos of systems, e.g. [4-8]. The literature on

2. DATA AND METHODS

2.1. Shannon's entropy

Entropy associated with a random variable has been proposed by Shannon [11]. Equation below gives the expression of entropy when extended to entropy index.

$$E(P) = -\sum_{i=1}^k p_i \log(p_i) \quad (1)$$

where k are elements making contribution to the given system P , and p_i is the fraction contributed by an element i to the system in a particular time. Hence p_i is given by

$$p_i = \frac{x_i}{X} \quad (2)$$

where x_i is the quantity of element i and X is the total quantity representing the system P . The unit is in bits if the base of the logarithm of Equation (1) is 2, in Napiers if the base is e , and in decibels (dB) if the base is 10. In this study, the bits will be used. Entropy index is bound between the minimum entropy (0) and the maximum entropy $\log(k)$. When the contribution of elements to the total quantity is uniformly distributed, i.e., all frequencies/probabilities are equal, the maximum entropy is attained.

For the purpose of this study, in the above equations, k represents the number of universities within the higher education system regulated by DHET.

2.1.1 Relative entropy

The relative entropy of a variable can be used to compare entropies of elements with different contributions or entropies occurring at different times. The variable, i.e. student enrolment for each public university will contribute to the total enrolment related to the set of IHE. Each enrolment number represents a fraction of this total quantity.

The relative entropy can be expressed in its standardised form using Equation (3), as shown below

$$E(P)_{rel} = \frac{E(P)}{\log N} \quad (3)$$

2.2. Joint entropy and mutual information

Since each university has its own student enrolment plan, a reasonable assumption could be made that enrolments in each university occurs independently statistically from one another. One could say for instance, enrolment at the University of Johannesburg (UJ) does not influence UNISA enrolments. Therefore, the joint entropy index between these 2 institutions is the sum of the entropy index related to each enrolment. Generalising, the joint entropy associated with the university system is the sum of entropy indices and is given by Equation (4) below:

$$JE(P) = -\sum_{i=1}^k p_i \log(p_i) \quad (4)$$

Therefore, this equation is equivalent to (1) for the South African university system.

By virtue of the assumed independent enrolments among universities, the mutual information which shows the amount of information related to enrolment interdependences between two given universities is null.

2.3. Relative change of entropy between consecutive years

The relative change in entropy is defined between 2 consecutive times, i.e. years t and $t+1$ by Equation (5) as shown below:

$$\Delta E_j = \frac{E_j(t+1) - E_j(t)}{E_j(t)} * 100 \quad (5)$$

This can be monitored with respect to the relative change in enrolments, between years t and $t+1$, i.e.

$$\Delta x_j = \frac{x_{j+1}(t+1) - x_{j+1}(t)}{x_{j+1}(t)} * 100 \quad (6)$$

2.4. Data availability

This study used the data as published by DHET, in terms of number of first-time undergraduate students enrolled in public IHE, by institution from 2009 to 2019 [14], hence 10 years. Out of 26 universities, only 3 cover at the most 5 years of data because they have been created recently. Hence, the 3 institutions were not considered in this study. These are the University of Mpumalanga, Sefako Makgatho Health Science University and Sol Plaatje University. The 23 universities considered for the study are Cape Peninsula University of Technology (CPUT),

University of Cape Town (UCT), University of Kwazulu-Natal (UKZN), Durban University of Technology (DUT), Mangosuthu University of Technology (MUT), Nelson Mandela Metropolitan University (NMMU), North-West University (NWU), Rhodes University (Rhodes), Tshwane University of Technology (TUT), University of Fort Hare (UFH), University of Johannesburg (UJ), University of Kwazulu Natal, University of Limpopo (UL), University of Pretoria (UP), University of South Africa (UNISA), University of Free State (UFS), University of Venda (Univen), University of Western Cape (UWC), University of the Witwatersrand (Wits), University of Zululand (UZ), Vaal University of Technology (VUT) and Walter Sisulu University (WSU).

3. RESULTS AND DISCUSSION

Entropy values for each university were calculated and summarised in Table 1 (Appendix), where the public university system entropy (pus) is calculated in the last row. The annual values are relatively high and are displayed in the graphical form in Figure 1. The temporal evolution of entropy tends to the maximum entropy, i.e. the tendency is towards pseudo uniformity. This tendency is largely influenced by UNISA, which is the major contributor to the system entropy and has been considered as the largest open distance education in Africa. When UNISA is omitted from the data, the pus entropy dropped by 10 % from its initial value. The annual average entropy in their standardised form are shown in Figure 1 for each university and depicts the enrolment contribution of each university to the pus entropy, from 2009 to 2019. Hence Figure 2 shows the descending order of universities with respect to the marginal entropy associated with enrolments. The higher the entropy, the higher the exposure of the institution to chaos associated with student enrolments. UNISA for instance has the highest degree of uncertainty contributing 12 % to the total entropy out of 23 universities, hence this institution of higher learning would require strong management system coupled with adequate resources to deal with issues around enrolments. This is followed by UJ, with Rhodes University showing the least entropy. Besides UNISA, the rest of universities each contribute below 1% of the system entropy. The lowest entropy for Rhodes university could mean enrolments in this institution are associated with relatively low chaos as compared with other institutions. However, issue of sustainable enrolments that could impact on economic return should be investigated.

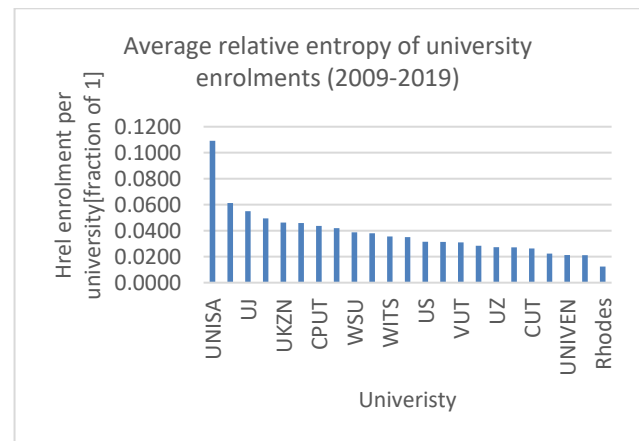


Figure 1. Average relative entropy associated with student enrolments in public universities.

The trend in pus entropy is linear and closely parallel to the time axis. This shows that the temporal entropy variation is quasi-constant over time. The same trend is translated in Fig 3 where relative entropy values are presented in a standardised form with respect to the maximum entropy ($\text{Log}_2(23) = 4.52$). Relatively high values of entropy from year to year signal that attention should be paid to enrolments of first-time students in universities since the entropy of the public university system is relatively high. This value would mean that enrolment numbers are distributed equitably across all IHE, but the enrolment distribution is not necessarily uniform due to the differences in marginal entropy among institutions. To recall the major contribution to this uncertainty is UNISA due to its size and gigantesque enrolment plan.

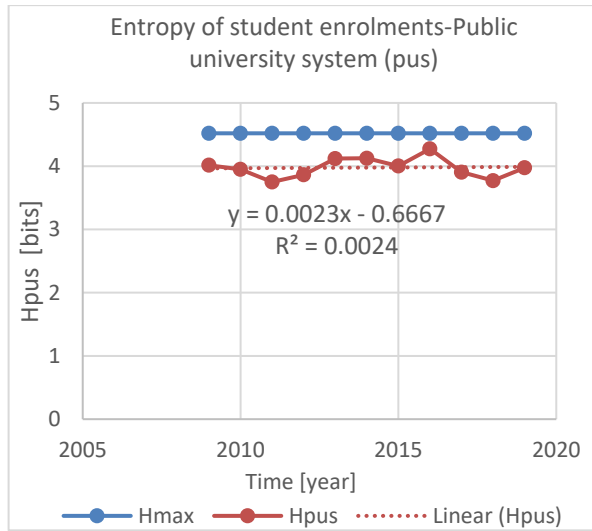


Figure 2. Entropy of student enrolments in the public university system of South Africa. This entropy is symbolised by Hpus and varies between 0 and max entropy.

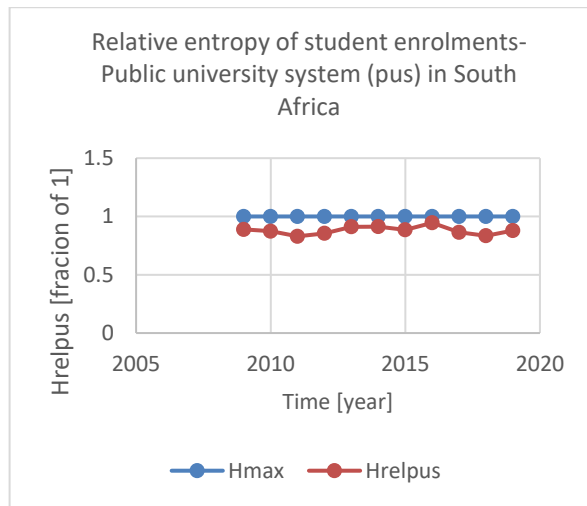


Figure 3. Relative entropy of students' enrolments in the public university system of South Africa. This entropy is symbolised by Hrelpub and varies between 0 and 1.

Figure 4 shows there is a strong correlation between relative change in entropy of enrolments versus relative change in enrolment. This would mean that the variations in these 2 variables entities generally point in the same direction. Sudden changes in enrolments may yield to higher changes in uncertainty of the university system.

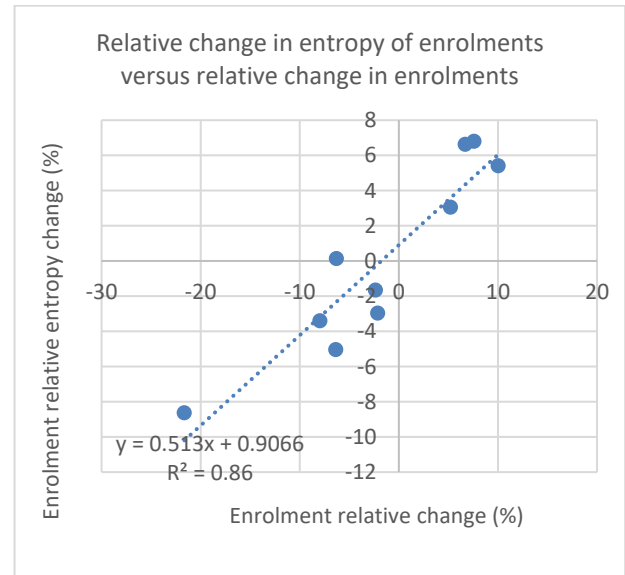


Figure 4. Relative change in entropy of student enrolments vs enrolment relative change of the public university system of South Africa.

Availability of space to accommodate students should be assessed carefully since the system entropy is relatively high. In case enrolment plans are exceeded the maximum allowable registrations, mechanisms should be put in place to have rotational classes for examples. This will also require extra resources such as administrative and academic in proportion with the workload. The employment of extra staff on contract could be envisaged for example. This is common practice in most universities, especially those situated in metropolitan areas. Flip classroom technology can be envisaged to enable lectures to be delivered across universities offering the same programmes if these agree formally. This technology can limit the space constraints of teaching and learning [15]. Extra consumables especially for institutions equipped with science and engineering laboratories could be revisited. However, it will be wise for an institution exceeding its maximum capacity to make it in a reasonable and manageable fashion. In fact, the growth of satellite campuses currently for most public institutions of high learning, the long and early queues during student's registration could explain the degree of uncertainty associated with students' enrolments. As documented, in the past during registration in a particular year, long queues broke into a stampede, which yielded to an unfortunate loss of a potential student at UJ. Exceeding students' enrolment plans come with issues of residence accommodation. This is a puzzling aspect for most universities, especially for applicants from disadvantaged background. The government has come up with an encouraging bursary scheme to meet halfway the needs of these students who qualify for the scheme.

The relatively higher entropy could suggest that the public education system assess on a regular basis chaos in terms of student management, teaching and learning, and student support.

Proactive decision making should be put in place to mitigate any adverse negative impact of enrolments on good functioning of universities. This study could help education managers and practitioners to avoid an unbearable chaos that emanates from students' enrolments. Hence, they could come up with sustainable management strategy of student enrolments, should chaotic situations arise. It should be noted that an uncertainty free system does not exist, and this would imply a perfect educational system. A certain level of uncertainty is necessary to the system since it makes the system adjust through self-organisation and come back to its normal course.

Hence it is necessary for a system to keep at the minimum acceptable threshold of uncertainty associated with enrolments to make the system resilient when subjected to enrolment disturbances. Below the minimum entropy, the system is stable but may have difficulty to adapt when chaotic situations arise suddenly since the system has never been exposed to significant enrolment perturbations. Therefore, based on linear resilience concept [12], it is proposed 3 situations of enrolments that educational system could consider. Institutions of higher learning should navigate into 3 zones of entropy with regards to enrolments demarcated by 2 thresholds of entropy, i.e. minimum entropy and maximum entropy:

-Zone of lower entropy: This zone is bound by the minimum entropy. The educational system is stable when subjected to minor enrolment increases. But it may still be vulnerable as it does not have mechanism of fast adaptability when big enrolment deviations occur. This zone presents a certain degree of vulnerability, should a high surge in enrolments occurs.

-Zone of intermediate entropy. This zone is between the minimum and maximum entropy and corresponds to sustainable enrolment deviations. The educational system is sustainable when subjected to manageable changes in enrolments and is within the entropy thresholds. Enrolments should be maintained very reasonable and sound management put in place to handle student intakes without stretching too much resources.

-Zone of chaos: the educational system exceeds the maximum entropy and becomes chaotic since high perturbations due to huge enrolment deviations that have exceeded the maximum uncertainty. Enrolments become very unpredictable and the system become vulnerable and cannot cope effectively with student numbers. Huge student intakes beyond the acceptable capacity of the institution can compromise the purpose of teaching and learning and may lead to unbearable workloads for the academic staff. This zone is associated with high unpredictability or uncertainty.

Hence entropy is good tool to measure the level of chaos that could emanate from the enrolment exercise. It signals that adjustments in students' enrolments management plan but does not show how management strategies should be implemented.

4. CONCLUSIONS

The versatility of Shannon entropy has been shown again here, i.e. to measure the level of uncertainty that comes with students' enrolments in institutions of higher learning of South Africa. Entropy calculations showed that there is spread of student across universities. The relative entropy showed that the system of public university system is associated with higher entropy at least 80% of the maximum entropy, but the system can still be managed. The enrolment spread among universities is not uniform. Universities have been also ranked based on level of

entropy, which showed that UNISA has the highest entropy and account for 12 % on average of the total entropy over 10 years and implying strong enrolments management plans to be put in place to cope with huge numbers. Other institutions are below 1% of the total entropy. A structural entropy has been suggested based on linear zoning concept of entropy, where the zone of sustainable enrolment, zone of chaotic enrolments and zone of minimum entropy have been identified. Considering simultaneously all students' enrolments, it was shown that entropy is good measure for the uncertainty of the university system.

5. REFERENCES

- [1] N. Cloete, "The South African higher education system: performance and policy". **Studies in Higher Education**, Vol. 39, No.8, pp.1355–1368, 2014. Available at <http://dx.doi.org/10.1080/03075079.2014.949533>
- [2] K.S. Govinder, N. P. Zondo, M.W. Makgoba, "A new look at demographic transformation for universities in South Africa", **Demographic transformation in universities in South Africa**, pp.1-11, 2013.
- [3] T. N. Mafumo, "Social justice in South African Universities: A bridge too far?" Available at: <https://journals.co.za/doi/pdf/10.10520/EJC121492> (Accessed on 21 January 2022)
- [4] V. Arya, S. Kumar, "A new picture fuzzy information measure based on Shannon entropy with applications in opinion polls using extended VIKOR–TODIM approach", **Computational and Applied Mathematics**, Vol. 39, Issue 3, pp.1-24.
- [5] M. Ribeiro, T. Henriques, L. Castro, A. Souto, L. Antunes, C. Costa-Santos and A. Teixeira, "The Entropy Universe." **Entropy**, 23, 222, 2021. Available at <https://doi.org/10.3390/e23020222>
- [6] A. Namdari, L. S. Zhaojun, "A review of entropy measures for uncertainty quantification of stochastic processes." **Advances in Mechanical Engineering**, Vol. 11, No. pp.1–14, 2019.
- [7] K. R. Singh, R. Dutta, A.S. Kalamdhad, B. Kumar, "Information entropy as a tool in surface water quality assessment". **Environmental Earth Sciences**, Vol. 78,15, 2019.
- [8] K.-H. Cho, D.-H. Lee, T.-S. Kim, G.-S. Jang, "Measurement of 30-Year Urban Expansion Using Spatial Entropy in Changwon and Gimhae, Korea". **Sustainability**, 2021, Vol.13, 632
- [9] A. Mohameda, H. Worku, "Quantification of the land use/land cover dynamics and the degree of urban growth goodness for sustainable urban land use planning in Addis Ababa and the surrounding Oromia special zone", **Journal of Urban Management**, Vol. 9, pp.145-158, 2019.
- [10] K. Cegielska, A. Kukulska-Kozielec, T. Salata, P. Piotrowski, M. Szylar, "Shannon entropy as a peri-urban landscape metric: concentration of anthropogenic land cover element", **Journal of Spatial Science**, 2018, DOI: 10.1080/14498596.2018.1482803, pp.1-21.
- [11] C.E. Shannon, "A mathematical theory of communication," **The Bell System Technical Journal**, Vol. 27, pp. 379–423, 623–656, 1948.
- [12] M. Ilunga, "Assessing catchment resilience using entropy associated with mean annual runoff for the Upper Vaal catchment in South Africa". **Entropy**, 19, 147, 2017
- [13] K. Rastogi, V. Jain, "Gaurav. Urban sprawl analysis using shannon's entropy and fractal analysis: a case study on Tiruchirappalli city, India", **The International Archives of the Photogrammetry, Remote Sensing and Spatial Information**

Sciences, Volume XLII-5, 2018 ISPRS TC V Mid-term Symposium “Geospatial Technology – Pixel to People”, 20–23 November 2018, Dehradun, India.

[14] Department of Higher Education and Training. Statistics publications, Tables on statistics on Post school Education and Training, 2019. Available at

<https://www.dhet.gov.za/SitePages/DocPublications.aspx>

[15] J. Li, X. Zhang, Z. Hu, “The Design and Application of Flip Classroom Teaching Based on Computer Technology”, **International Journal Engineering Technology**, Vol. 13, No. 10, pp. 95-107, 2018

Appendix

Table 1. Entropy of enrolment in bits for each public university in South Africa (Only 23 universities considered)

| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|----------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| CPUT | 0.216 | 0.211 | 0.198 | 0.207 | 0.210 | 0.202 | 0.194 | 0.217 | 0.177 | 0.167 | 0.173 |
| UCT | 0.134 | 0.120 | 0.110 | 0.124 | 0.128 | 0.125 | 0.129 | 0.139 | 0.118 | 0.103 | 0.117 |
| CUT | 0.129 | 0.112 | 0.092 | 0.098 | 0.119 | 0.123 | 0.119 | 0.141 | 0.136 | 0.114 | 0.128 |
| DUT | 0.191 | 0.193 | 0.169 | 0.172 | 0.196 | 0.201 | 0.200 | 0.200 | 0.187 | 0.177 | 0.201 |
| UFH | 0.087 | 0.089 | 0.088 | 0.098 | 0.088 | 0.096 | 0.101 | 0.102 | 0.097 | 0.097 | 0.105 |
| UFS | 0.131 | 0.151 | 0.161 | 0.174 | 0.169 | 0.165 | 0.147 | 0.216 | 0.191 | 0.195 | 0.189 |
| UJ | 0.292 | 0.245 | 0.267 | 0.243 | 0.254 | 0.270 | 0.245 | 0.271 | 0.218 | 0.204 | 0.225 |
| UKZN | 0.213 | 0.210 | 0.194 | 0.192 | 0.230 | 0.251 | 0.208 | 0.218 | 0.204 | 0.186 | 0.194 |
| UL | 0.116 | 0.145 | 0.150 | 0.153 | 0.154 | 0.157 | 0.138 | 0.154 | 0.131 | 0.124 | 0.134 |
| MUT | 0.106 | 0.097 | 0.086 | 0.099 | 0.105 | 0.095 | 0.097 | 0.112 | 0.109 | 0.098 | 0.111 |
| NMU | 0.162 | 0.153 | 0.161 | 0.153 | 0.162 | 0.171 | 0.161 | 0.174 | 0.138 | 0.148 | 0.161 |
| NWU | 0.173 | 0.195 | 0.192 | 0.205 | 0.231 | 0.226 | 0.229 | 0.269 | 0.244 | 0.235 | 0.257 |
| UP | 0.212 | 0.211 | 0.190 | 0.197 | 0.226 | 0.220 | 0.219 | 0.215 | 0.182 | 0.197 | 0.210 |
| Rhodes | 0.067 | 0.059 | 0.049 | 0.053 | 0.059 | 0.060 | 0.059 | 0.056 | 0.050 | 0.047 | 0.055 |
| UNISA | 0.499 | 0.514 | 0.529 | 0.523 | 0.476 | 0.471 | 0.501 | 0.368 | 0.515 | 0.527 | 0.504 |
| US | 0.136 | 0.142 | 0.134 | 0.126 | 0.147 | 0.154 | 0.154 | 0.158 | 0.140 | 0.133 | 0.140 |
| TUT | 0.286 | 0.266 | 0.241 | 0.273 | 0.304 | 0.297 | 0.282 | 0.305 | 0.284 | 0.256 | 0.254 |
| UNIVEN | 0.071 | 0.066 | 0.072 | 0.081 | 0.120 | 0.118 | 0.113 | 0.121 | 0.095 | 0.095 | 0.105 |
| VUT | 0.173 | 0.173 | 0.140 | 0.137 | 0.134 | 0.124 | 0.109 | 0.156 | 0.127 | 0.133 | 0.135 |
| WSU | 0.176 | 0.173 | 0.159 | 0.154 | 0.178 | 0.168 | 0.190 | 0.208 | 0.173 | 0.165 | 0.180 |
| UWC | 0.112 | 0.123 | 0.119 | 0.124 | 0.131 | 0.131 | 0.127 | 0.158 | 0.128 | 0.120 | 0.136 |
| WITS | 0.186 | 0.157 | 0.137 | 0.157 | 0.167 | 0.170 | 0.158 | 0.187 | 0.154 | 0.147 | 0.148 |
| UZ | 0.148 | 0.145 | 0.110 | 0.120 | 0.130 | 0.129 | 0.122 | 0.129 | 0.109 | 0.103 | 0.112 |
| Hpus (bits) | 4.016 | 3.949 | 3.750 | 3.864 | 4.120 | 4.141 | 4.072 | 4.372 | 3.996 | 3.878 | 4.096 |

Self-Physical Fitness Training Program with Sit up Sensor to Enhance the Abdominal Muscle Strength

Nuttaporn SUDDEE¹

Chulalongkorn University Demonstration Elementary School,
Faculty of Education, Chulalongkorn University Bangkok, 10330, Thailand

Noawanit SONGKRAM²

Department of Education and Communication Technology,
Faculty of Education, Chulalongkorn University Bangkok, 10330, Thailand

ABSTRACT

Technological advancements have resulted in changing the people of today's behaviours and has encouraged a change in lifestyles. And is an exercise that can be done by yourself, anywhere you like and when done regularly with correct posture, it will strengthen the abdominal muscles. Also, by doing this you will reduce the chance of an injury by doing sit-ups. This can be included within modern exercise trends, as those who want to exercise are already familiar with using technological exercise equipment. This study aimed to develop a self-physical fitness training program with a sit-up sensor to enhance abdominal muscle strength. It featured 60 undergraduate students from Chulalongkorn University, ages 18 to 23, who were split into two groups with 30 participants each using purposive sampling: the experimental group, which used the self-physical fitness training program with a sit-up sensor, and the control group, which used the program without the sensor for three days a week over six weeks, or 18 days in total. These were the research's findings: The Self-Physical Fitness Training Program with Digital Innovation to Improve Abdominal Muscle Strength study discovered a substantial difference between the study results of the current stage and the needs analysis of technologically connected devices for exercising in the program at the 0.05 level. As a result of this innovation, a chest strap could measure the slope of the exerciser's body while performing a sit-up to measure the length when connected to a smartphone and the Sit-Up Fitness Tracker Application, which reduces injuries and makes self-exercising convenient, efficient, and easy. After using the Self-Physical Fitness Training Program's digital technology, the experimental group's mean increased with a significant difference at 0.05 levels. (M=4.99, SD=0.03) Keywords: Self-Physical Fitness Training Program, Sit Up, Sit Up Sensor, Abdominal Muscle Strength

Keyword : Fitness Training Program, Sit up, Sit up sensor, Abdominal Muscle Strength

1. INTRODUCTION

Technology has changed today's world so it changes human behavior and lifestyle. [1] From the survey between 2013 to 2015, there is an increase from 66.3 percent to 68.3 among the population Generation Y (Generation Y) aged 11-32 years, but in 2015 it was found that many children and young people have the least physical behavior compared to Silane. Generation (Silent generation), Baby boomer (Baby boomer), and Generation X (Generation X) [2] because of the changing lifestyles of the current generation, resulting in NCDs (Noncommunicable diseases) are diseases caused by habits or lifestyle behaviors that are not under good hygiene practices. Non-communicable NCDs include diseases of the cardiovascular system such as hypertension, coronary artery disease, stroke, diabetes, cancer, metabolic syndrome, and other diseases. The data supported by the World Health Organization indicates that over the past 10 years, NCDs have been the number one cause of death for Thai people, with 14 million Thai people dying before the age of 60, more than 300,000 people per year and up to 73% higher than the global average [3]. Therefore, to adjust the behavior that causes NCDs disease, one has to adjust one's own behavior. Emphasis is placed on regular exercise, at least 30 minutes per session, at least 5 times per week [4] or a lot of administrative space can be done by everyone on their own [5], such as sitting up, wall pushing, pushing up, stretching, different types of abdominal exercises, body exercises with a chair, etc. Sitting up (sit up) is an exercise that helps work the muscles in every part of the body. Sit-ups also helps to burn calories as well. Sit-up exercises come in a variety of positions, but the basic ones start with lying on your back on the floor, bending the knee up, putting your hands on the nape of the neck, on the chest or wherever you like, then exerting force from the small abdomen in order to lift the body up so that the back is high above the floor at a sitting angle of 90 °. It is considered a sit-up angle that causes changes in the waistline and abdomen better than sitting angles of 45 ° and 120 °. There is also evidence proving that sit-ups will cause changes in abdominal fat to decrease. This will have a huge impact on health [6]. For people who do not posture correctly, there is a risk of injury in the neck and lower back as well [7]. To reduce such injury problems

the researcher invented a digital innovation in sports to help make exercise easier with sit-ups benefits and the ability to practice on their own to reduce injury and allows exercisers to know their ability level and readiness of their health. If the exerciser does the sit-up posture correctly, it will increase the physical performance in the strength of the abdominal muscles.

2. LITERATURE REVIEW FRAMEWORK

Self-Physical Fitness Training Program

Physical fitness is a health-related attribute as well as the ability of an individual's body to work, in which a person with good physical fitness will be able to perform various tasks in daily life smoothly and happily. The component of physical fitness has 2 components: 1) the component of physical fitness for health. (Health-Related Physical Fitness) consists of Muscle Endurance, Muscle Strength, Speed, and Flexibility. Body composition 2) physical performance related to skills (Skill-related Fitness), consisting of agility, balance, coordination of body movement relations, muscle power, reaction time, speed and which physical fitness training programs help develop the body to have the ability to work or do physical activities effectively. Some scholars and researchers have presented the principles, and details of a variety of physical fitness training programs. The exercise program to build muscle strength should do activities for 2 or more days per week.[8] Physical fitness was measured using a physical fitness test. The purpose of the test is to cover various aspects of physical fitness, the test's reliability, and that the tool has a fixed rating of validity and standardized testing. Users of the physical fitness test should select the test item that is suitable for the actual situation and also meets the objectives that one wants to test. Most of the studies on physical fitness have been studied on the effects of using a series of training activities to enhance physical performance including the development of physical fitness criteria [9-14]

Abdominal Muscle Strength

Abdominal muscle strength is the ability to perform the work of the abdominal muscle groups that are subjected to maximum resistance. Abdominal muscles are part of the core muscle group. There are 4 parts of abdominal muscles: 1) Rectus Abdominis 2) External Abdominal Oblique 3) The inner abdominal muscles (Transverse Abdominis) are the parts that support the functioning of the internal organs and helps to have a good posture and a straight back and 4) The internal abdominal oblique muscles are useful for movement and balance. The sit-up posture is a skill used to exercise the abdomen to create strength. Abdominal muscles, waist circumference, thigh muscles, and lower back muscles. The research by Giacomini, M.B. et al. (2016) [15] showed that using a Pilates program helps

promote the growth of abdominal wall muscles and increase respiratory muscle strength, and effective prevention of abdominal muscle weakness.

Sit-up Sensor

The Sit-up Sensor is a sports digitalized innovation for use in exercising with sit-up postures, developed to meet the needs of today's people. It is designed to be modern for people who love sports and like to use technology. It is the aim to increase confidence in self-exercise in the sit-up position for the new generation who want to start exercising whilst learning new technologies that will make their exercise more fun. There are also modern and interesting digital innovations such as Ski Sensors, Checklight, Exercise Devices, Fitness Trackers, etc. The research by Kato, et. al. (2017) [16] showed that in fitness equipment there was a significantly higher intra-abdominal and intra-abdominal muscle accumulation of FDG in the experimental group. In addition, the research report of Termpech Sookhanaphibarn and Earn Suriyachay (2021) [17] showed that a web application for health promotion was written by using VUE.js technology and the google cloud vision engine encouraging users to run a distance of 100 kilometers within 100 days. There were 90% having a better score on health-related physical fitness by comparing before and after the activity.

Research Framework

From the study of the above 3 concepts and the research hypothesizes that the physical fitness training program together with the sit-up sensor helps to promote the strength of the abdominal muscles. The variables used in the study consisted of the self-training program with Sit-up Sensor and is a training program to effectively develop the physical fitness of the abdominal muscles of each individual with digital innovation, consisting of 1) Sit-up Sensor device with Chest strap 2) Smartphone with a specific application (Application) and strength of the abdominal muscles. Here, it means being able to do sit-ups for 60 seconds as many times as possible. The details are shown in Figure 1 showing the relationship between the study variables.

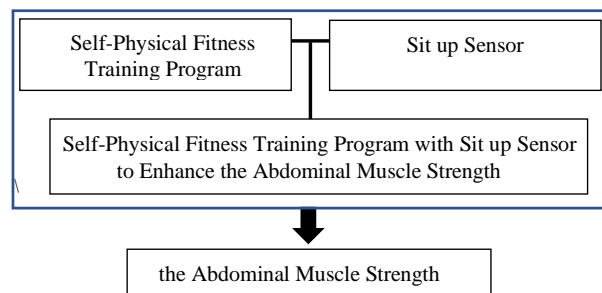


Figure 1: Conceptual framework of a research program for self-training physical fitness with the sit-up sensor to promote strength of the abdominal muscles.

3. METHOD

Phase 1: To study the need for self-service physical fitness training programs and the acceptance of digital innovations in physical education. The samples were undergraduate students across the country consisting of males and females aged between 18 and 23 years old of 1,001 people who did not exercise regularly. 52% of them were male students and 48% of them were females. 0.8% were aged 17-18 years old, 45.3% were aged 21-22 years old, 42.1% were aged 19-20 years old and 11.8% were aged 23 and over. The sample group was 2nd-year university students 32%, 3rd-year university students 26%, 4th-year university students 20.2%, and 5th-year university students 10.3%. 50.8% were non-athletes and 49.2% were athletes. The research instruments were questionnaires. Part 1 was the condition and needs of using physical fitness training programs by themselves. It is a 7-level estimation scale (1 = least need, 7 = most need) and part 2 acceptance of digital innovation in physical education. It is a 7-point estimation scale (1= strongly disagree, 7 = strongly agree). Part 1 of the questionnaire had a reliability value of 0.97 and part 2 of the questionnaire had a reliability value of 0.95. The data was analyzed using inferential statistics: Confirm Factor Analysis and Structural Equation Modeling Analysis.

Phase 2: Create a prototype of a self-physical fitness training program with the Sit-up Sensor to promote the strength of the abdominal muscles. Data collection was conducted with a Focus Group Discussion Form by a specialist in the fitness training program, digital innovation experts muscle strength specialist and research experts totaling 5 persons.

Phase 3: To study the effects of using a self-physical fitness training program with the Sit-up Sensor to promote abdominal muscle strength. The participants comprised of 60 undergraduate university students aged between 18-23 years old from the Faculty of Education at Chulalongkorn University. The study was divided into two groups: the experimental group and the control group, each consisting of 30 participants. (20 males, 10 females) The experimental group used digital innovation with a self-physical fitness training program. The control group used the self-physical fitness training program without digital innovation. The programs lasted for six weeks, three days per week (18 days in total). Before the experiment, the subjects assessed their readiness before training according to the physical fitness training program by themselves in combination with the sit-up sensor. The research tool was a 6-week self-physical fitness

training program and digital innovation included a Sit up Sensor device with a chest strap digital clock or smartphone installed with an experimental application (sit-up application). The data was analyzed using descriptive statistics, and inferential statistics.

Phase 4: To verify the effectiveness of the Self-Physical Fitness Training Program with Sit up Sensor to promote the strength of the abdominal muscles. 5 experts evaluated the physical fitness training program by themselves with the Sit up Sensor to promote the strength of the abdominal muscles to certify the physical fitness training program by themselves with the Sit-up Sensor to promote the strength of the abdomen muscles.

4. ANALYSIS RESULTS

The condition and need for a self- physical fitness training program with Sit up Sensor to promote the strength of the abdominal muscles.

The comparison results of the actual mean and the need for manual programming were significantly different at the .05 level (Sig=.000), with the actual mean being at quite a high level (M = 4.04, S.D. =1.46) and the demand is in quite a high level (M = 4.40, S.D. = 1.36) compared to the average reality and the need for technologically connected equipment used for exercise. In the self- physical fitness training program, the difference was statistically significant at the .05 level. (Sig=.000) The actual condition was at a high level (M = 4.86, S.D. = 1.62) and the demand was at a high level (M = 5.12, S.D. = 1.56). Confirmation Factor Analysis and Structural Equation Modeling Analysis found that perceived usefulness had a CR value of 0.943, an AVE value of 0.768, and a perception of ease of use. Perceive ease of use had a CR value of 0.938, AVE had a value of 0.750, Attitude had a CR value of 0.951, AVE had a value of 0.796, behavioral intention had a CR value of 0.947, and AVE had a value of 0.782. Actual Use, CR 0.956, AVE 0.814, Cronbach Alpha, whole issue 0.975, factor loading ranged from 0.732-0.851, AVE ranged from 0.750-0.814, Cr ranged from 0.938-0.956. There was a direct effect on attitude equal to 0.34 Perception of ease of use (p < 0.001). There was a direct effect on attitude equal to 0.53 (p < 0.001), attitude had a direct effect on behavioral intention equal to 0.88 (p < 0.001), behavioral intention had a direct effect on actual use equal to 0.84 (p < 0.001), X²-test value, P-value = 0.000, chi-square = 2.55 (X²/df = 656.58/257), GFI 0.95, CFI 1.00, AGFI 0.92, RMSEA 0.039 and SMER. 0.032 details as shown in Figure 2

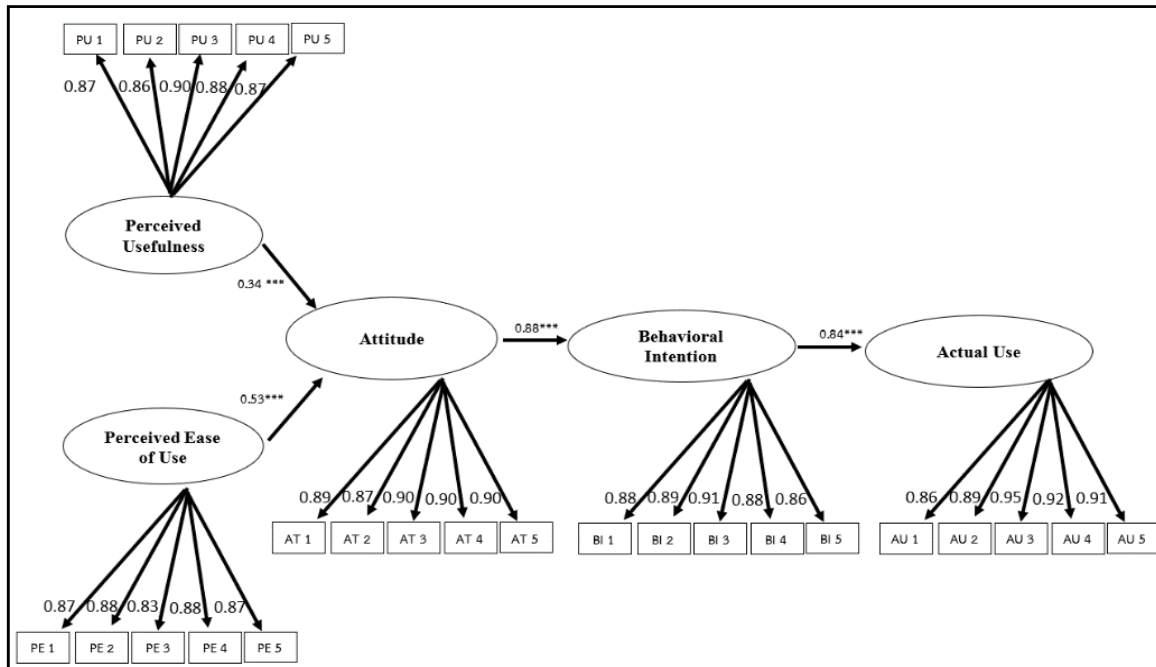


Figure 2 : Structural equation model for accepting digital innovations in physical education

Development of a self -physical fitness training program with a sit up sensor to enhance the abdominal muscle strength

Smart chest strap device (Sit-Up Fitness Tracker) is a chest strap for measuring the inclination of the torso for sit-up exercises and when the sit-up has reached the standard incline or desired incline. There will be a warning sound as in Figure 3 with regard to the level of the lower back muscles raised off the floor. It will also include functions that tell about the strength of the abdominal muscles and the appropriate sit-up time for each age group. Plus, there are other related functions. By working with a smart phone and a specific application (Sit-Up Fitness Tracker Application) to make a sit-up effective. It is also ensured that the exercise is easy to use and does not cause injury. The set of equipment used consists of an abdominal muscle exercise monitor, chest strap and USB-C charging cable, as shown in Figure 4. To start, hook the chest strap onto the chest strap eye of the device. Wear and adjust the device to chest level as in Figure 4. After that, press the button. Turn on/off the device once to turn on the device. To turn it off, press and hold for approximately 5 seconds or until the device display turns off. Make a connection to the application and access the device through the application. When the machine is turned on, the screen will show the letter B (Bluetooth) and that it is waiting to connect to the application. When connected, it will change to R (Ready) as in Figure 5.

The machine can set the angle of the sit-up position. In the application, as in Figure 6, when finished, it will appear on the screen of the Sit-Up Fitness Tracker to let the user know and be ready to start practicing sit-ups immediately. When starting sit-ups, the system will count the number of sit-ups, and show the whole screen. When the sit-ups are completed, the system will summarize the time per round, rest time per round, degrees, total number of times and number of sets are shown to the user as shown in Figure 7.

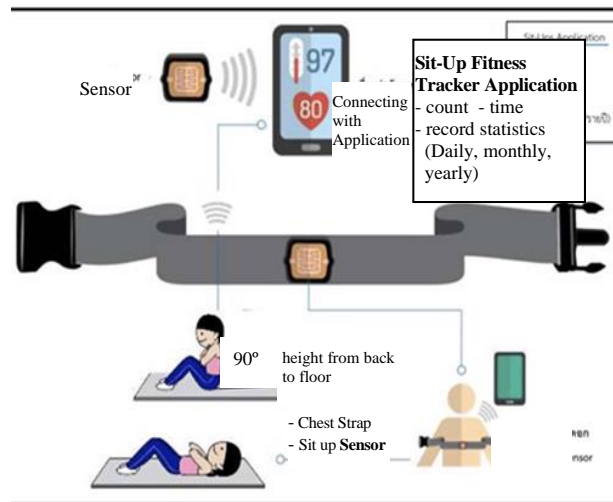
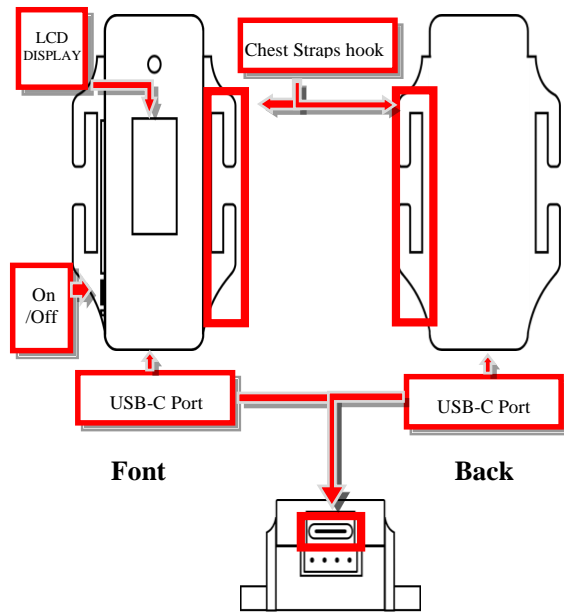


Figure 3: Digital innovations in sports to build abdominal strength



Below



Figure 4: Equipment to train the strength of the abdomen

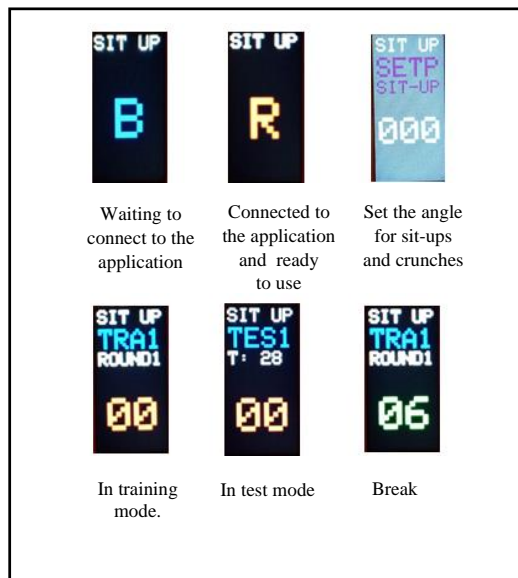


Figure 5: Sit-Ups Fitness Tracker screen

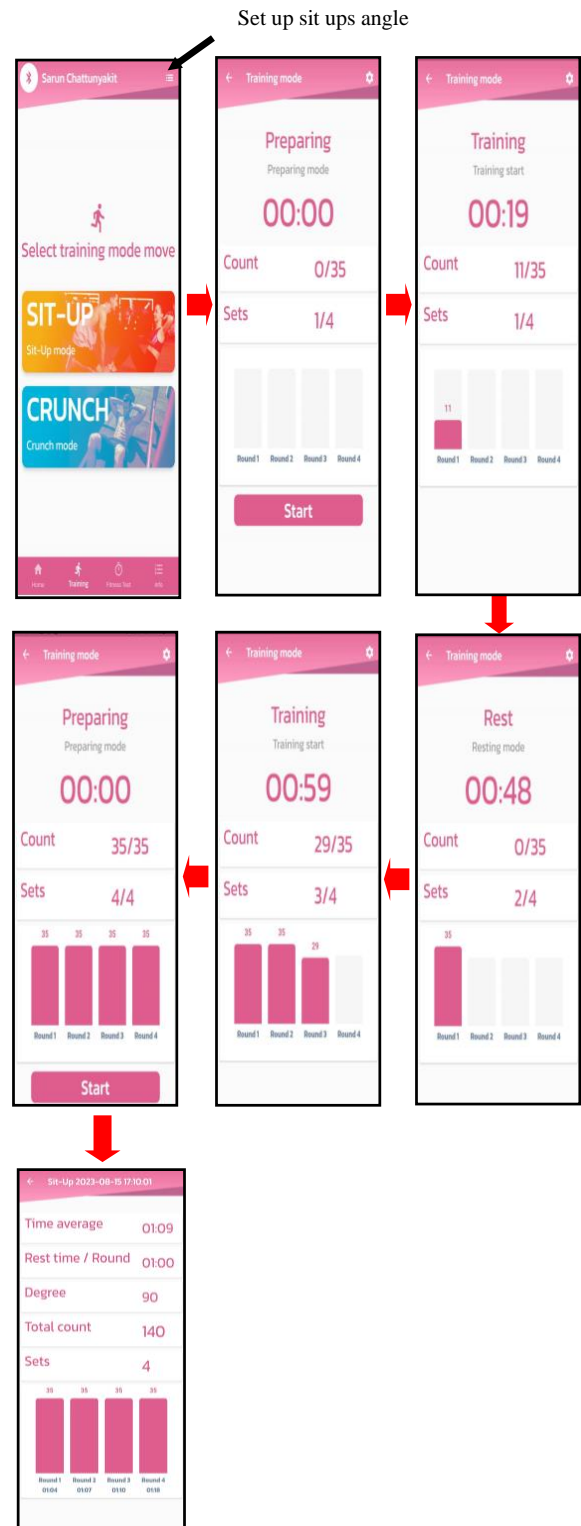


Figure 6: Application screen

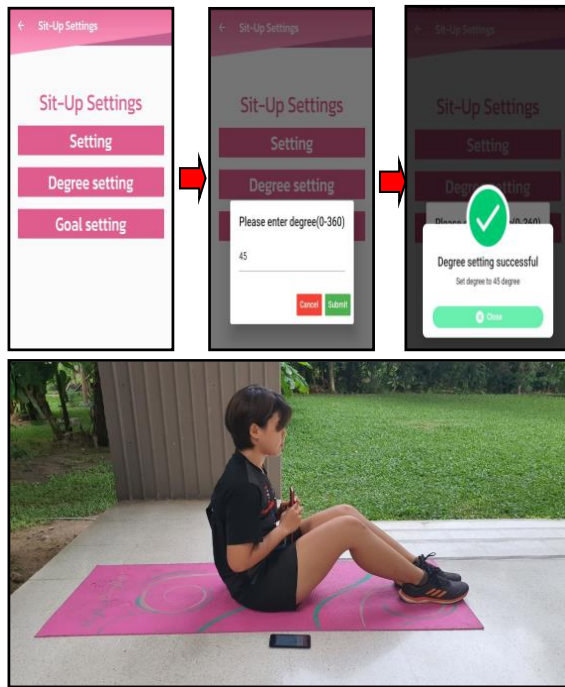


Figure 7: Setting degrees

The effect of using a physical fitness self-physical fitness training program with the Sit up Sensor to enhance the abdominal muscle strength

The participants who used the self-physical fitness training program with the Sit-Up Sensor to enhance abdominal muscle strength had a higher mean number of completed sit-ups in the allotted time than before the experiment used the program and equipment. The difference was statistically significant at the .05 level, and those who used the physical fitness training program with the sit-up sensor to enhance the strength of the abdominal muscles had a higher average number of sit-up times than the group using the training program without the Sit-up Sensor device, the difference was statistically significant at the .05 level as shown in Table 1 and Table 2.

Table 1: Experimental results of the group using the self-physical fitness training program with the Sit-up Sensor.

| TEST | N | Number of times in Sit-up | | t | P |
|-----------|----|---------------------------|------|--------|-------|
| | | Mean | S.D. | | |
| Pre test | 30 | 22.67 | 6.21 | 14.65* | .000* |
| Post test | 30 | 31.43 | 7.31 | | |

p < .05

Table 2: Experimental results of the group using the self-physical fitness training program with the Sit-Up Sensor and the group using the training program without the Sit-up Sensor.

| TEST | N | Number of times in sit-up | | t | P |
|---|----|---------------------------|------|------|-------|
| | | Mean | S.D. | | |
| The group using the training program with the Sit-Up Sensor | 30 | 27.87 | 5.57 | 2.16 | .035* |
| The group using the training program without the Sit-up sensor. | 30 | 31.43 | 7.13 | | |

p < .05

The results of the test verify the effectiveness of a Self-Physical Fitness Training Program using a Sit up Sensor to enhance abdominal muscle strength to optimum levels.

5. CONCLUSION

Discussion

Conditions and needs for Self-Physical Fitness Training Program with a Sit-up Sensor to enhance abdominal muscle strength found that the actual situation and the need for technologically connected devices for exercising were significantly different at the .05 level. The study of acceptance of educational innovation found that recognition of the benefits of using this has a direct effect on attitude. Perceived ease of use had a direct effect on attitude. Attitude had a direct effect on behavioral intention and behavioral intention has a direct effect on actual usage. Since today's world has many facilities being driven by science and technology, things have changed dramatically over the past decade. In particular, technology has resulted in people nowadays having behaviors and lifestyles that have changed. It has long-term effects on both physical and mental health. Most of the time each day is spent working and traveling with a lack of regular exercise. Therefore, the availability of technology and facilities allows people to exercise more. The reach of wearable trackers allows consumers to monitor their physical activity alongside online applications, with the tool showing that Exercise programs and equipment are necessary and important to facilitate everyday life [1]

Using a self-physical fitness training program with the Sit-up Sensor to enhance abdominal muscle strength allows users to do more sit-ups with the sit-up device to strengthen their abdominal muscles. Innovations and sports technology were developed to meet the needs of people in today's era. It has a direct effect on health, reducing sedentary behavior among young people that can lead to obesity. This leads to a better life as well, including muscle strength training, there is a specificity of training, should focus on training the muscles or muscle groups that will actually be used to achieve maximum benefit, including the duration of training and continuity, the character of the body will develop more strength.

Limitation

Sit-up Sensors or sports digital innovation developed are devices that are small, lightweight, and easy to use. The device will connect to the application on the smartphone with a Bluetooth signal. The sensor will send the signal to the smartphone for counting the number of times the particular exercise can be performed. In addition, the application saves personal data, sets the range of time and sets degrees of posture including saving data for users to see details about the data of the operation, to develop their strength even further in the future to make the equipment more complete and modern, The researcher found that other indicators should be added to the application and added other functions, such as adding vibration for the blind, deaf, showing the body fat, bone mass, etc., as well as physical fitness training programs and that this device is used for sit-ups only. Therefore, to meet the needs of various types of exercises, it should be used with exercise equipment to enhance performance in other areas as well. The sample was limited because of the participants. have similar backgrounds too without being different from other factors. In order to expand the research results more broadly, future research developments may include trials with more diverse participants.

6. REFERENCES

- [1] World Health Organization. (2019). **World health statistics 2019: monitoring health for the SDGs, sustainable development goals.** World Health Organization.
- [2] Institute for Population and Social Research , Mahidol University. (2016). **Thai people's health 2016 : Naturally die, The way you choose.** Nakhon Pathom : Amarin Printing and Publishing Public Company Limited.
- [3] World Health Organization. (2018). **World health statistics 2018: monitoring health for the SDGs, sustainable development goals.** World Health Organization.
- [4] Patient Knowledge Management Center Bumrungrad International Hospital. (2016). **Noncommunicable diseases group (NCDs). behavioral disease.** Retrieved from <https://www.bumrungrad.com/th/health-blog/>
- [5] Booncharoen, T. (2013). New Trends in Health Technology. **Journal of Science and Technology** ,(5)5, 25-32.
- [6] Todingan, R., Moningka, M., Danes, V. (2016). Hubungan besar sudut sit up dengan perubahan lingkaran perut pada mahasiswa Fakultas Kedokteran Universitas Sam Ratulangi. **Jurnal e-Biomedik (eBm)**, 4, Nomor I, January-June, 229-237.
- [7] Yumthiang, P., Sarakrai, P., and Homdok, V. (2016). The Development of Weight Training Program for Abdominal and Lower Extremity Muscle' Strength in Male Football Players in Sport and Health Science Football Team Institute of Physical Education Phetchabun. **Phetchabun Rajabhat Journal**, 18(1), 61-66.
- [8] World Health Organization. (2020). **Who Guidelines On Physical Activity And Sedentary Behaviour.** Retrieved from <https://apps.who.int/iris/bitstream/handle/10665/337001/9789240014886-eng.pdf>
- [9] Intharachai, K and Thiabthong, B. (2020). Effects Of Using the Circuit Training Activity Set to Promote Physical Fitness for the Undergraduates in Physical Education Activity Course. **Journal of Education Studies**, 48(3), 41-59.
- [10] Nimsuwan, N. (2021). Physical Fitness and Exercise Behaviors of Students in Swimming Course, Prince of Songkla University, Hat Yai Campus. **Journal of Education Prince of Songkla University.**, 31(1), 110-122,
- [11] Kitmetheekun ,R., Onsiri, S .,Tanphanich, A and Kongjinda, V. (2021). Application of FITT Principle in Teaching Physical Education to Improve Health Related Physical Fitness among Kasetsart University Students. **Journal of Health, Physical Education and Recreation**, 46(2), 107-117.
- [12] Chen, W. et al. (2002). Approaching healthy body mass index norms for children and adolescents from health related physical fitness. **Obesity Reviews**, 3(3), 225-232.

- [13] Taşkin, H. (2009). Effect of Circuit Training on the Sprint-Agility and Anaerobic Endurance. **Journal of Strength and Conditioning Research**, 23(6), 1803-1810.
- [14] Hofstetter, M., C., Mäder, U., and Wyss, T. (2012). Effects of a 7-Week Outdoor Circuit Training Program on Swiss Army Recruits. **Journal of Strength and Conditioning Research**, 26(12), 3418-3425.
- [15] Giacomini, M.B. et al. (2016). The Pilates Method increases respiratory muscle strength and performance as well as abdominal muscle thickness. **Journal of bodywork and movement therapies**, 20(2), 258-264 .
- [16] Kato, et. al. (2017). Innovative exercise device for the abdominal trunk muscles: An early validation study. **PLoS ONE**, 12(2). <https://doi.org/10.1371/journal.pone.0172934>
- [17] Sookhanaphibarn ,T. and Suriyachay, E. (2021). Health Promotion with a Web Application of 100 Days 100 KM. **2021 IEEE 3rd Global Conference on Life Sciences and Technologies (LifeTech)**, 198-199.

Teaching Health Informatics in Middle School: Experience from an NIH AIM-AHEAD pilot

Gregory TARDIEU

Alexandria City Public Schools
Alexandria, VA 22314, USA

Senait TEKLE

Biomedical Informatics Center, The George Washington University
Washington, D.C. 20037, USA

Linda ZANIN

Alexandria City Public Schools
Alexandria, VA 22314, USA

Ter L. CAPSHAW

Alexandria City Public Schools
Alexandria, VA 22314, USA

Alexander LIBIN

Georgetown-Howard Universities Center for Clinical and Translational Science
Washington, D.C. 20057, USA

Qing ZENG-TREITLER*

Biomedical Informatics Center, The George Washington University
Washington, D.C. 20037, USA

**Correspondence: Qing Zeng-Treitler, PhD, Professor & Director, The George Washington University, Biomedical Informatics Center, 2600 Virginia Ave NW, Suite 300, Washington, DC 20037, zengq@gwu.edu, 202-994-3143*

ABSTRACT

Health informatics is rarely introduced to middle school students due to their age and insufficient background knowledge in computing and healthcare. At the same time, it has been observed that many students have lost interest in science and technology when they reach high school. Funded by the NIH AIM-AHEAD initiative, we embarked on a project to create a health informatics after-school initiative focused on AI. We recognize that youth who identify as racial or ethnic minorities are less likely to be introduced to and less prepared for a range of STEM-H careers. Limited diversity in the life sciences and health professions has significant consequences for access to healthcare services. Preparing diverse students for the future digitally proficient healthcare workforce is fundamental to addressing health disparities, increasing cross-cultural communication, and positively impacting health equity. We acknowledge that students are more likely to thrive academically in areas of STEM-H when they have access to instructors from diverse races, ethnicities, and backgrounds who understand their experiences and perspectives.

Keywords: Health informatics education, middle schoolers, AI, healthcare, disparity, digitally proficient.

1. INTRODUCTION

The overall approach of our project is focused on transforming student lives and increasing diversity in the digitally proficient healthcare workforce. According to one study, women make up

15% of AI researchers at Facebook and 10% at Google [1]. It has also been reported that less than 3% of workers at technology companies are Black [2]. The healthcare workforce also faces challenges: A cross-sectional study using data from the 2019 American Community Survey (ACS) to compare the diversity of 10 healthcare occupations (advanced practice registered nurses, dentists, occupational therapists, pharmacists, physical therapists, physician assistants, physicians, registered nurses, respiratory therapists, and speech-language pathologists) reported that Blacks and Hispanics are underrepresented in these occupations that have higher education requirements [3]. On the surface, Asians are overrepresented in many technology and healthcare fields. Studies, however, revealed strong discrimination against Asian workers. For example, among all races and ethnicities, Asians are most likely to be hired by a technology company and are the least likely to be promoted to senior leadership positions and receive lower performance ratings [4].

Diversity also goes beyond race and gender [5]. Young people from immigrant backgrounds, speaking English as a second language, growing up in low-income neighborhoods, etc., are disadvantaged when it comes to early exposure to advanced technology fields such as AI. Our project aims to provide a solution to this problem by bringing AI in a medical training program to a diverse group of middle school students in the form of AIM-AHEAD after-school clubs using a state-of-the-art mobile classroom.

Theorem/Proof/Lemma: The pilot objective is promoting diversity, equity, and inclusion in healthcare and

informatics education. Students in US schools are growing increasingly racially and ethnically diverse, teachers and school leaders, for the most part, do not reflect this diversity [6]. To address the unique needs of students, our project is guided by the Culturally Responsive Teaching (CRT) model, which is an approach to teaching that is based on the idea that students learn best when their cultural backgrounds and experiences are taken into account. It is a student-centered approach that focuses on building relationships, creating a safe and supportive learning environment, and engaging students in meaningful learning

experiences. CRT also emphasizes the importance of intrinsic motivation, which is the idea that students are more likely to be successful when they are motivated by their own interests and curiosity [7].

Our overarching hypothesis is that personalized and representative informatics will increase children’s knowledge, interest, and future participation in a STEM-H workforce (Fig. 1).

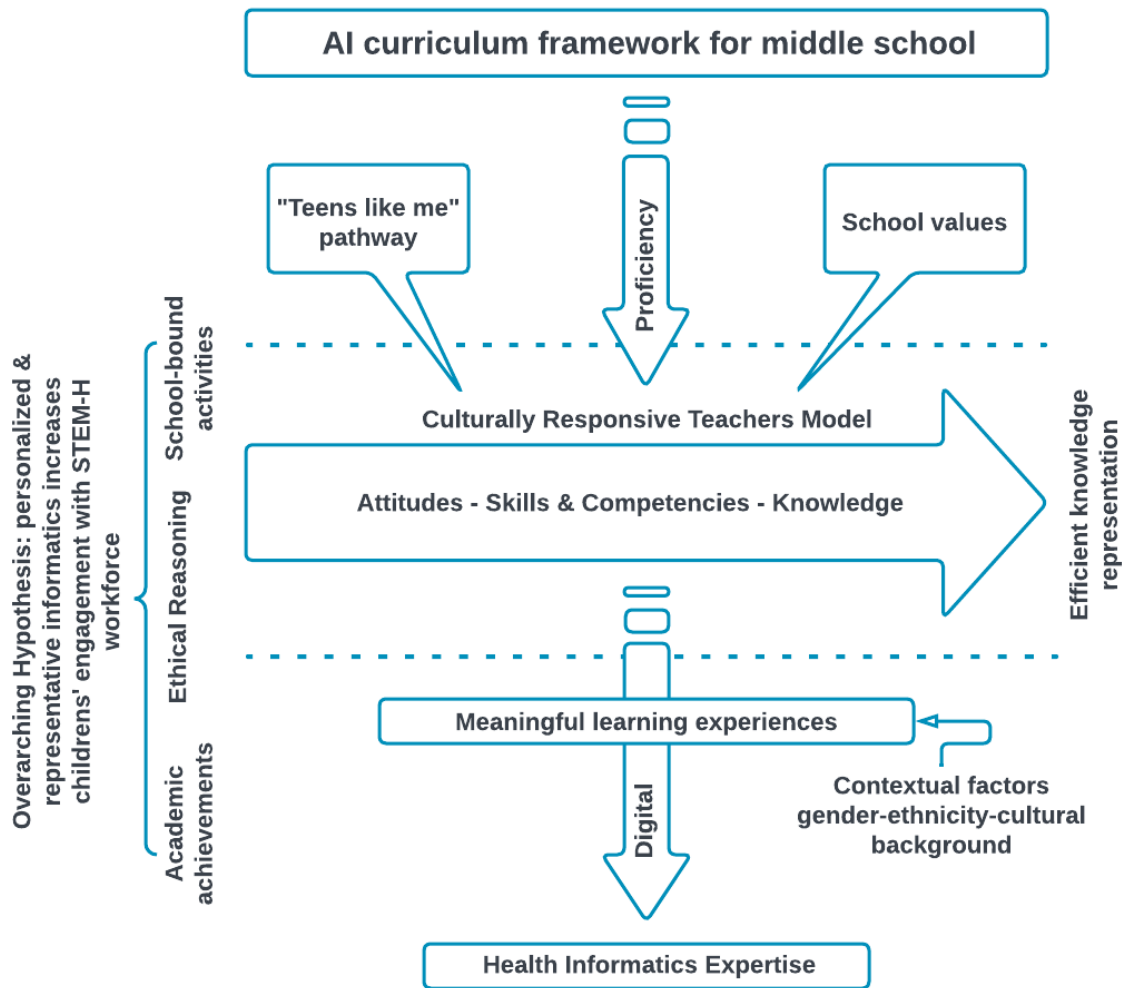


Fig. 1. Conceptual framework for diversified AI-focused medical training program for middle school students.

The pilot target population is Alexandria City Public Schools (ACPS) in Virginia, serving more than 15,700 students who hail from more than 119 countries and speak 124 languages. ACPS has 18 schools, including two middle schools (6-8 grade), two K-8 schools, one pre-K school, and the internationally recognized Alexandria City High School. Middle school challenges include providing students access to advanced technology resources, such as AI, and providing early exposure to technology to enhance learning experiences. Introducing this technology allows students the ability to apply, evaluate, and improve their skills in a controlled learning environment, without the risk of real-world consequences. Created learning scenarios are repeatable to allow students to improve performance through carefully analyzing mistakes and being free to make them

without real-world risks. The immersive nature of our approach adds an experiential and spatial component that helps learners to retain information.

The after-school STEM-H programming is an effort to provide students with hands-on collaborative interactive activities to learn the basics of health informatics, computing, and AI.

2. BIG DATA APPROACH TO HEALTH INFORMATICS EDUCATION IN CHILDREN AND ADOLESCENTS

The AIM-AHEAD after-school club takes place in the Immersive Learning Center (Fig. 2 & Fig. 3) and has 3 key components:



Fig. 2. Sixth- and seventh-grade students are learning about health informatics in the Immersive Learning Center.



Fig. 3. The Immersive Learning Center.

1) Mini “Tech Talks” on AI in medicine:

We recruited a wide range of speakers from pioneers in AI in medicine and health informatics experts who are developing cutting-edge solutions in academia and industry to middle- high-school/college students who are learning about AI. We asked each speaker to record a 15-20 minute talk to inspire students with a focus on AI applications rather than the technical details of methodology. By providing concrete and compelling examples of AI applications that have an impact on health and healthcare, we hope to introduce the field of AI and health informatics as both exciting and important.

One example of a “Tech Talk” is a lesson by Marius George Linguraru, DPhil, MA, MSc, Children’s National Hospital/The George Washington University, on the uses of advanced AI in facial recognition for early detection of Down syndrome in diverse populations and in developing countries. Image recognition is a powerful technology with significant implications in everyday life. AI image recognition picks up hidden patterns, even those not apparent to the human eye (Fig. 4). While the technology is sophisticated, even middle school students can appreciate the disparity problem and the benefit of the image recognition solutions.



Fig. 4. Dr. Marius George Linguraru of Children’s National Hospital/The George Washington University gave a “Tech Talk” on “AI for Children with Rare Diseases.”

2) Hands-on programming using Lego Robots:

Since most of our ACPS middle school population is students from diverse backgrounds with no prior exposure to programming, we decided to teach programming using Lego Inventor Robot. Considering the limited classroom time, we recruited a team of middle and high school students to pre-assemble the robots, allowing the after-school participants to jump into the programming components directly (Fig. 5, Fig. 6).

The first part of the programming lessons is focused on the basic commands, control structures, use of variables, and sensors. The second part dives into machine learning. The lessons give students an opportunity to experiment with learning from audio and visual data. The students are also able to use the trained model to make the robots more “intelligent.”

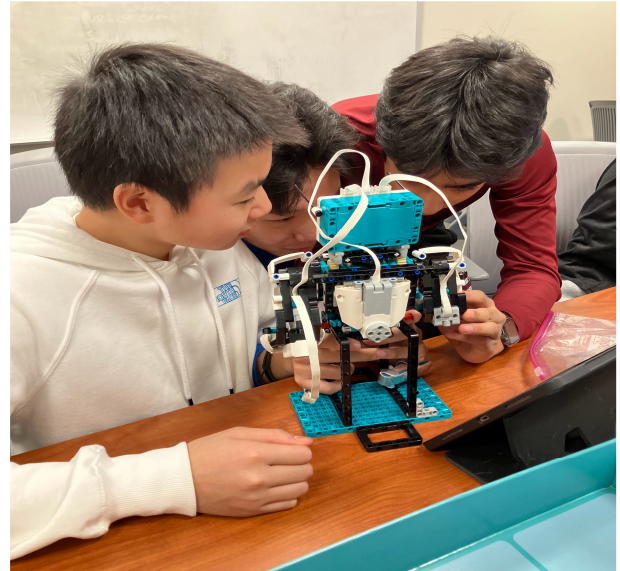


Fig. 5. Students building and programming Lego robots. We are also working on designing a final project that demonstrates how Lego robots could be used in the health domain.



Fig. 6. Students in middle school after-school club using code to control the Lego robots.

3) Experiment with big, real word healthcare data in a “Teens Like Me” app:

To introduce the middle school students to real life, big data in healthcare, we curated two adolescent-focused datasets using the Cerner Real World Data (RWD) and the National Health and Nutrition Examination Survey (NHANES) (Table 1). We have experience working with both datasets. RWD is a huge, national electronic health record (EHR) dataset from more than 100 healthcare facilities across the US [8]. As its name suggests, it contains valuable real world clinical data that can be used to demonstrate the power of AI. NHANES, on the other hand, is a yearly survey conducted by the US Centers for Disease Control (CDC). NHANES collects cross-sectional data from a nationally representative sample, while over-samples certain minority groups [9]. We have identified subjects in their teens from both datasets, to allow the “like me” analyses that are more relatable for the students. One analysis we have conducted is to characterize the nutrient patterns of food items in adolescent diets using data from a novel citizen science project we have previously carried out with the ACPS and the NHANES. In this analysis, we used two different unsupervised learning methods to discover the common nutrient profiles of food items consumed by teenagers and visualized the deficiencies and excesses according to the FDA recommended daily values (DV) [10] (Fig. 7).

TABLE 1. The demographic characteristics of the CDW and NHANES datasets.

| | Cerner CDW (N=1,450,782) | NHANES (N=7,110) |
|------------------|-----------------------------|---------------------|
| | Mean/N | Mean/N |
| Age | | |
| | 14.74 | 15.4 |
| Gender | | |
| Female | 673,417 | 3,460 |
| Male | 776,482 | 3,650 |
| Unknown | 883 | 0 |
| Race | | |
| White American | 904,844 | 2,034 |
| African American | 184,865 | 1,752 |
| Asian | 28,643 | N/A |
| Others | 0 | 965 |
| Unknown | 196,032 | 0 |
| Ethnicity | | |
| Non-Hispanics | 967,974 | 4,751 |
| Hispanics | 308,496 | 2,359 |

Given that most students do not have the level of programming skills to train realistic machine learning models, we are developing a “Teens Like Me” app to allow the students to experiment with risk prediction models. For example, the students can use the app (instead of R or python) to explore the unsupervised learning analyses of the nutrients’ datasets and observe the effect of using different clustering methods and number of clusters.

3. DISCUSSION POINT: PM METHODOLOGY OF HEALTH INFORMATICS EDUCATION FOR MIDDLE SCHOOL LEARNERS

Development of AI-based technologies calls for a new social contract between the computer sciences (CS) community, including ITs, ICTs, programmers (aka IT specialties) and digital society stakeholders in order to be successful with adolescents that have been immersed with the computer-mediated interactions since early childhood. Traditional education is transformed by new learning practices focusing not only on knowledge acquisition, but efficient knowledge implementation expressed through learning and professional competencies. In our pilot, students from diverse backgrounds and knowledge levels have joined an after-school club to learn more about health informatics. The proposed method was applied in an after-school club for 6-8th grade students (Fig. 8). There were four after-school 6-8th grade student clubs, with 12-26 students participating in each club.

An important part of the after-school club was to give students the chance to have hands-on learning experiences with health informatics. A unique combination of this technology promotes interactivity, and engagement, allowing students to enhance critical thinking and communication skills, team building and collaboration, and technical knowledge. The cumulative learning outcomes can be defined in our conceptual framework as generalized intellectual capital in education (InC^{ED}), expressed through an algorithm comprising four different factors: ethical reasoning, academic achievements, coping with complex school-bound activities and related everyday life situations, and, most

% of DV

| | Cluster Size | Energy | Protein | Total Lipid | Carbohydrates | Dietary Fiber | Total Sugars | Calcium | Iron | Potassium | Sodium | Cholesterol |
|----------------|--------------|--------|---------|-------------|---------------|---------------|--------------|---------|------|-----------|--------|-------------|
| K-Means | 28% | 3% | 2% | 0% | 4% | 0% | 5% | 0% | 0% | 0% | 1% | 0% |
| | 16% | 3% | 5% | 1% | 4% | 4% | 8% | 2% | 2% | 4% | 2% | 0% |
| | 14% | 12% | 21% | 14% | 8% | 5% | 4% | 5% | 7% | 0% | 20% | 9% |
| | 14% | 18% | 13% | 2% | 23% | 7% | 0% | 0% | 13% | 0% | 16% | 0% |
| | 11% | 6% | 40% | 5% | 0% | 0% | 0% | 0% | 4% | 0% | 8% | 20% |
| | 7% | 22% | 32% | 33% | 2% | 0% | 0% | 0% | 7% | 0% | 34% | 13% |
| | 5% | 20% | 23% | 12% | 26% | 32% | 30% | 5% | 17% | 5% | 11% | 0% |
| | 4% | 18% | 8% | 10% | 25% | 5% | 79% | 0% | 4% | 0% | 9% | 0% |
| | <1% | 14% | 25% | 3% | 7% | 0% | 0% | 0% | 1% | 18% | 257% | 0% |
| GMM | 32% | 2% | 2% | 0% | 4% | 0% | 9% | 1% | 0% | 2% | 1% | 0% |
| | 21% | 11% | 21% | 9% | 7% | 4% | 3% | 2% | 6% | 0% | 19% | 12% |
| | 11% | 9% | 6% | 11% | 10% | 9% | 3% | 2% | 5% | 0% | 8% | 0% |
| | 10% | 18% | 13% | 0% | 28% | 0% | 0% | 0% | 18% | 2% | 0% | 0% |
| | 8% | 10% | 29% | 19% | 1% | 0% | 0% | 0% | 3% | 0% | 16% | 0% |
| | 8% | 10% | 23% | 14% | 1% | 0% | 2% | 2% | 2% | 3% | 14% | 28% |
| | 6% | 14% | 7% | 6% | 23% | 6% | 48% | 0% | 3% | 1% | 12% | 0% |
| | 3% | 20% | 15% | 18% | 21% | 19% | 49% | 5% | 14% | 4% | 16% | 0% |
| | 1% | 10% | 16% | 12% | 9% | 5% | 24% | 0% | 0% | 0% | 31% | 10% |

Fig. 7. This figure shows the nutrient profiles of 9 clusters of food items generated using two different methods (K-Means and GMM). It suggests that the largest clusters are low in many nutrients, with sugar and protein being the exceptions when compared to the DV.

importantly, digital proficiency. It is hypothesized that InC^{ED} has a direct impact on learning competencies of students, warranting future successful management of professional and life challenges [11]



Fig. 8. 8th grade students participating in the afterschool program in the Immersive Learning Center.

Our conceptual framework recognizes certain limitations of the approach undertaken. Teaching and learning health informatics

is challenging in the middle school 6-8th grades. Both teachers and students require a great deal of support.

We recognize that youth who identify as racial or ethnic minorities are less likely to be exposed to and less prepared for a range of STEM-H careers. Limited diversity in the life sciences and health professions has significant consequences for access to healthcare services. Preparing diverse students for the future digitally proficient healthcare workforce is fundamental to addressing health disparities, increasing cross-cultural communication, and positively impacting health equity. We acknowledge that students are more likely to thrive academically in areas of STEM-H when they have access to instructors from diverse races, ethnicities, and backgrounds who understand their experiences and perspectives.

The proposed AI curriculum framework for middle schoolers addresses the existing gap in teaching digital core competencies as an integrated discipline for middle school students. Education through children-centered health informatics focuses on providing a methodology and metrics for aligning AI-based technologies with school values, and also enhances primary education with research and development components across traditional and innovative teaching disciplines.

The process of piloting and expanding initiatives like this are challenging. However, educating diverse students for careers in health informatics is fundamental to addressing disparities in healthcare, increasing cross-cultural communication, and positively impacting equity in health career pathways. Ultimately, to achieve change and to prepare a diverse healthcare workforce, ongoing commitments from secondary and higher education, as well as community collaborations are required. We will continue to work closely with teachers, leadership, and community partners to ensure that our middle school after-school programs have the support needed to take root and thrive. We are also planning to create an online curriculum that can be shared with other school districts.

4. ACKNOWLEDGMENT¹

We would like to thank Alexandria City Public Schools, The George Washington University School of Medicine and Health Sciences Immersive Learning Center, Dr. Anil Shanker, Senior Vice President for Research and Innovation Professor of Biochemistry, Cancer Biology, Neuroscience, and Pharmacology, Meharry Medical College, and the citizen scientists for their support and participation in this project.

5. REFERENCES

- [1] S. M. West, M. Whittaker, and K. Crawford, "Discriminating systems: Gender, Race and Power in AI," AI Now Institute, Apr. 2019.
- [2] A. Brown, "Fixing AI's Diversity Crisis Through Edtech: An In-Depth Interview With Tony Effik, Co-Founder Of The Black And Brilliant Advocacy Network," *Forbes*, Jul. 23, 2021.
<https://www.forbes.com/sites/anniebrown/2021/07/23/fixing-ais-diversity-crisis-through-edtech-an-in-depth-interview-with-tony-effik-co-founder-of-the-black-and-brilliant-advocacy-network/> (accessed Jul. 24, 2022).
- [3] E. Salsberg *et al.*, "Estimation and Comparison of Current and Future Racial/Ethnic Representation in the US Health Care Workforce," *JAMA Network Open*, vol. 4, no. 3, p. e213789, Mar. 2021, doi: 10.1001/jamanetworkopen.2021.3789.
- [4] Centers for Disease Control and Prevention, "Framework for Program Evaluation," Feb. 08, 2022.
<https://www.cdc.gov/evaluation/framework/index.htm> (accessed Jul. 24, 2022).
- [5] T. Faist, "Diversity – a new mode of incorporation?," *Ethnic and Racial Studies*, vol. 32, no. 1, pp. 171–190, Jan. 2009, doi: 10.1080/01419870802483650.
- [6] K. Schaeffer, "America's public school teachers are far less racially and ethnically diverse than their students," *Pew Research Center*. <https://www.pewresearch.org/fact-tank/2021/12/10/americas-public-school-teachers-are-far-less-racially-and-ethnically-diverse-than-their-students/> (accessed Mar. 09, 2023).
- [7] G. Gay and J. A. Banks, *Culturally Responsive Teaching: Theory, Research, and Practice*, 2nd edition. New York: Teachers College Press, 2010.
- [8] L. Ehwerhemuepha *et al.*, "Cerner real-world data (CRWD) - A de-identified multicenter electronic health records database," *Data Brief*, vol. 42, p. 108120, Jun. 2022, doi: 10.1016/j.dib.2022.108120.
- [9] L. J. Akinbami *et al.*, "National Health and Nutrition Examination Survey, 2017-March 2020 Prepandemic File: Sample Design, Estimation, and Analytic Guidelines," *Vital Health Stat 1*, no. 190, pp. 1–36, May 2022.
- [10] J. T. Treitler, S. Tekle, J. Ushe, and Q. Zeng-Treitler, "Nutrient profiles of food items in adolescent diet: a cluster analysis of data collected from a high school citizen science project," presented at the 2022 International Conference on Computational Science and Computational Intelligence, Las Vegas, 2022.
- [11] E. Libin, "Coping Intelligence: Efficient Life Stress Management," *Frontiers in Psychology*, vol. 8, 2017, Accessed: Mar. 15, 2023. [Online]. Available: <https://www.frontiersin.org/articles/10.3389/fpsyg.2017.00302>

¹AIM AHEAD Acknowledgement. Findings reported in this publication were supported by the Artificial Intelligence and Machine Learning Consortium funded by the National Institutes of Health under Award Number 1OT2OD032581. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

²GHUCCTS Acknowledgement. Findings reported in this publication were partially supported by the National Center For Advancing Translational Sciences of the National Institutes of Health under Award Number UL1TR001409. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

The Influence of Basic Psychological Needs Satisfaction on Well-Being: A Study on Higher Education Faculty in the New Normal

Janine Marie BALAJADIA
Maria Micole Veatrizze DY
Lukas PARIÑAS
Christine Leila TAGUBA
Alessandra Grace TAN
Maxine Therese TUAZON
Jerome Patrick UY
Genejane ADARLO

Health Sciences Program, Ateneo de Manila University
Quezon City 1108, Philippines

ABSTRACT

The world enters a new normal in response to the crisis brought on by the COVID-19 pandemic. This new normal has its unique challenges and opportunities for the faculty as physical campuses gradually re-open for teaching and learning. Although a growing amount of research has shown a relationship between the extent of basic psychological needs satisfaction and the state of well-being in diverse populations, studies focused on the faculty in the new normal remain limited. An online survey of 100 faculty from an institution of Catholic higher education in the Philippines was thereby carried out in the latter half of 2022 to examine such a relationship. The results of this study showed that satisfying the basic psychological needs of the faculty during the new normal can contribute significantly to their well-being. These results can inform higher education institutions on how they can best support their faculty in the new normal and promote student learning.

Keywords: Basic Psychological Needs Satisfaction, Self-Determination Theory, Well-Being, Mental Health Continuum, Higher Education, Faculty Development

1. INTRODUCTION

The COVID-19 pandemic has disrupted the way we live our lives. Countries across the world seemingly halted in the middle of March 2020 as governments strictly enforced precautionary measures and restrictions, such as community lockdowns, to contain the spread of COVID-19 particularly in areas with vulnerable health systems. These community lockdowns involved limiting the movement of people and closing the national borders. Not spared from these community lockdowns was the education sector as physical campuses were forced to close in adherence to government mandates. To continue the education of students in this adverse situation, higher education institutions, for example, shifted from offering in-person classes to using online learning platforms [1]. This abrupt shift in the delivery of teaching posed several challenges that may impact the well-being of the faculty. These challenges include the need to learn new technology, difficulty in engaging the students, lack of connection with students, and absence of work-life balance, among others [2].

The Philippines implemented one of the world's longest and most stringent community lockdowns [3]. It gradually eased restrictions on conducting in-person classes two years after the start of the COVID-19 pandemic, being the last country in the world to allow its students to return to classrooms [4]. With the

decline in COVID-19 cases and rollout of vaccines, the pandemic has eventually ushered the Philippines and other countries into a new normal where drastic changes have taken place as a result of adapting to the crisis [5]. This new normal though is not without its unique challenges and opportunities that may influence the well-being of the faculty. An area of scholarship not yet extensively explored is how satisfaction of basic psychological needs or lack thereof during the new normal can affect the well-being of faculty teaching in higher education institutions.

Hence, this study aims to 1) determine the level of satisfaction of basic psychological needs for autonomy, competence, and relatedness among higher education faculty during the new normal using the Basic Psychological Needs Satisfaction (BPNS) Scale; 2) assess the state of emotional, psychological, and social well-being among higher education faculty during the new normal using the Mental Health Continuum-Short Form (MHC-SF); 3) investigate if there is a correlation between their level of satisfaction of basic psychological needs and state of well-being during the new normal; 4) determine if the level of satisfaction of basic psychological needs is a significant predictor of well-being among faculty with age, gender, civil status, years of teaching, current engagement as a faculty, rank, academic discipline, and mode of teaching as co-variates. Results from this study can hopefully contribute to ongoing discussions on how higher education institutions can support faculty development in the new normal. Fostering faculty development is significant as it is an essential element in meeting the Sustainable Development Goals on quality education as well as on health and well-being.

2. THEORETICAL FRAMEWORK

Self-Determination Theory (SDT) suggests that satisfaction of the three basic psychological needs, namely autonomy, competence, and relatedness, can bring about a sense of well-being in individuals. Although these three basic psychological needs are inherent and universal, a need-supportive environment is warranted for individuals to flourish and fully function. A lack of a need-supportive environment, on the other hand, can lead to impaired well-being and failure to thrive [6, 7].

Autonomy refers to an individual's self-endorsement and sense of ownership of their actions. It can be realized when one's actions are done wholeheartedly and are in line with their interests. In contrast, autonomy can be hindered by socio-contextual and interpersonal factors that tend to pressure and control an individual's actions [6, 7].

Competence entails a sense of mastery or a belief that one can achieve and progress. This basic psychological need is best fulfilled in well-structured environments that provide opportunities for growth, optimal challenges, and positive feedback. Conversely, it is undermined in environments where non-constructive criticisms, negative feedback, and social comparisons are pervasive, and challenges are unreasonably difficult [6, 7].

Lastly, relatedness involves experiencing a sense of belonging and kinship with peers and social organizations that individuals are a part of. It refers to the feeling of being connected and involved with others. Mutual respect and expression of care can facilitate relatedness, while unresponsiveness, neglect, and insensitivity can impede it [6, 7].

One of the most comprehensive constructs of well-being is the operationalization of mental health as the presence of positive feelings and functioning in life. This construct describes mental health as a continuum in terms of emotional, psychological, and social well-being [8]. If individuals are feeling good about and functioning well in their personal and social life, they are considered flourishing [9] and tend to have high levels of well-being [8]. Otherwise, they are deemed as languishing and are likely to have low levels of well-being [8, 9].

Emotional well-being (EWB) is viewed as the presence or absence of positive feelings and emotions about life. This emotional dimension of well-being centers on the individuals' capacity to have positive feelings in life as they go through various emotional experiences [8]. It not only includes the presence of positive affect and the absence of negative affect, but it also accounts for perceived satisfaction in life [8, 9].

Psychological well-being (PWB) represents the degree to which individuals perceive themselves functioning in their personal life [8]. It is characterized by self-acceptance, personal growth, purpose in life, positive relations with others, autonomy, and environmental mastery [8, 9]. Individuals are functioning well in their personal life if they like most parts of themselves, find themselves developing into better persons, have direction in life, enjoy warm and trusting relationships, demonstrate self-determination, and can shape their environment according to their needs [8].

Social well-being (SWB), on the other hand, highlights the importance of functioning well in one's social life [8]. It involves social integration, social acceptance, social contribution, social coherence, and social actualization [8, 9]. Individuals can function well in their social life if they feel that they belong to and are accepted in society, they see themselves contributing to society, and they find society meaningful and has the potential for growth [8].

Satisfying the three basic psychological needs of teachers not only affects their well-being favorably, but also influences their teaching practices positively [6]. Several studies showed that teachers whose needs for autonomy and relatedness are met tend to experience greater engagement in teaching aside from encountering lesser incidences of burnout and emotional exhaustion [10, 11]. Another study also revealed that providing teachers with a need-supportive environment seems related to their use of effective teaching strategies [12]. These findings though only speak of circumstances before the pandemic. Hence, investigating the relationship between satisfaction of basic

psychological needs and state of well-being among the faculty has become more salient particularly in this new normal as student learning depends on these teacher-related factors.

3. METHODOLOGY

This study used an observational, non-experimental approach as it is the most appropriate research design for measuring the relationship between variables and predicting how one variable influences the other variable [13]. Satisfaction of the three basic psychological needs based on the BPNS scores of the surveyed faculty is the independent variable in this study, while the state of well-being based on their MHC-SF scores is the dependent variable. These variables alongside co-variables were collected from a sample at one point in time [14].

Setting and Participants

This study was set in an institution of Catholic higher education in the capital of the Philippines. This higher education institution was chosen as a research setting because of its faculty development programs that aim to support teachers in their teaching, research, and community service. It was also selected as a research setting as this higher education institution provided among others a month-long training of its faculty during the initial weeks of the pandemic to equip them in utilizing online learning platforms for teaching, such as the use of learning management system for asynchronous learning and videoconferencing for synchronous learning. It likewise instituted alternative learning models when students were allowed by the government to gradually return to the physical campuses as part of the new normal. In June 2022, faculty from this higher education institution adopted fully online, hybrid learning, or both as modes of teaching for the summer term to suit the needs of the course offered while considering their contexts and the students involved. By the first semester in August 2022, they assumed fully online, fully onsite, flex learning, or any combination of these modes of teaching as government restrictions against in-person classes eased further.

There are about 1,030 full-time and part-time faculty in this institution of Catholic higher education during the summer term (i.e., June to July 2022) and first semester (August to December 2022) of the academic year 2022 to 2023. After securing ethics clearance from an institutional review board, this study recruited these faculty to take part in a survey by sending them notifications to their institutional emails twice (two weeks apart) to address non-response bias. They should have taught during the summer term and/or first semester of the academic year specified above to be included in the study to assure representativeness. Those faculty, who have direct supervision of teaching and hold high-level administrative positions, were not included in this study to minimize social desirability bias. However, faculty diagnosed to have mental illness were still included in the study to lessen selection bias. As part of ethical considerations, psychological help was made available in case mental health issues arise from taking part in this study. Furthermore, those faculty, who opted not to join in the survey and who decided to withdraw their participation, were excluded from the study to recognize their rights.

Data Gathering

To collect data on the faculty's perceived satisfaction of their basic psychological needs and their state of well-being as the

physical campus re-opens for teaching and learning, this study administered an online survey questionnaire using Google Forms last September 2022. The online survey contained items from the BPNS scale to quantify the level of satisfaction of basic psychological needs among the faculty and items from the MHC-SF to measure their state of well-being in the new normal. It also consisted of questions related to demographic information, which may be considered confounding variables.

Basic Psychological Needs Satisfaction (BPNS) Scale. This scale is composed of 21 items that can measure how satisfied individuals are with their three basic psychological needs. Seven items were meant to quantify satisfaction with the need for autonomy (e.g., *I feel like I am free to decide for myself how to live my life*), six items for competence, (e.g., *People I know tell me I am good at what I do*), and eight items for relatedness (e.g., *I really like the people I interact with*). Survey respondents were asked to indicate the degree to which each item was true or relatable to them in the new normal by rating it on a Likert scale of 1 (i.e., *not at all true*) to 7 (i.e., *very true*). The higher the mean average score for the scale and its subscales, the higher the degree to which survey respondents were satisfied with their basic psychological needs. The BPNS scale is a highly researched instrument demonstrating excellent reliability and validity across cultures [15, 16].

Mental Health Continuum-Short Form (MHC-SF). This short form is one of the most common instruments that can measure positive mental health. It is derived from the 40-item Mental Health Continuum-Long Form and consists of 14 items, with three statements looking into EWB (e.g., *Happy*), six statements for PWB (e.g., *That you liked most parts of your personality*), and five statements for SWB (e.g., *That you had something important to contribute to society*). Survey respondents were requested to specify how often within the past month they experience certain indicators of well-being by rating them on a Likert scale of 0 (i.e., *never*) to 5 (i.e., *every day*). Higher scores for the MHC-SF and its subscales signify higher levels of well-being. The MHC-SF is also a highly researched instrument garnering excellent reliability and validity across cultures [17, 18].

Demographic Information. Certain demographic information was also collected in the survey given that they can affect how satisfied the faculty are with their basic psychological needs and how they perceived their state of well-being in the new normal. These confounding variables include age, gender, civil status, years of teaching, current engagement as a faculty, rank, academic discipline, and mode of teaching during the summer term and first semester.

Data Analysis

Frequency and percentage distribution were used to describe the study population in terms of their demographic information. Mean and standard deviation (SD) were gotten to illustrate how satisfied the surveyed faculty are with their basic psychological needs (i.e., BPNS scores) and how they viewed their state of well-being in the new normal (i.e., MHC-SF scores). Pearson correlation at a 95% confidence interval was carried out to investigate if there is a significant relationship between the BPNS and MHC-SF scores of the surveyed faculty. Lastly, multiple linear regression at a 95% confidence interval was conducted to determine if their BPNS scores can be a significant predictor of MHC-SF scores with age, gender, civil status, years of teaching,

current engagement as a faculty, rank, academic discipline, and mode of teaching as co-variables. Jamovi was used as statistical software in this study.

4. RESULTS

100 higher education faculty participated in this study, representing around a 10% survey response rate. This sample size can be considered ample for this research since an estimate of ten survey respondents is needed per independent variable or co-variate included in the multiple linear regression analysis [19]. Table 1 shows a summary of their demographic information.

Table 1. Demographic Information of Surveyed Faculty

| Age | n (%) |
|--|----------|
| 25 to 34 years old | 31 (38%) |
| 35 to 44 years old | 19 (19%) |
| 45 to 54 years old | 28 (28%) |
| 55 to 64 years old | 13 (13%) |
| 65 years old and above | 9 (9%) |
| Gender | |
| Female | 55 (55%) |
| Male | 44 (44%) |
| Prefer Not to State | 1 (1%) |
| Civil Status | |
| Single | 46 (46%) |
| Married | 47 (47%) |
| Separated, Annulled, or Widowed | 7 (7%) |
| Years of Teaching | |
| 0 to 4 years | 37 (37%) |
| 5 to 9 years | 15 (15%) |
| 10 to 14 years | 14 (14%) |
| 15 to 19 years | 17 (17%) |
| 20 to 24 years | 7 (7%) |
| 25 years and above | 10 (10%) |
| Current Engagement as a Faculty | |
| Full-Time Faculty | 44 (44%) |
| Part-Time Faculty | 56 (56%) |
| Rank | |
| Lecturer | 44 (44%) |
| Instructor | 19 (19%) |
| Assistant Professor | 22 (22%) |
| Associate Professor | 8 (8%) |
| Professor | 7 (7%) |
| Academic Discipline | |
| Humanities | 19 (19%) |
| Management | 18 (18%) |
| Science and Engineering | 24 (24%) |
| Education and Social Sciences | 39 (39%) |
| Mode of Teaching for the Summer Term | |
| None | 50 (50%) |
| Fully Online Learning | 28 (28%) |
| Hybrid Learning | 18 (18%) |
| Both Fully Online and Hybrid Learning | 4 (4%) |
| Mode of Teaching for the First Semester | |
| Fully Online Learning | 23 (23%) |
| Fully Onsite Learning | 25 (25%) |
| Flex Learning | 14 (14%) |
| Both Flex and Fully Online Learning | 6 (6%) |
| Both Flex and Fully Onsite Learning | 14 (14%) |
| Both Fully Online and Onsite Learning | 14 (14%) |
| Fully Online, Onsite, and Flex Learning | 4 (4%) |

The survey respondents felt their basic psychological needs for autonomy, competence, and relatedness were satisfied in general

during the new normal. Their mean average scores on the BPNS scale and its subscales can be seen in Table 2. Based on their responses to the MHC-SF, 45 (45%) of them were categorized as flourishing, 1 (1%) was languishing, and 54 (54%) were neither flourishing nor languishing. Their total scores on the MHC-SF and its subscales can be found in Table 2.

Table 2. BPNS and MHC-SF Scores of the Surveyed Faculty

| Variable | Mean | SD |
|--|-------|------|
| BPNS Scores (Likert scale of 1 to 7) | 5.22 | 0.82 |
| Autonomy (seven items) | 5.04 | 0.97 |
| Competence (six items) | 5.23 | 1.02 |
| Relatedness (eight items) | 5.40 | 0.79 |
| MHC-SF Scores (Likert scale of 0 to 5) | 43.59 | 9.96 |
| EWB (three items) | 10.79 | 2.66 |
| PWB (six items) | 15.19 | 4.09 |
| SWB (five items) | 21.21 | 5.10 |

Pearson correlation at a 95% confidence interval showed a strong, positive relationship between BPNS and MHC-SF scores ($r = 0.72, p < 0.001$). The correlations of scores between the subscales of the BPNS and MHC-SF were significant (r ranging from 0.43 to 0.79, $p < 0.001$) as reported in Table 3.

Table 3. Correlation between Subscale Scores

| Variable | 1 | 2 | 3 | 4 | 5 | 6 |
|---------------|------|------|------|------|------|------|
| 1 Autonomy | 1.00 | 0.71 | 0.64 | 0.65 | 0.52 | 0.59 |
| 2 Competence | | 1.00 | 0.64 | 0.64 | 0.61 | 0.73 |
| 3 Relatedness | | | 1.00 | 0.43 | 0.50 | 0.54 |
| 4 EWB | | | | 1.00 | 0.75 | 0.76 |
| 5 PWB | | | | | 1.00 | 0.79 |
| 6 SWB | | | | | | 1.00 |

Assumptions for the use of multivariate analysis, namely minimal autocorrelation (e.g., DW statistics within the range of 1.5 to 2.5), minimal multicollinearity (e.g., variance inflation factor below 4 and tolerance values above 0.25) and normality (Shapiro-Wilk p value greater than 0.05), were met in this study. Multiple linear regression at a 95% confidence interval demonstrated the BPNS score as a significant predictor of the MHC-SF score ($\beta = 0.73, p < 0.001$). Specifically, an accompanying 0.73 unit increase in the MHC-SF score could be expected for each unit of increase in the BPNS score. The covariates included in the regression model as confounding variables had no significant effect on the MHC-SF scores (β ranging from -0.03 to 0.17, $p \geq 0.05$). This regression model showed 56% of the variance in MHC-SF scores could be explained by the BPNS scores and co-variables ($R^2 = 0.56, p < 0.001$). The remaining 44% were unaccounted for.

5. DISCUSSION

The surveyed faculty perceived that their basic psychological needs were generally met as they taught in this new normal. Relatedness, being the most satisfied need, can be due to the presence of an environment that fosters social connectedness and genuine care. Competence, the second most satisfied need, can be attributed to an environment that allows them to be effective and adept in their teaching. Autonomy, despite ranking third, can be credited to an environment that supports self-endorsed decisions and actions [20]. Whether such an environment solely describes their workplace is less clear though. Other non-work-related factors can be contributory.

Almost half of the surveyed faculty were classified as flourishing, while the remaining half were neither flourishing nor languishing based on their responses to the MHC-SF items. These figures suggest that the survey respondents enjoyed EWB, PWB, and SWB despite the challenges that have accompanied the new normal.

This study also revealed that there was a strong, positive correlation between BPNS and MHC-SF scores within the context of the new normal. Moderate to strong, positive correlations were also documented between the BPNS and MHC-SF subscales. These results are similar to the findings of previous studies on the likely relationship between basic psychological needs satisfaction and well-being [6, 7, 20, 21, 22].

Given the new normal, this study showed BPNS score was a significant predictor of MHC-SF score after controlling for age, gender, civil status, years of teaching, current engagement as a faculty, rank, academic discipline, and mode of teaching for the summer term and first semester. These results support the assumptions of SDT on how basic psychological needs satisfaction can influence well-being [6, 7, 22]. Such results emphasize the importance of satisfying the three basic psychological needs of the higher education faculty in ensuring their overall well-being as they teach in the new normal [20, 21]. Higher education institutions are thereby encouraged to foster a need-supportive environment for their faculty in the new normal not only to look after their professional and personal development but to also facilitate quality teaching and better student learning.

6. LIMITATIONS AND FUTURE RESEARCH

Several limitations were encountered in this study. First, study participants were recruited through voluntary sampling. The response rate to the online survey was also low despite resending email notifications. This selection bias limits the representativeness of the surveyed respondents and affects the generalizability of the results. Future studies can address this selection bias by employing probability sampling, surveying faculty from multiple higher education institutions, and explaining the significance of their participation in the research. Second, surveyed faculty could have provided social desirability responses on the online questionnaire. Future research can minimize social desirability bias by emphasizing anonymity and data confidentiality when obtaining informed consent. Third, the scope of this study only included basic psychological needs satisfaction and well-being as independent and dependent variables, respectively. Motivation and negative indicators of mental health were not measured. Additional studies can incorporate these variables to gather a more comprehensive understanding. Fourth, this study used the BPNS scale and MHC-SF as constructs for basic psychological needs and well-being, respectively. Future studies can explore other definitions and measurements of needs satisfaction and well-being. Fifth, the research design undertaken in this study could only offer a snapshot view of the variables at one point in time and could not establish causal associations. Further studies can investigate causality by conducting a longitudinal follow-up. Finally, the quantitative nature of this study could not offer definitive explanations for the results. Additional studies can carry out a mixed methods design to gather an in-depth understanding of the quantitative data based on the qualitative data.

7. CONCLUSION

Higher education faculty felt their basic psychological needs for autonomy, competence, and relatedness were generally satisfied as they teach in the new normal. They also experienced emotional, psychological, and social well-being amidst the demands brought by the gradual re-opening of physical campuses for teaching and learning. Data from the faculty suggest satisfying their basic psychological needs seems contributory to their perceived state of well-being. These results have theoretical and practical implications on how higher education institutions can support their faculty as they navigate through the changing realities that characterized the new normal.

8. DECLARATION OF FUNDING AND COMPETING INTEREST

Funding was not received for this study. The authors have no competing interest to declare.

9. REFERENCES

- [1] H. Onyeaka, C. Anumudu, Z. Al-Sharify, E. Egele-Godswill, and P. Mbaegbu, "COVID-19 Pandemic: A Review of the Global Lockdown and Its Far-Reaching Effects", **Science Progress**, Vol. 104, No. 2, 2021, pp. 1-18.
- [2] Y. An, R. Kaplan-Rakowski, J. Yang, J. Conan, W. Kinard, and L. Daugherty, "Examining K-12 Teachers' Feelings, Experiences, and Perspectives regarding Online Teaching during the Early Stage of the COVID-19 Pandemic", **Educational Technology Research and Development**, Vol. 69, 2021, pp. 2589-2613.
- [3] B. de Vera, "PH Economy Sinks Deeper into Recession", **Philippine Daily Inquirer**, May 12, 2021 [Online]. Available: <https://business.inquirer.net/322729/ph-economy-sinks-deeper-into-recession>. [Accessed May 22, 2023].
- [4] C. Deiparine, "After 19 Months, Philippines Begins Gradual Return to Classrooms", **Philippine Star**, November 15, 2021 [Online]. Available: <https://www.philstar.com/headlines/2021/11/15/2141445/after-19-months-philippines-begins-gradual-return-classrooms>. [Accessed May 22, 2023].
- [5] S. Tomacruz, "COVID-19 Weekly Watch: What to Expect as Metro Manila Enters New Normal", **Rappler**, February 27, 2022 [Online]. Available: <https://www.rappler.com/newsbreak/iq/covid-19-weekly-watch-february-27-march-5-2022>. [Accessed May 22, 2023].
- [6] R.M. Ryan and E.L. Deci, **Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness**. New York: The Guilford Press, 2017.
- [7] R.M. Ryan and E.L. Deci, "Intrinsic and Extrinsic Motivation from a Self-Determination Theory Perspective: Definitions, Theory, Practices and Future Directions", **Contemporary Educational Psychology**, Vol. 61, 2020, pp. 1-11.
- [8] C.L. Keyes, "The Mental Health Continuum: From Languishing to Flourishing in Life", **Journal of Health and Social Behavior**, Vol. 43, No. 2, 2002, pp. 207-222.
- [9] C.L. Keyes, S.S. Dhingra, and E.J. Simoes, "Change in Level of Positive Mental Health as a Predictor of Future Risk of Mental Illness", **American Journal of Public Health**, Vol. 100, No. 12, 2010, pp. 2367-2371.
- [10] G. Roth, A. Assor, Y. Kanat-Maymon, and H. Kaplan, "Autonomous Motivation for Teaching: How Self-Determined Teaching May Lead to Self-Determined Learning", **Journal of Educational Psychology**, Vol. 99, No. 4, 2007, pp. 761-774.
- [11] R.M. Klassen, N.E. Perry, and A.C. Frenzel, "Teachers' Relatedness with Students: An Underemphasized Component of Teachers' Basic Psychological Needs", **Journal of Educational Psychology**, Vol. 104, No. 1, 2012, pp. 150-165.
- [12] R.H. Stupnisky, A. BrckaLorenz, B. Yuhas, and F. Guay, "Faculty Members' Motivation for Teaching and Best Practices: Testing a Model Based on Self-Determination Theory across Institution Types", **Contemporary Educational Psychology**, Vol. 53, 2018, pp. 15-26.
- [13] W.A. Edmonds and T.D. Kennedy, **An Applied Guide to Research Designs: Quantitative, Qualitative, and Mixed Methods**, California: SAGE Publications, Inc., 2017.
- [14] P. Leavy, **Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based, and Community-Based Participatory Research Approaches**, New York: The Guilford Press, 2023.
- [15] E.L. Deci and R.M. Ryan, "The What and Why of Goal Pursuits: Human Needs and the Self-Determination of Behavior", **Psychological Inquiry**, Vol. 11, No. 4, 2000, pp. 227-268.
- [16] M. Gagne, "The Role of Autonomy Support and Autonomy Orientation in Prosocial Behavior Engagement", **Motivation and Emotion**, Vol. 27, No. 3, 2003, pp. 199-223.
- [17] S.M.A. Lamers, G.J. Westerhof, E.T. Bohlmeijer, P.M. ten Klooster, and C.L.M. Keyes, "Evaluating the Psychometric Properties of the Mental Health Continuum-Short Form (MHC-SF)", **Journal of Clinical Psychology**, Vol. 67, No. 1, 2011, pp. 99-110.
- [18] M. Zemojtel-Piotrowska et al., "The Mental Health Continuum-Short Form: The Structure and Application for Cross-Cultural Studies – A 38 Nation Study", **Journal of Clinical Psychology**, Vol. 74, No. 6, 2018, pp. 1034-1052.
- [19] J.E. Bartlett, J.W. Kotrlik, and C.C. Higgins, "Organizational Research: Determining Appropriate Sample Size in Survey Research", **Information Technology, Learning, and Performance Journal**, Vol. 19, No. 1, 2001, pp. 43-50.
- [20] B. Chen et al., "Basic Psychological Need Satisfaction, Need Frustration, and Need Strength across Four Cultures", **Motivation and Emotion**, Vol. 39, 2015, pp. 216-236.
- [21] M.L.M. van Hooft and I.E. De Pater, "Daily Associations between Basic Psychological Need Satisfaction and Well-Being at Work: The Mediating Role of Need Strength", **Journal of Occupational and Organizational Psychology**, Vol. 92, 2019, pp. 1027-1035.
- [22] J. Lataster, J. Reijnders, M. Janssens, M. Simons, S. Peeters, and N. Jacobs, "Basic Psychological Need Satisfaction and Well-Being Across Age: A Cross-Sectional General Population Study among 1709 Dutch Speaking Adults", **Journal of Happiness Studies**, Vol. 23, 2022, pp. 2259-2290.

Stressors and Coping Strategies in the New Normal: A Case Study of Teachers in a Higher Education Setting

Janine Marie BALAJADIA
Maria Micole Veatrizze DY
Lukas PARÍÑAS
Christine Leila TAGUBA
Alessandra Grace TAN
Maxine Therese TUAZON
Jerome Patrick UY
Genejane ADARLO

Health Sciences Program, Ateneo de Manila University
Quezon City 1108, Philippines

ABSTRACT

When governments restricted holding in-person classes to contain the spread of COVID-19, many higher education institutions turned to digital technology to continue the education of their students. This abrupt change in the delivery of teaching and learning posed pedagogical and technological challenges to the teachers. And as governments have gradually allowed the return of students to physical classrooms with the decline in COVID-19 cases and the rollout of vaccines, teachers must adapt once more to a different arrangement for teaching and learning. Using the Job Demands-Resources Model as a theoretical framework, this case study examined the stressors (i.e., job demands) encountered by teachers in a higher education setting as students have returned to physical campuses. It also explored their coping strategies (i.e., job resources) that helped them adjust to the demands of using a different arrangement for teaching and learning in the new normal. Thematic analysis of responses to open-ended questions in a survey of 100 teachers in an institution of Catholic higher education in the Philippines showed demands related to teaching as a job and other competing concerns were brought up as stressors when in-person classes resumed after two years of fully online teaching. It also revealed seeking social support, focusing on teaching and research, and practicing self-care as their ways of coping with the demands of the new normal. Findings from this study can contribute to policies that can cater to faculty development.

Keywords: Job Demands-Resources Model, Stressors, Coping Strategies, Teachers, Higher Education, New Normal, Faculty Development

1. INTRODUCTION

The COVID-19 pandemic has changed everything in an instant, leaving no one prepared for the crisis it has caused [1]. It has unraveled the normal, which we can no longer regain [1, 2]. In its wake is a new normal that is characterized by a great reset of many aspects of our lives [3]. This great reset has compelled us to adapt to the drastic changes in our personal, social, economic, and spiritual spheres [4].

Not exempted from this great reset is the education sector [2, 3]. The COVID-19 pandemic has forced educational institutions across the world to reproduce digital versions of themselves as governments have restricted the conduct of in-person classes [3, 5]. Specifically, many educational institutions have hurriedly

adopted digital technology in teaching and learning to ensure continuity of education despite this global crisis [6]. Such an abrupt shift from holding in-person classes to occupying digital spaces has been challenging for teachers, who must design modules, prepare asynchronous activities, and deliver synchronous classes [5]. These teachers, among others, have been at risk of psychological distress brought on by the duration of community lockdown, fear of infections, feelings of frustration and boredom, inadequate resources, and uncertainties due to insufficient information [6].

Several studies have documented the stressors that teachers encountered as physical campuses closed to contain the spread of COVID-19 and the delivery of teaching and learning relocated to digital spaces [5, 7, 8, 9, 10]. As physical campuses have gradually re-opened for teaching and learning due to a decline in COVID-19 cases and the rollout of vaccines, the future of digital practices instituted during the pandemic is less clear [10]. Other stressors may have also emerged as the delivery of teaching and learning has resumed in-person attendance of classes. These stressors may warrant further coping strategies from teachers as they must adapt anew to a different arrangement for teaching and learning. Studies are few though that look into the stressors that teachers encounter and the coping strategies that they undertake as physical campuses have gradually re-opened for teaching and learning.

Hence, this study aims to examine the stressors faced by teachers in a higher education setting as in-person classes have gradually resumed as part of the new normal. It also seeks to explore the coping strategies used by them to respond to the demands brought by the re-opening of physical campuses for teaching and learning amidst the threats of the pandemic. A higher education setting was chosen in this study as there is a growing openness among higher education institutions toward innovation and new learning modalities because of the opportunities gleaned in using digital technology for teaching and learning [9]. Findings from this study can contribute to efforts toward meeting the Sustainable Development Goals on quality education as well as health and well-being.

2. THEORETICAL FRAMEWORK

To identify the perceived stressors and self-reported coping strategies of teachers in higher education institutions as the delivery of teaching has gradually returned to physical classrooms, this study used the Job Demands-Resources (JD-R)

Model as a theoretical framework. The JD-R Model is apt for the purposes of this research as it can be applied in diverse occupational settings, such as teaching, in evaluating the demands of a job and the resources available in the workplace [11].

Job demands are described as the physical, psychological, social, or organizational aspects of a job that necessitate sustained cognitive and emotional effort or skills. These demands at work have accompanying physiological and psychological costs to the individual [11, 12]. They include challenges at the workplace that may not necessarily be taken as negative [11]. When reasonable, certain occupational challenges can foster a sense of mastery or competence, for instance [13, 14]. Job demands become negative only if they turn into stressors wherein huge efforts are demanded in fulfilling an occupation and recovery from them seems insufficient [11]. These stressors may include qualitative job demands (e.g., emotional, mental, and physical demands), quantitative job demands (e.g., work overload and pace of change), and organizational demands (e.g., bureaucracy, role conflicts, and interpersonal conflicts) [12].

Job resources, on the other hand, refer to the physical, psychological, social, or organizational aspects of a job that impact an individual's ability to reach occupational goals, offset the physiological and psychological costs of the job demands, and encourage the individual's growth, learning, and development [11]. These resources include external (i.e., social, work, organizational, and developmental resources) and internal factors (i.e., personal resources) that can motivate an individual at work [11, 12]. Any resource, which can mitigate a stressful situation or environment, can be considered a coping resource or a coping strategy [15].

A coping resource involves cognitive and behavioral efforts that aim to manage the external and/or internal demands of a stressful situation or environment [15, 16]. Problem-focused coping seeks to handle a problematic situation, while emotion-focused coping intends to control one's emotional response to difficulties. To cope at work depends on the resources that are available or unavailable to an individual [15]. A coping strategy can either be functional (e.g., seeking support) or dysfunctional (e.g., excessive drinking of alcohol). When teachers attribute their stressors to external factors, they tend to display functional rather than dysfunctional coping strategies. When they internalize the constraints at work, they are more likely to exhibit dysfunctional over functional coping strategies [17].

The JD-R Model suggests that the interaction between job demands (i.e., stressors) and job resources (i.e., coping strategies) can influence an individual's well-being [11]. Burnout can happen when job demands are high and job resources are lacking. In contrast, work engagement can ensue when job resources are abundant amidst high job demands [11, 12].

Several studies have used the JD-R Model in investigating the effects of job demands and job resources on the well-being of teachers as they taught in the initial months of the COVID-19 pandemic [18, 19, 20, 21]. However, most of them have recruited respondents from teachers in basic education. The perspectives of teachers in higher education are underrepresented. Furthermore, these studies have only offered insights into the experiences of teachers as they carried out emergency remote teaching in the first few months of the pandemic. Little is known about the stressors and coping strategies of teachers as the

physical campuses have gradually re-opened for in-person classes. Lastly, only a few studies have collected qualitative data that describe in depth the job demands and job resources of teachers in higher education as they adapt once again to changing realities in teaching and learning during the new normal.

3. METHODOLOGY

This study is part of a larger research project that looked at the well-being of teachers in higher education as they teach in the new normal. It employed a case study approach as it is the most suitable research design for examining a phenomenon within its real-life context, namely teaching in the new normal [22]. A case study approach is also useful in arriving at an in-depth understanding of a bounded phenomenon [23].

Setting and Participants

This study was set in the Philippines, where the world's longest and most stringent community lockdown was implemented [24]. The Philippines was the last country to allow its students to physically return to schools as it only eased restrictions against holding in-person classes two years after the COVID-19 pandemic was declared by the World Health Organization [25].

Specifically, this case study was carried out in an institution of Catholic higher education located in one of the highly urbanized cities in the Philippines. This higher education institution was selected for this study due to its faculty development programs that are geared toward supporting its teachers in their teaching, research, and community service. It was also chosen as a setting for this research as this higher education institution provided training workshops during the first few weeks of the COVID-19 pandemic to equip its teachers for the pedagogical and technological aspects of online learning. Furthermore, this higher education institution fits the aims of this study as it instituted alternative learning models that make the most of digital technology in teaching. In June 2022, teachers of this higher education institution explored fully online, hybrid learning, or both in the delivery of teaching for the summer term. Hybrid learning involves students attending their classes onsite and online alternately. By the first semester in August 2022, they adopted fully online, fully onsite, flex learning, or combinations of these approaches in teaching as government restrictions against holding in-person classes eased further. Flex learning entails several students attending class onsite, while others are online.

This higher education institution had 1,032 full-time and part-time teachers in the summer term (i.e., June to July 2022) and first semester (i.e., August to December 2022) of the academic year 2022 to 2023. After securing ethics approval from an institutional review board, this study invited these teachers to participate in a survey as part of a larger research project by sending them notifications to their institutional emails twice (two weeks apart). Teachers assuming high-level administrative positions, opting not to take part in the survey, or withdrawing their participation were excluded from the study.

Data Gathering

To gather data on perceived stressors and self-reported coping strategies of teachers as physical campuses have gradually re-opened for teaching and learning, this study administered an online survey questionnaire in September 2022 by sending via

email the URL link to Google Forms. The online survey requested the teachers to signify their informed consent, complete their demographic information (i.e., age, gender, civil status, years of teaching, current engagement as a faculty, rank, academic discipline, and delivery of teaching during the summer term and first semester), and respond to the following open-ended questions:

- 1) As an educator, what stressors have negatively impacted your well-being during the transition to the new normal?
- 2) While teaching during the transition to the new normal, what coping strategies have helped you maintain your well-being?

The teachers were also asked to provide additional information about their teaching experiences in the new normal, which they deemed valuable for this study.

Data Analysis

Thematic analysis was used in this case study to make sense of the qualitative responses gathered from the online survey. It allows the identification of underlying themes or patterns from the repeated meanings that can be found in qualitative datasets [26]. The thematic analysis involved immersing in the data by reading the survey responses to the open-ended questions several times to increase familiarity with the data. Coding was then carried out by assigning a word or phrase to best describe a segment of data [27]. Both a priori coding (i.e., codes developed beforehand based on a theoretical framework) and in-vivo coding (i.e., codes emerging from the study participants' own language) were performed. Coding was likewise theory-driven (i.e., deductive coding) and data-driven (i.e., inductive coding) so that existing concepts from the literature can guide the analysis while being open to codes that developed organically from the study participants [27, 28]. Afterward, similar or related codes were grouped together. Patterns from the categories of codes were looked for to arrive at emerging themes that provide larger meanings [27]. Finally, recurring themes were kept and reported as findings [26].

Taguette was used as an online software application for qualitative data analysis because it permits multiple researchers to collaborate in the coding and theming process. Several steps were undertaken in this study to ensure the gathered qualitative data were interpreted in the most truthful ways possible. First, detailed documentation, such as memo writing and journaling, was adhered to throughout the thematic analysis to leave an audit trail. Second, researcher triangulation was observed by having multiple researchers do the coding and theming process to guarantee consistency in assigning and classifying codes into themes. Third, themes and subthemes were reviewed against the raw data. Fourth, relevant quotes from study participants were included in the findings to support the reported themes. Lastly, initial findings were presented to a panel of experts to address researcher bias and assure the integrity of the thematic analysis [26, 27, 29, 30, 31].

4. FINDINGS

100 teachers from this higher education institution participated in the online survey, yielding almost a 10% response rate. Table 1 summarizes their demographic information.

Table 1. Demographic Information of Surveyed Teachers

| Age | n (%) |
|--|----------|
| 25 to 34 years old | 31 (38%) |
| 35 to 44 years old | 19 (19%) |
| 45 to 54 years old | 28 (28%) |
| 55 to 64 years old | 13 (13%) |
| 65 years old and above | 9 (9%) |
| Gender | |
| Female | 55 (55%) |
| Male | 44 (44%) |
| Prefer Not to State | 1 (1%) |
| Civil Status | |
| Single | 46 (46%) |
| Married | 47 (47%) |
| Separated, Annulled, or Widowed | 7 (7%) |
| Years of Teaching | |
| 0 to 4 years | 37 (37%) |
| 5 to 9 years | 15 (15%) |
| 10 to 14 years | 14 (14%) |
| 15 to 19 years | 17 (17%) |
| 20 to 24 years | 7 (7%) |
| 25 years and above | 10 (10%) |
| Current Engagement as a Faculty | |
| Full-Time Faculty | 44 (44%) |
| Part-Time Faculty | 56 (56%) |
| Rank | |
| Lecturer | 44 (44%) |
| Instructor | 19 (19%) |
| Assistant Professor | 22 (22%) |
| Associate Professor | 8 (8%) |
| Professor | 7 (7%) |
| Academic Discipline | |
| Humanities | 19 (19%) |
| Management | 18 (18%) |
| Science and Engineering | 24 (24%) |
| Education and Social Sciences | 39 (39%) |
| Delivery of Teaching for the Summer Term | |
| None | 50 (50%) |
| Fully Online Learning | 28 (28%) |
| Hybrid Learning | 18 (18%) |
| Both Fully Online and Hybrid Learning | 4 (4%) |
| Delivery of Teaching for the First Semester | |
| Fully Online Learning | 23 (23%) |
| Fully Onsite Learning | 25 (25%) |
| Flex Learning | 14 (14%) |
| Both Flex and Fully Online Learning | 6 (6%) |
| Both Flex and Fully Onsite Learning | 14 (14%) |
| Both Fully Online and Onsite Learning | 14 (14%) |
| Fully Online, Onsite, and Flex Learning | 4 (4%) |

Thematic analysis of their responses to the open-ended questions in the survey revealed demands related to teaching as a job and other concerns were identified by the study participants as stressors when in-person classes resumed after two years of fully online teaching. It also showed several strategies they used to cope with the demands of teaching in the new normal.

Stressors

Stressors in the new normal among the study participants include job-related demands (i.e., qualitative demands, quantitative demands, and organizational demands) and other demands that affect in one way or another their functioning as teachers.

Job-Related Demands

Qualitative Demands. A common stressor that affected the study participants emotionally is the unremitting fear of getting infected with COVID-19. Despite the lowering of COVID-19 cases in the population and increasing availability of vaccines, there is still, as Teacher 45 pointed out, “a constant threat of the COVID-19 infection.” “Variants of the virus,” as Teacher 71 explained, “are still evolving and there is no real certainty that the pandemic is over.” Several study participants, such as Teachers 39 and 83, were also anxious that they would “bring home the disease to [their] loved ones” and found this possibility worrisome as they “live with people with co-morbid conditions.” Hence, “being in a crowd” and “being in close contact with people during the daily commute” would be distressing for Teachers 43 and 49, among others.

Many of them, including Teachers 65 and 82, were anxious about whether their students are “learning well enough” given the different arrangements for teaching and learning. Compared to fully onsite learning, they felt a sense of connection with the students is lacking when teaching has an online component. Teacher 56, for instance, described their experience in flex learning as facing the “uncertainty of connecting with [their] students on a literal (technical challenges) and figurative (teaching something useful to them) level.” Teachers 4, 34, and 56 attributed this desire to “connect better with [their] students” to the “limited interaction” and “less social contact” that they came across in fully online, hybrid, and flex learning.

Study participants, such as Teachers 29, 39, 50, and 93 were concerned about the well-being of their students as schoolwork in the new normal can be “overwhelming” for them. However, others, namely Teachers 28, 35, and 92, felt some of their students can be “demanding” and “emotionally manipulative” as they expect their teachers would “always be available” and would “live only for the students.” Teacher 60 and others also observed “the above normal number of students, who would absent from class” and “numerous requests [from students] to move deadlines or be lenient with requirements.” This “sense of entitlement” among the students, according to Teacher 72, can be quite stressful for them to deal with.

Another common stressor brought up by the study participants is the many adjustments that they must make as holding in-person classes gradually resumed in the new normal. First, they must adjust to different arrangements for teaching and learning. Teacher 89, for example, found themselves having to adjust to hybrid and flex learning when they barely got accustomed to teaching online. “Toggling between [their] onsite and online students [in a flex arrangement]” was “a source of strain and frustration” for Teacher 46, among others. Second, study participants must adjust their manner of course delivery. Teacher 32 and others “need to restructure [their] lessons and teaching styles.” This restructuring, as described by Teacher 39, entails “having to think and rethink teaching strategies to make the most of the situation.” For Teacher 80, “the demands of learning new ways of teaching and new tools [for teaching]” can be mentally draining. Lastly, study participants must adjust to the use of technology for their classes, particularly for flex learning. Teachers 66 and 74, for instance, must learn “a lot of tech-based stuff with very little time.” Teachers 18, 45, and others found such “full dependence on technology” for their classes as “anxiety-provoking” as it “sometimes does not work and gets

faulty.” That is why experiencing “spotty internet” while teaching was worrisome for many, such as Teachers 63 and 79.

Several study participants, including Teachers 1, 44, and 45, raised their concerns about how physically taxing commuting has been to and from the campus. The public transportation system, according to Teacher 45, has been “chaotic” compared to how it used to be before the pandemic. Others, such as Teachers 60, 88, 93, and 94, complained about how exhausting the traffic situation and the long drive have been for them.

Quantitative Demands. Furthermore, study participants felt burdened by their heavier workload. This sentiment stemmed from how teaching in the new normal, as Teachers 65 and 97 elaborated, involves “a lot of preparations.” They, including Teachers 18, 83, and 91, must also “juggle” multiple classes to teach, administrative responsibilities to fulfill, various meetings to attend, and emails to reply. These tasks, as Teacher 18 emphasized, would “take up so much of [their] time [to a point that] 24 hours seem not enough.” Their “workload,” as described by Teacher 20, “seems to deny the existence of a pandemic.”

Organizational Demands. There are study participants, such as Teacher 8, who felt some of the university policies as stressful because they “are not well-thought-out.” Teacher 23, for instance, found the policy to resume holding in-person classes while the pandemic is still ongoing as difficult to comply with. This apprehension to return onsite for teaching, as Teacher 40 and others explained, can be attributed to their views on the COVID-19 protocols and health care coverage of the university as lacking.

Teacher 5, among others, also considered the academic policies of the university as “too prescriptive.” Specifically, policies on how to structure and conduct their classes were “annoying” since these policies tend to limit their exercise of academic freedom. Moreover, several study participants, including Teacher 67, criticized the policies that tend to set the “bar to education too low just to accommodate the demands of the students.” As such, Teacher 88 and others believed “too much compassion and consideration [are] given to students.” These policies, according to Teacher 76, “asked [them] to care for the students during the transition.” Yet they “did not feel the same care from [the administration].”

Another common stressor among the study participants is their salary. Teacher 19 and others felt their salaries are no longer sufficient due to inflation and rising fuel prices. For Teacher 76, the compensation they received is also “unjust” given the various demands being asked from them by the university in this new normal.

Other Demands

Several study participants raised other competing concerns that are not directly related to their teaching as a job but have a significant impact on their functioning at work. Teacher 11, for instance, found the current socio-political situation of the country worrisome. Many of them, such as Teachers 24, 25, 68, and 97, also deemed the country’s socio-economic circumstances (i.e., high inflation rate and prohibitive fuel prices) disturbing. Issues within their family, on the other hand, deeply affected Teachers 10, 18, and 53, among others.

Coping Strategies

A list of external (i.e., social, work, organizational, and developmental) and internal (i.e., personal) resources were tapped by the study participants to cope with the previously mentioned job-related demands and other competing concerns in the new normal.

External Coping Resources

Social Resources. Most of the study participants viewed garnering social support as a coping strategy to the demands of teaching in the new normal. First, several of them, including Teacher 11, turned to colleagues in the faculty for their “support group.” For instance, Teachers 29, 92, and others could “air out their grievances” with colleagues as they basically “go through the same things.” Aside from sharing their daily experiences with colleagues, study participants, such as Teachers 29 and 91, would also spend time hanging out together. For Teacher 93, this “unwinding with colleagues” entails “letting [themselves] be open to unscheduled invitations.” Second, many of the study participants relied on their family and friends for support. Teachers 47 and 58, among others, would “find time” to be with their family and friends despite their hectic schedules. This “reaching out” to their family and friends, as Teacher 52 stated, is comforting for them as they could make the most of spending time with them. Third, several of the study participants, such as Teachers 11, 36, and 56, found consolation from their students. Specifically, their interaction with students would remind them why they choose to teach. Lastly, some of them, including Teachers 6, 50, and 74, found asking for help and assistance valuable. In the case of Teacher 14, their mental health benefited from seeking professional help from a counselor.

Work and Organizational Resources. Teachers 30, 36, and others considered teaching itself as a coping strategy. Focusing on their teaching, such as learning to use technology for teaching, accepting the challenge to re-tool, and preparing course materials, aided Teachers 69, 74, and 90 in dealing with their stressors. “Doing relevant research,” on the other hand, helped Teachers 9 and 66 get by. “Being able to meet deadlines and accomplish things” at work kept Teacher 18 “sane.” Several of the study participants, including Teacher 25, also “appreciated [their] relative freedom to pursue [their] interests as a researcher and educator.”

A few of them, however, adopted dysfunctional coping strategies in response to the various demands of teaching in the new normal. Teacher 8, for instance, would rather not expect “competence” from the administrators of the university as they felt most of their policies were unreasonable. Teacher 98 would preferably “deny the importance of [their] job so that they would care less about the subject not being taught the way they want to teach it.”

Developmental Resources. Many of the study participants, such as Teachers 54 and 77, chose to stay positive amidst the demands of teaching in the new normal. They, including Teachers 4, 17, 33, 66, 78, and 84, believed they were able to manage well because they practiced self-affirmation, gratitude, openness, and work-life balance, among others.

Internal Coping Resources

Personal Resources. Aside from social resources, making use of personal resources is commonly mentioned as a coping strategy in the new normal by the study participants. Teachers 5, 10, 12, 16, 20, 22, 70, 91, and others made it a point to work out and exercise. Some of them, such as Teacher 76, also tried yoga and meditation. Several of the study participants, including Teachers 5, 57, and 95, made sure to eat healthy, get enough sleep, and practice other daily self-care routines. Engaging in hobbies (i.e., watching tv series and movies, playing video games, listening to music, and reading a book) and taking care of pets were helpful for Teachers 16, 84, and others. Also, praying and deepening their relationship with God comforted Teachers 3, 14, 45, 58 and others amidst the demands of teaching in the new normal.

5. DISCUSSION

The resumption of holding in-person classes while the pandemic is ongoing entails teachers being in close contact with others, which increases their risk of exposure to COVID-19 and the likelihood of them infecting significant others [32]. That is why it is understandable that many of the study participants were apprehensive about teaching classes onsite. They fear contracting COVID-19 and were also worried about how they could potentially endanger the well-being of their family.

Study participants considered being concerned about their students’ learning, disruptive behaviors, and well-being in the new normal as added stressors. They yearned for meaningful connection with their students particularly during these online arrangements for teaching and learning that have become part of the new normal as literature showed building student-teacher relationships matters for students to engage in learning [33]. A previous study also showed their role as teachers goes beyond the confines of the classroom. They must deal with the disruptive behaviors of students and look after their well-being [34].

This study demonstrated that teachers adjusted anew when different arrangements for teaching and learning were instituted as physical campuses re-opened for in-person classes. These adjustments posed additional pedagogical and technological challenges to the teachers in their already demanding profession [34].

The physical demands of commuting to and from the university exacerbated the stressful situations of some of the study participants in the new normal. In contrast to holding in-person classes, the disadvantages of commuting were not a concern when teaching was fully online. Aside from the flexibility offered by the work-from-home arrangement, teachers can save time and money when they do not have to commute [35].

Handling increased workload and taking on multiple roles and responsibilities are unrealistic job-related demands in the new normal that can adversely affect the well-being of teachers [34, 36]. Study participants also felt some university policies were unfavorable to their circumstances in the new normal. Similar to a previous study, they believed these not well-thought-out policies interfered with their effectiveness as teachers [34]. Moreover, many of the study participants considered their salaries to be no longer sufficient based on the expectations asked of them at work as well as the prevailing socio-economic conditions in the country.

In times of pandemics and other crises, job-related demands become interconnected with the demands of various life domains [37]. Additional competing demands seen in this study include family issues, socio-political situations, and socio-economic circumstances.

Furthermore, this study showed the importance of social support from colleagues, family, friends, and students in coping with the demands of teaching in the new normal. Social support is a key job resource that can offset the load at work, minimize the occurrence of burnout, and promote well-being among teachers [36, 38, 39].

Interestingly, focusing on teaching and research is viewed by several study participants as their way of coping in the new normal. Keeping themselves busy at work to de-stress is likewise reported as a job resource in a previous study [39].

Study participants overcame the demands of teaching in the new normal by drawing from their personal resources, such as engaging in leisure activities, practicing self-care, and taking part in spiritual activities. Some of these coping strategies are existing approaches to job demands, while others are new [36].

6. LIMITATIONS AND FURTHER RESEARCH

This study encountered several limitations, which may affect the generalizability of its findings. First, there is selection bias as voluntary sampling from one higher education institution was used to recruit the study participants. Future studies can minimize this selection bias by employing probability sampling in multiple higher education institutions. Second, the study participants could have provided social desirability responses when answering the online questionnaire. Future research can address this social desirability bias by emphasizing their rights to anonymity and data confidentiality when obtaining informed consent. Third, the data used for thematic analysis only came from open-ended responses of the study participants in an online survey. Further research can benefit from employing interviews to gather an in-depth understanding. Lastly, this study used the JD-R Model in examining the stressors (i.e., job demands) and coping strategies (i.e., job resources) of teachers in the new normal. Future studies can explore other theoretical frameworks to understand the phenomenon.

7. CONCLUSION

This study aims to examine the stressors and coping strategies of teachers in a higher education setting as holding in-person classes has resumed as part of the new normal. Demands related to teaching as a job and other competing demands were identified as stressors when in-person classes resumed after two years of fully online teaching. Several strategies they used to cope with the demands of teaching in the new normal include seeking social support and adhering to self-care routines. Findings from this study can offer insights on how higher education institutions can better support their faculty in the new normal.

8. DECLARATION OF FUNDING AND COMPETING INTEREST

Funding was not received for this study. The authors have no competing interests to declare.

9. REFERENCES

- [1] J.A. Pacheco, "The 'New Normal' in Education", **Prospects**, Vol. 51, 2021, pp. 3-14.
- [2] S. Žižek, **PANDEMIC! COVID-19 Shakes the World**, New York: Or Books, 2020.
- [3] A. Bozkurt and R.C. Sharma, "Education in Normal, New Normal, and Next Normal: Observations from the Past, Insights from the Present, and Projections for the Future", **Asian Journal of Distance Education**, Vol. 15, No. 2, 2020, pp. i-x.
- [4] J.C.G. Corpuz, "Adapting to the Culture of New Normal: An Emerging Response to COVID-19", **Journal of Public Health**, Vol. 43, No. 2, pp. e344-e345.
- [5] J. Mananay, R. Alda, and M.S. Delos Santos, "Glimpses of Teaching in the New Normal: Changes, Challenges, and Chances", **International Journal of Learning, Teaching, and Educational Research**, Vol. 21, No. 4, 2022, pp. 276-291.
- [6] H. Onyeaka, C. Anumudu, Z. Al-Sharify, E. Egele-Godswill, and P. Mbaegbu, "COVID-19 Pandemic: A Review of the Global Lockdown and Its Far-Reaching Effects", **Science Progress**, Vol. 104, No. 2, 2021, pp. 1-18.
- [7] J.A. De Villa and F.K.B. Manalo, "Secondary Teachers' Preparation, Challenges, and Coping Mechanism in the Pre-Implementation of Distance Learning in the New Normal", **IOER International Multidisciplinary Research Journal**, Vol. 2, No. 3, 2020, pp. 144-154.
- [8] B.J. Tuga, J.V. Jocson, and R.A.S. Mabunga, "The Impact of COVID-19 on a Philippine University: Challenges and Responses Towards a New Normal", **AsTEN Journal of Teacher Education**, no. 1, 2021, pp. 8-13.
- [9] C. Rapanta, L. Botturi, P. Goodyear, L. Guardia, and M. Koole, "Balancing Technology, Pedagogy, and the New Normal: Post-Pandemic Challenges for Higher Education", **Postdigital Science and Education**, Vol. 3, pp. 715-742.
- [10] H. Cool, T. Apps, K. Beckman, and S. Bennett, "Digital Competence for Emergency Remote Teaching in Higher Education: Understanding the Present and Anticipating the Future", **Educational Technology Research and Development** Vol. 71, 2023, pp. 7-32.
- [11] A.B. Bakker and E. Demerouti, "The Job Demands-Resources Model: State of the Art", **Journal of Managerial Psychology**, Vol. 22, No. 3, 2007, pp. 309-328.
- [12] W.B. Schaufeli, "Applying the Job Demands-Resources Model: A How to Guide to Measuring and Tackling Work Engagement and Burnout", **Organizational Dynamics**, Vol. 46, 2017, pp. 120-132.
- [13] R.M. Ryan and E.L. Deci, **Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness**, New York: The Guilford Press, 2017.
- [14] R.M. Ryan and E.L. Deci, "Intrinsic and Extrinsic Motivation from a Self-Determination Theory Perspective: Definitions, Theory, Practices and Future Directions", **Contemporary Educational Psychology**, Vol. 61, 2020, pp. 1-11.
- [15] R.S. Lazarus and D. Folkman, **Stress, Appraisal, and Coping**, New York: Springer, 1984.
- [16] M.M. Matthieu and A. Ivanoff, "Using Stress, Appraisal, and Coping Theories in Clinical Practice: Assessment of Coping Strategies after Disasters", **Brief Treatment and Crisis Intervention**, Vol. 6, No. 4, 2006, pp. 337-348.
- [17] F. Klapproth, L. Federkeil, F. Heinschke, and T. Jungmann, "Teachers' Experiences of Stress and their Coping Strategies

- during COVID-19 induced Distance Teaching”, **Journal of Pedagogical Research**, Vol. 4, No. 4, 2020, pp. 444-452.
- [18] L.J. Sokal, L.G. Eblie Trudel, J.C. Babb, “Supporting Teachers in Times of Change: The Job Demands-Resources Model and Teacher Burnout during the COVID-19 Pandemic”, **International Journal of Contemporary Education**, Vol. 3, No. 2, 2020, pp.67-74.
- [19] M. Chan, J.D. Sharkey, S.I. Lawrie, D.A.N. Arch, and K. Nylund-Gibson, “Elementary School Teacher Well-Being and Supportive Measures Amid COVID-19: An Exploratory Study”, **School Psychology**, Vol. 36, No. 6, 2021, pp. 533-545.
- [20] L.E. Kim, L. Oxley, and K. Asbury, “My Brain Feels Like a Browser with 100 Tabs Open: A Longitudinal Study of Teachers’ Mental Health and Well-Being during the COVID-19 Pandemic”, **British Journal of Educational Psychology**, Vol. 92, 2022, pp. 299-318.
- [21] B. Klusmann, M. Trippenzee, M. Fokkens-Bruinsma, R. Sanderman, and M.J. Schroevers, “Providing Emergency Remote Teaching: What are Teachers’ Needs and What Could Have Helped Them to Deal with the Impact of the COVID-19 Pandemic?”, **Teaching and Teacher Education**, Vol. 118, 2022, pp. 1-10.
- [22] W.A. Edmonds and T.D. Kennedy, **An Applied Guide to Research Designs: Quantitative, Qualitative, and Mixed Methods**, California: SAGE Publications, Inc., 2017.
- [23] J.W. Creswell and C.N. Poth, **Qualitative Inquiry and Research Design: Choosing among Five Approaches**, California: SAGE Publications, Inc., 2017.
- [24] B. de Vera, “PH Economy Sinks Deeper into Recession”, **Philippine Daily Inquirer**, May 12, 2021 [Online]. Available: <https://business.inquirer.net/322729/ph-economy-sinks-deeper-into-recession>. [Accessed May 22, 2023].
- [25] C. Deiparine, “After 19 Months, Philippines Begins Gradual Return to Classrooms”, **Philippine Star**, November 15, 2021 [Online]. Available: <https://www.philstar.com/headlines/2021/11/15/2141445/after-19-months-philippines-begins-gradual-return-classrooms>. [Accessed May 22, 2023].
- [26] N.R. Wooten, N.M. Cavanagh, L.J. Cornelius, **Thematic Analysis of Guided Reflective Journal Narratives on HIV/AIDS in the Southern United States**, United Kingdom: SAGE Publications, Ltd., 2019.
- [27] P. Leavy, **Research Design: Quantitative, Qualitative, Mixed Methods, Arts-Based, and Community-Based Participatory Research Approaches**, New York: The Guilford Press, 2023.
- [28] J. Saldana, **The Coding Manual for Qualitative Researchers**, California, SAGE Publications, Inc., 2009.
- [29] V.N. Anney, “Ensuring the Quality of Findings of Qualitative Research: Looking at Trustworthiness Criteria”, **Journal of Emerging Trends in Educational Research and Policy Studies**, Vol. 5, No. 2, 2014, pp. 272-281.
- [30] M. Maguire and B. Delahunt, “Doing a Thematic Analysis: A Practical, Step-by-Step Guide for Learning and Teaching Scholars”, **All Ireland Journal of Teaching and Learning in Higher Education**, No. 3, 2017, pp. 3351-33514.
- [31] L.S. Nowell, J.M. Norris, D.E. White, N.J. Moules, “Thematic Analysis: Striving to Meet the Trustworthiness Criteria”, **International Journal of Qualitative Methods**, Vol. 16, 2017, pp. 1-13.
- [32] A. Padmanabhanunni and T. Pretorius, “I Teach, Therefore I Am: The Serial Relationship between Perceived Vulnerability to Disease, Fear of COVID-19, Teacher Identification, and Teacher Satisfaction”, **International Journal of Environmental Research and Public Health**, Vol. 18, No. 24, 2021, p. 13243.
- [33] A. Bray, J. Banks, A. Devitt, and E. Ni Chorcora, “Connection before Content: Using Multiple Perspectives to Examine Student Engagement during COVID-19 School Closures In Ireland”, **Irish Educational Studies**, Vol. 40, No. 2, 2021, pp. 431-441.
- [34] L.E. Robinson, A. Valido, A. Drescher, A.B. Woolweaver, D.L. Espelage, S. LoMurray, A.C. Long, A.A. Wright, and M.M. Daile, “Teachers, Stress, and the COVID-19 Pandemic: A Qualitative Analysis”, **School Mental Health**, Vol. 15, No. 1, 2023, pp. 78-89.
- [35] S. Cornell, B. Nickel, E. Cvejic, C. Bonner, K.J. McCaffery, J. Ayre, T. Copp, C. Batcup, J. Isautier, T. Dakin, and R. Dodd, “Positive Outcomes associated with the COVID-19 Pandemic in Australia”, **Health Promotion Journal of Australia**, Vol. 33, No. 2, 2022, pp. 311-319.
- [36] L.E. Kim, L. Oxley, and K. Asbury, “My Brain Feels Like a Browser with 100 Tabs Open: A Longitudinal Study of Teachers’ Mental Health and Well-Being during the COVID-19 Pandemic”, **British Journal of Educational Psychology**, Vol. 92, No. 1, 2022, pp. 299-318.
- [37] E. Demerouti and A.B. Bakker, “Job Demands-Resources Theory in Times of Crises: New Propositions”, **Organizational Psychology Review**, Vol. 0, No. 0, 2022, pp. 1-28.
- [38] D.G. Taylor and M. Frechette, “The Impact of Workload, Productivity, and Social Support on Burnout among Marketing Faculty during the COVID-19 Pandemic”, **Journal of Marketing Education**, Vol. 44, No. 2, 2022, pp.134-148.
- [39] P. Hidalgo-Andrade, C. Hermosa-Bosano, and C. Paz, “Teachers’ Mental Health and Self-Reported Coping Strategies during the COVID-19 Pandemic in Ecuador: A Mixed-Methods Study”, **Psychology Research and Behavior Management**, Vol. 14, 2021, pp. 933-944.

Uses of quantification and modelling category. The case of antimicrobial coating development.

Claudio GAETE-PERALTA

Departamento de Matemáticas y Ciencias de la Ingeniería, Universidad Bernardo O'Higgins
Santiago, 8320000, Chile

Katherine DELGADO

Facultad de Ingeniería, Ciencia y Tecnología, Universidad Bernardo O'Higgins
Santiago, 8320000, Chile

Jaime HUINCAHUE

Centro de Investigación de Estudios Avanzados del Maule, Universidad Católica del Maule
Talca, 3480005, Chile

ABSTRACT

In order to provide elements for the construction of reference frameworks that allow the educational community to value and recover the uses of mathematical knowledge of people that occur in specific situations in their daily life, the aim of this research was to analyse the uses of quantification that emerge in a specific situation of measurement by a professional community. To address this objective, the uses of quantification of a chemical engineer were analysed by means of a debate between performance and form in a specific measurement situation whose argumentation was given by the quantification of grams of additive necessary to elaborate an antimicrobial coating. The results of this research allowed to account for the uses of quantification that emerged by the chemical engineer in this specific measurement situation. Among the conclusions, this research allowed the identification of epistemological aspects and contextualised rationalities that emerged in this situation and that are expected to provide elements for the construction of this type of reference frameworks.

Keywords: Modelling category, Engineering, Antimicrobial coating, Measurement situation, Uses of quantification.

1. INTRODUCTION

One of the purposes of mathematics teaching is to achieve a link with reality [1, 2]. Parra-Sandoval and Villa-Ochoa [3] point out that attending to this link implies recognising the existence of mathematical knowledge that is not institutionalised and that is used in different situations in everyday life. However, when making this type of link, schools often resort to the development of stereotyped tasks whose realities turn out to be artificial [4] and contribute little to the achievement of the link at issue [5]. Moreover, the cultural conception of mathematics as an abstract and infallible discipline is a factor that further complicates the achievement of this link, as it recognises school mathematics as something untouched, where the student is usually limited to learning in a mechanical way, leaving aside the functionality of mathematical knowledge [6], understood as knowledge that is useful for people in situations of everyday life, work and profession [7].

Mendoza and Cordero [8] indicate that the teaching of mathematics, in addition to being distanced from everyday reality, ignores the uses of mathematical knowledge by people that occur in non-school scenarios, where functional justifications prevail that do not necessarily respond to logical-mathematical reasoning. In this regard, when we speak of functional justification, we refer to the fact that the mechanisms in which the uses of knowledge in specific situations are developed are functional, that is, the justification is based on what is useful to humans [9].

A frame of reference for school mathematics is understood as a construct from the socioepistemological theory [10] that points out the elements that comprise the different possible perspectives and configurations that indicate guidelines and trace explanations about the ways of constructing and disseminating the teaching and learning of mathematical knowledge [11]. Considering that idea, this research aims to provide elements for the construction of frames of reference that allow the educational community to value and recover the uses of mathematical knowledge of the people that occur in specific situations in which they are involved. Along these lines, the concept of mathematical modelling in education is an attractive tool to support the construction of this type of frame of reference. Within the different approaches that exist to carry out the study and development of the concept of mathematical modelling (for example, Borromeo [12]; Lesh and Caylor [13]; Lesh and Doer [14]; Rodríguez and Quiroz [15], among others), we find the category of modelling [16], which is positioned as a process focused on people's uses of mathematical knowledge that occur in specific situations in which they are involved. For this reason, the category of modelling will be developed in this research to provide elements for the construction of the required frame of reference.

The structure of this article is as follows: Section 2 will show the theoretical framework that will support this research, where the modelling category will be presented. In addition, the research objective will be stated in this section. Section 3 will show the methodology that will make it possible to respond to the stated objective. Section 4 will report on the analysis and results, and finally, in section 5, the conclusions of this research will be presented.

2. THEORETICAL FRAMEWORK

For the Socioepistemological Theory of Mathematics Education [10], a fundamental thesis to favour the learning of the meanings of mathematics is to know *the environment of reciprocal relations between mathematical knowledge and the reality of the learner* [2]. Socioepistemology focuses on studying people's uses of mathematical knowledge in specific everyday situations, in order, on the one hand, to recover the social character of mathematics, by focusing on the practices that regulate the social construction of mathematical knowledge [17], and, on the other, to contribute to a decentring of mathematical objects in the teaching of mathematics. It is important to highlight that, for socioepistemology, to speak of the social construction of mathematical knowledge refers to a notion that considers the interactions and processes of debate that communities experience, in order to carry out processes of institutionalisation of mathematical knowledge, together with its functionality in specific contexts and situations [6].

SOLTSA Programme

This research is framed within the socioepistemological programme called *Forgotten Subject and Transversality of Knowledge* (SOLTSA, acronym in Spanish), whose main objective is to reveal the uses of mathematical knowledge and its resignifications that emerge in the mathematical knowledge communities of people at school, at work or profession and in their daily lives, where the functionality of mathematical knowledge predominates. Regarding the *uses of mathematical knowledge*, these are understood as the organic functions of situations (functionings), which are manifested by the “tasks” that make up the situation, and forms of use that refer to the kind of those “tasks”. As for the tasks, these can be activities, actions, executions or alternations of domains proper to the organism of the situation [16]. When the alternation of tasks takes place, a new organic function originates, which debates with the forms of uses. This “act of use” is the *resignification of uses of mathematical knowledge* [9], which happen in specific situations that are part of that environment of reciprocal relations between mathematical knowledge and reality [18].

The argumentation of mathematical knowledge generated in a specific situation is a resignification of uses constructed in that situation, understanding by argumentation of mathematical knowledge the guiding thread of the specific situation from which mathematical knowledge emerges [6]. Additionally, these resignifications are also constructed when transversalities of uses of mathematical knowledge occur between domains of knowledge, understanding by transversality of uses the resignification of uses of mathematical knowledge between scenarios or domains of knowledge, for example, between school and work; or between mathematics and engineering [18]. In other words, when the functionings and forms of the uses of mathematical knowledge that occur in a specific situation S_{in} , proper to a domain knowledge D_n , debate with other functionings and forms that occur in a specific situation S_{jm} ($i \neq j$) proper to a domain S_{jm} ($i \neq j$) thus generating new resignifications of uses.

The modelling category

The modelling category [16] has been worked on in the SOLTSA programme as the use of mathematical knowledge in a specific situation [6]. Several researches have developed this category - that is, they have promoted a resignification of uses of mathematical knowledge - by analysing the uses of mathematical knowledge that emerge from people in different types of specific situations, as is the case of the uses of optimisation in selection situations [18], the uses of compensation in weighting situations [19], the uses of accumulation in situations of change [20], the uses of anticipation in situations of periodisation [21] (Pérez-Oxté, 2021) and the uses of behaviour reproduction in situations of transformation [22], among others. These investigations have provided elements to build reference frameworks that serve as a basis for the design of school situations that allow the educational community to promote, in the teaching of mathematics, the uses of mathematical knowledge that emerge from the people in specific situations in which they are involved. In order to develop the category of modelling, and thus provide elements for the construction of reference frameworks that serve as a basis for the design of this type of situation, the objective of this research is to analyse the uses of quantification that emerge in a specific situation of measurement by a professional community.

3. METHODOLOGY

Context and participants

Delgado [23] developed an antimicrobial additive through the incorporation of copper-based particles (see Figure 1). This additive has the potential to be incorporated in different types of surface coatings as a complementary measure in the prevention of different diseases caused by pathogenic microorganisms, for example, those diseases caused by coliform bacteria contamination.

The additive consists of a copper-based antimicrobial agent supported on zeolite. Zeolite is an organic material considered to be a *carrier* because of its ability to absorb or support other materials, where *carrier* means an inert material to which other materials are added (adsorbed, impregnated or coated). The antimicrobial additive is in powder form and can range in size from 20 to 100 microns.

In order to test the potential of this additive, a professional community working at a Chilean university participated in a research project to validate *in situ* the antibacterial properties of a commercial epoxy coating containing an antimicrobial additive. In particular, it was evaluated whether it would significantly reduce the amount of coliform bacteria present on the walls of the prison cells of a police station located in Santiago, Chile.

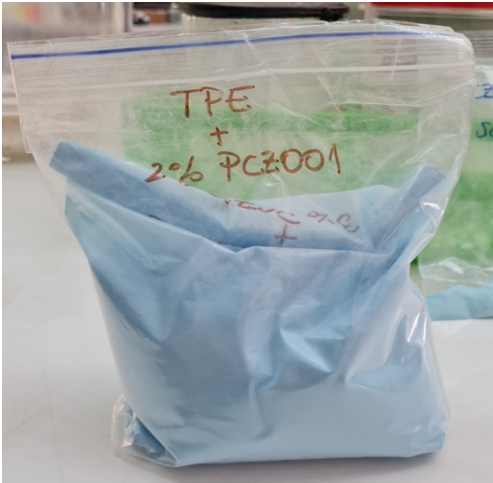


Figure 1. Antimicrobial additive used for the production of an antimicrobial coating.

An antimicrobial coating is the one that inhibits or eliminates the growth of bacteria adhering to its surface. To evaluate the antimicrobial activity of a coating it is necessary to quantify the number of bacteria adhering over time. If the number of bacteria decreases, it means that there is antimicrobial activity.

The professionals who were part of this community were four: a Civil Chemical Engineer with a PhD in Engineering Sciences, with specialisation in Materials Science (P1), a Chemical Engineer (P2), a Chemist with a PhD in Chemistry (P3) and a Biochemist with a PhD in Biotechnology (P4). The immersion with this community comprised four moments (M1, M2, M3, M4): M1: Preparation of an antimicrobial coating based on an antimicrobial additive, M2: Painting of the walls of the prison cells with an antimicrobial coating, M3: Sampling of coliform bacteria on the walls of the prison cells painted with an antimicrobial coating and M4: Counting of coliform bacteria. However, this research will report the uses of quantification that occurred during M1, which was conducted by P2. Specifically, this immersion was carried out in a specific measurement situation (situation in which we searched for measuring the amount, in grams, of additive needed to make an antimicrobial coating) which had the purpose of quantifying the grams of additive to be mixed with the grey oil-based coating¹ that came in a 20 litre bucket (see Figure 2), in order to transform it into an antimicrobial coating that could be applied to the walls of the police station's prison cells.

¹ This paint is traditionally used by Carabineros (Chilean national law enforcement police) to paint the walls of the police station's cells.



Figure 2. Paint used by Carabineros to paint the walls of the cells.

Data collection

During this immersion, data collection was carried out by means of: (a) audiovisual and photographic records to support the observation carried out by the researchers, (b) semi-structured interviews with the professionals in this community who participated in the process of making an antimicrobial coating, in order to better understand this process of elaboration. In order to avoid introducing possible obstacles to the objectivity of the data collected through the researchers' participation in this community, this research chose the researchers to play the role of observers [24]. However, according to Guber [25], the researchers took on the role of participants only when necessary and always remembering that their primary role was that of observers. The above allowed us to identify the routine situation where this community made use of quantification.

Data analysis

The uses of quantification that emerged in this specific measurement situation were analysed according to the analysis of uses of mathematical knowledge carried out in different socio-epistemological works (for example, see [18]; Opazo and Cordero [26]; Tuyub and Zapata [27]; Morales and Cordero [28], who carried out this type of analysis by means of a debate between functioning and form, where functioning responds to *what knowledge is used for* and form responds to *how knowledge is used* [29]).

4. ANALYSIS AND RESULTS

The preparation process of the antimicrobial coating was carried out in the chemistry laboratory of the university where the community professionals worked. To prepare the antimicrobial coating, P1, the project leader, decided that one kilogram of mixture should be made up of 95% paint and 5% additive. This percentage was determined on the basis of experience and the background of an investigation in which hospital intravenous poles (IV poles) were coated with paint containing 3% by mass of the antimicrobial additive, which did not result in a significant decrease in the number of bacteria [30]. Therefore, P1 decided that the 3% should be increased to 5%.

Based on this indication, P2 undertook to develop an antimicrobial coating. For this purpose, he made use of a

graduated glass container that allowed him to take out the paint in a smaller volume so that he could handle the paint more easily and comfortably. His initial idea was to take one litre of paint out of the bucket with this container, put it in another plastic container and there make one litre of antimicrobial coating, and then repeat this process 20 times in order to make 20 litres of antimicrobial coating. Before starting this process, P2 used an electronic balance to find out the mass of the plastic container, so that he could tare the mass. Thus, when calculating the mass of the plastic container with paint, the electronic balance would only indicate the mass of the paint and would not consider the mass of the plastic container. In this regard, P2 stated the following:

P2: This weighs 66.86 grams [referring to the plastic container] and what we are going to do is tare it, leave the balance at zero [grams] to eliminate the factor [referring to the mass of the plastic container] (see Figure 3).



Figure 3. Calculation of the mass of the plastic container on the electronic balance.

However, due to convenience, P2 decided to work with 800 ml instead of one litre, as otherwise he would stain his glove with paint and it would be uncomfortable for him to take the graduated glass container. In this regard, an extract of P2's statement is shown:

P2: We are going to leave it at 800 [ml] in fact...

Researcher: It's not going to be the litre any more?

P2: No...because otherwise it will touch my glove [referring to the paint] and make it dirty. We'd better use the 800 [ml] and then I can transfer it better (see Figure 4).



Figure 4. Using the glass container to remove 800 ml of paint.

Once the 800 ml of paint was placed in the plastic container, P2 proceeded to determine its mass using the electronic balance, determining that 800 ml of paint had a mass of 703.78 grams (see Figure 5).



Figure 5. Calculation of the mass of 800 ml of paint using an electronic balance.

To quantify the amount of grams of additive that should be in 703.78 grams of an antimicrobial coating, P2 made use of a simple rule of three, where he considered as 100% to 703.78 grams and as 5% to a x (amount of grams of additive), determining the latter equal to 35.189 grams (see Figure 6).

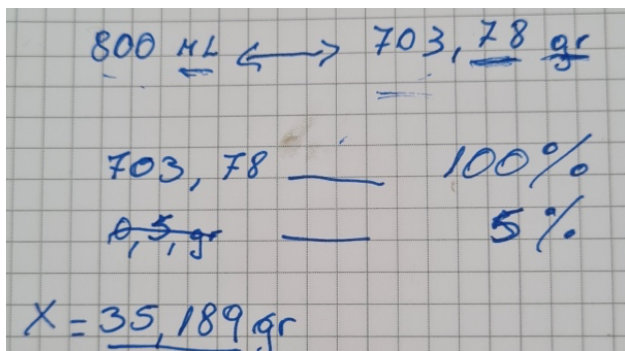


Figure 6. Quantification of the grams of additive to be used to make 800 ml of an antimicrobial coating.

The process of homogenising the mixture of the additive with the paint was first carried out manually and then mechanically, with the aid of mechanical stirrers operating at an average speed of 80 revolutions per minute for 10 hours (see Figure 7).



Figure 7. Use of mechanical stirrers to homogenise the mixture of the additive with the paint.

Once the homogenisation process was completed, P2 repeated this process 25 times to produce 20 litres of antimicrobial coating, which was subsequently used to paint the walls of the police station cells.

This specific situation corresponded to a *measurement situation* as it sought to measure the amount of grams of additive to be used to prepare 20 litres of antibacterial coating. Table 1 shows a use of P2 quantification in this specific measurement situation.

Table 1. Uses of P2 quantification.

| | |
|--|---|
| Functioning of the use of quantification (<i>what is quantification used for?</i>) | To determine the amount of grams of additive to be used to make 800 ml of an antimicrobial coating. |
| Form of the use of quantification (<i>how is quantification used?</i>) | By means of a simple rule of three. |

5. DISCUSSIONS AND CONCLUSIONS

The modelling category emerged in this research as the use of quantification by P2 in this specific measurement situation. The common thread of this situation that allowed the mathematical knowledge to emerge was given by the quantification of the grams of additive that were necessary to elaborate an antimicrobial coating. This allows us to point out that the argumentation generated from this specific measurement situation was given by the quantification, which in turn is a resignification of uses constructed in this situation.

This research provides elements to understand the mathematical knowledge that emerges from specific communities based on their functionality. The emphasis was not on paying attention to what people in the communities do not know and should learn, but on what they do, how they do it and what they do it for. The emphasis is then on the uses of mathematical knowledge put into play in this specific situation and not on the mathematical objects. In particular, this research has made it possible to identify epistemological aspects and contextualised rationalities that emerged in this situation and which are expected to provide elements for the construction of frames of reference that will allow the educational community to value and recover the uses of quantification that emerge from people in specific measurement situations. This idea will be possible by designing school situations that, once implemented in mathematics classes, can contribute to transforming school mathematics with the aim of generating a reciprocal relationship between people's daily lives and school mathematics, taking into account the functionality of mathematical knowledge.

6. ACKNOWLEDGEMENTS

Proyecto Fondecyt de Iniciación n° 11220346 and Proyecto Fondecyt de Iniciación n° 11201103.

7. REFERENCES

- [1]F. Cordero, **Modelación, funcionalidad y multidisciplinaridad: el eslabón de la matemática y el cotidiano**, In J. Arrieta & L. Díaz (Eds.), Investigaciones latinoamericanas de modelación de la matemática educativa, Barcelona: Gedisa, pp. 59-88, 2016.
- [2] F. Cordero, **La función social del docente de matemáticas: pluralidad, transversalidad y reciprocidad**, In S. Estrella, M. Goizueta, C. Guerrero, A. Mena-Lorca, J. Mena-Lorca, E. Montoya, A. Morales, M. Parraguez, E. Ramos, P. Vásquez & D. Zarkaryan (Eds.), **XX Actas de las Jornadas Nacionales de Educación Matemática**, Valparaíso: Sochiem, pp. 23-30, 2016.

- [3] H. Parra-Sandoval & J. Villa-Ochoa, “Vinculación de las Matemáticas con la realidad. Implicaciones en la conformación del pensamiento profesional del docente”, *Revista Paradigma*, Vol. XXXVIII, 2017, pp. 288-311.
- [4] C. ALSINA, “Si Enrique VIII tuvo 6 esposas, ¿cuántas tuvo Enrique IV? El realismo en Educación Matemática y sus implicaciones docentes”, *Revista Iberoamericana de Educación*, Vol. 43, 2007, pp. 85-101.
- [5] J. Villa-Ochoa, “Modelación matemática a partir de problemas de enunciados verbales: un estudio de caso con profesores de matemáticas”, *Magis*, Vol. 8, No.16, 2015, pp. 133-148.
- [6] F. Cordero, K. Gómez, H. Silva-Crocci & D. Soto, *El discurso matemático escolar: la adherencia, la exclusión y la opacidad*. Ciudad de México: Gedisa, 2015.
- [7] H. Arendt, *La condición humana*, Barcelona: Paidós, 2005.
- [8] J. Mendoza & F. Cordero, “La modelación en las comunidades de conocimiento matemático. El uso de las matemáticas en ingenieros biónicos. El caso de la estabilidad”, *Revista Latinoamericana de Etnomatemática*, Vol. 11, No. 1, 2018, pp. 36-61.
- [9] F. Cordero & F. Flores, “El uso de la gráfica en el discurso matemático escolar. Un estudio socioepistemológico en el nivel básico a través de los libros de texto”, *Relime*, Vol. 10, No. 1, 2007, pp. 7-38.
- [10] R. Cantoral, *Teoría Socioepistemológica de la Matemática Educativa*, Ciudad de México: Gedisa, 2013.
- [11] K. Gómez, *El fenómeno de la opacidad y la socialización del conocimiento. Lo matemático de la Ingeniería Agrónoma* (Doctoral Thesis), CINVESTAV-IPN, México, 2015.
- [12] R. Borromeo, “Theoretical and empirical differentiations of phases in the modeling process”, *ZDM Mathematics Education*, Vol. 38, No. 2, 2006, pp. 86-95.
- [13] R. Lesh & B. Caylor, “Introduction to the special issue: Modeling as application versus modeling as a way to create mathematics”, *International Journal of Computers for Mathematical Learning*, Vol. 12, 2007, pp. 173-194.
- [14] R. Lesh & H. Doerr (Eds.), *Beyond Constructivism – Models and Modeling Perspectives on Mathematics Problem Solving, Learning and Teaching*, Mahwah: Lawrence Erlbaum, 2003.
- [15] S. Rodríguez & S. Quiroz, S, “El papel de la tecnología en el proceso de modelación matemática para la enseñanza de las Naciones diferenciales”, *Relime*, Vol. 19, No. 1, 2006, pp. 99-24.
- [16] F. Cordero, J. Mendoza-Higuera, I. Pérez-Oxté, J. Huincahue & J. Mena-Lorca, *A Category of Modelling: The Uses of Mathematical Knowledge in Different Scenarios and the Learning of Mathematics*. In: M. Rosa, F. Cordero, D. Orey & P. Carranza, (Eds.), *Mathematical Modelling Programs in Latin America* (pp. 247–267), Springer, 2022.
- [17] R. Cantoral, D. Reyes-Gasperini & G. Montiel, “Socioepistemología, Matemáticas y Realidad”, *Revista Latinoamericana de Etnomatemática*, Vol. 7, No. 3, 2014, pp. 91-116.
- [18] F. Cordero, T. Del Valle & A. Morales, “Usos de la optimización de ingenieros en formación: el rol de la ingeniería mecatrónica y de la obra de Lagrange”, *Relime*, Vol. 22, No. 2, 2019, pp. 185–212.
- [19] D. Medina, *Transformación educativa del docente de matemáticas. Un episodio: El uso de la compensación como una resignificación de la media aritmética* (Doctoral Thesis), CINVESTAV-IPN, México, 2019.
- [20] S. Marcía, *Resignificación de la integral en una comunidad de estudiantes de docencia de la matemática. una categoría de acumulación y la perspectiva de identidad disciplinar* (Master's Thesis), CINVESTAV-IPN, México, 2020.
- [21] I. Pérez-Oxté, *Anticipar-periodizar: una socialización de saberes matemáticos entre la Ingeniería y la docencia* (Doctoral Thesis), CINVESTAV-IPN, México, 2021.
- [22] F. Giacoletti-Castillo, *La temporalización y la tendencia como factores funcionales de la reproducción de un comportamiento continuo a partir de discontinuos. Una resignificación de la Transformada de Laplace en un sistema de control* (Master's Thesis), CINVESTAV-IPN, México, 2020.
- [23] K. Delgado, *Estudio de la obtención de compósitos con propiedades antimicrobiales y antifouling formados por una matriz polimérica y nanopartículas a base de cobre* (Doctoral Thesis), Universidad de Chile, 2013.
- [24] L. Holy, *Theory, Methodology and Research Process*, In E. Roy (Ed.), *Ethnographic Research. A Guide of General Conduct* (pp. 13-34), London: Academic Press, 1984.
- [25] Guber, R. *La etnografía. Método, Campo y Reflexividad*, Buenos Aires: Siglo veintiuno, 2011.
- [26] C. Opazo & F. Cordero, “Estudiante de docencia en matemáticas y la construcción de la identidad disciplinar”, *Estudios Pedagógicos*, Vol. 47, No. 1, 2021, pp. 109–131.
- [27] I. Tuyub & Y. Zapata, “Una epistemología de usos de la composición de funciones en una comunidad de ingenieros civiles”, *Acta Latinoamericana de Matemática Educativa*, Vol. 33, No. 2, 2020, pp. 595-605.
- [28] A. Morales & F. Cordero, F, “La graficación-modelación y la Serie de Taylor. Una socioepistemología del Cálculo”, *Relime*, Vol. 17, No. 3, 2014, pp. 319-345.
- [29] T. Parra T & C. Méndez, *Ejemplos de metodologías de investigación que discuten sobre el papel de la diversidad en la Matemática Educativa*. In F. Cordero (Ed.), *La Matemática Educativa y Latinoamérica. Un diálogo entre programas de investigación: Chile y México* (pp.151-171), Gedisa, 2021.
- [30] H. Palza, M. Nuñez, R. Bastías & K. Delgado, “In situ antimicrobial behavior of materials with copper-based additives in a hospital environment”, *International Journal of Antimicrobial Agents*, Vol. 51, No. 6, 2018, pp. 912-917.

A Mathematical-Logic Technique Facilitating Good Teaching

Russell Jay HENDEL

Department of Mathematics, Towson University

Room 316, 7800 York Road

Towson, Maryland, 21252

RHendel@Towson.Edu

ABSTRACT

This paper presents a teaching strategy for topics in undergraduate courses which require simultaneous consideration of several parameters. Such topics present several challenges: i) initial learning is difficult because of the multiple issues (parameters) that must be checked, ii) covering all cases can leave students confused, leading to omission of certain details, iii) it is not clear what presentation vehicle is best for learning. This paper proposes a mathematical-logic technique, the prime implicant normal form, PINF, to address these problems. The PINF method can easily be mastered without technical knowledge. Familiar examples are provided from Statistics and English Grammar. A survey of alternate presentation methods, gleaned from a simple Google search, reveals several advantages of using the PINF method.

Keywords: prime implicant normal form, instructional design, good pedagogy, normal distribution, student t distribution, relative pronouns, matrix organizers, tables,

1. BACKGROUND and GOALS

Recall, that pedagogy theory teaches that identical content can be delivered by different vehicles, with some vehicles excelling over others in facilitating student learning and retention.

Perhaps the simplest illustration of a pedagogically superior presentation method is the use of graphical organizers such as tables or matrix displays [10, 11, 17]. Although a bulleted list can present *the same information* as the table, the table provides quicker *access* to contrasts and comparisons, because it displays more relationships. Hence, it is superior for presentation.

This paper presents a superior teaching method motivated by a technique of mathematical logic, the *prime-implicant normal form*, PINF, of Boolean algebra. This method is particularly useful when a course topic requires simultaneous consideration of multiple parameters. The capacity of PINF to facilitate student learning and retention is just as powerful as the use of graphic organizers but not as commonly known.

To illustrate the pedagogic superiority of this technique we select two undergraduate topics, one from statistics (Section 2) and the second from English grammar (Section 4). Contrastive to traditional textbooks and online teaching resources which present either by using bulleted lists, complicated flowcharts, or omitting cases (Section 3), the PINF is comprehensive, more compact, and clearer. The paper concludes by advocating that instructors incorporate the PINF technique into their courses (Section 5).

2. NORMAL, t, or PARAMETRIC DISTRIBUTIONS

2.1 Background: Statistics deals with making valid inferences from a sample obtained from a population. Typically, a sample statistic is computed, for example, the average or proportion of the particular sample studied. Statistics then informs you how confident you can be that the corresponding population statistic is within a certain margin of error from the sample statistic. In making this inference, the analyst must make computations with certain standard distributions. The three most frequently used methods used in making inferences from a sample to a population are i) the normal distribution, ii) the student *t*-distribution, and iii) non-parametric methods. Therefore, the analyst needs a *decision rule* by which to select the appropriate method. This entire theory is well understood and presented in numerous textbooks which typically service introductory statistic courses [5, 18].

Using the PINF technique, Section 2.2 presents a decision rule for how to select the appropriate one of these three methods. Section 2.3 is easy to follow; Section 2.3 explains the approach of the underlying PINF technique used without requiring familiarity with technical mathematical-logic. Section 3 then compares the PINF technique advocated by this paper with several alternative presentation vehicles.

2.2 The Decision Rule: Table 1, constructed with the PINF technique, compactly presents the decision rule for which of the three methods to use. To arrive at a conclusion of which distribution to use (last column), the table requires simultaneous consideration of several parameters, or attributes, of the given sample and the underlying population.

| Is the sample size large? (i.e., at least 30 (See Section 2.4)) | Is the population normally distributed? | Is the population variance known? | Then use the following distribution |
|---|---|-----------------------------------|-------------------------------------|
| Yes | | | Normal |
| | Yes | Yes | Normal |
| No | Yes | No | Student t |
| No | No | | Parametric |
| No | | No | Parametric |

Table 1: The PINF approach to choosing the correct method by which to make inferences from a sample.

Although Table 1 should be self-explanatory, we review the first two rows to fully clarify its meaning.

- **Row 1:** The first question to consider is whether the sample

size is large (Column 1). If it is, no other questions need be asked; one should use the normal distribution (last column).

- Row 2: If the answer to the following two questions is, "Yes",
 - Is the population known to be normal? (Column 2)
 - Is the variance of the population known? (Column 3),
 then we use the normal distribution to make inferences (last column).

2.3 PINF: To clarify the PINF technique used in Table 1, we contrast it with the *disjunctive normal form* taught in mathematic logic courses. These courses traditionally use a *truth table*. The truth table would contain one column for each question asked. In the example studied in this section we consider three questions, i) Is the sample large? ii) Is the population normal? iii) Is the variance of the population known? as shown in the first three columns of Table 1.

Notice that each of these three questions has a *yes* or *no* response. The disjunctive normal form requires that the *truth table* contains all eight possibilities of *yes* and *no*, each possibility presented in a separate row. For each row, the table then indicates whether the method is normal, *t*, or parametric.

The contrast to the disjunctive normal form introduced by the PINF table is that blank cells are allowed which contain neither *yes* nor *no*. We can illustrate this with the first row of Table 1. The disjunctive normal form would require the following four rows to replace the first row of Table 1.

| Is the sample size large? (usually bigger than 30; but other numbers are possible) | Is the population normal? | Is the population variance known? | Then use the following distribution |
|--|---------------------------|-----------------------------------|-------------------------------------|
| Yes | No | No | Normal |
| Yes | No | Yes | Normal |
| Yes | Yes | No | Normal |
| Yes | Yes | Yes | Normal |

Table 2: The first row of Table 1 would require the four rows of Table 2 if disjunctive normal form were used.

By comparing Table 2 with the first row of Table 1 we immediately see the advantage of PINF. The PINF table focuses on what drives use of the normal form, namely *largeness* of the sample. Contrastively, Table 2 is too busy; it overwhelms the reader, not allowing such a focus.

This example illustrates *how* an instructor can construct a PINF table: i) First gather all rules, ii) next list all questions, issues, or parameters that must be asked, iii) assure that each of these questions has simple *yes-no* responses, iv) list all known rules in a table, v) then, if not already done, reduce redundant rows and information in the table by leaving certain cells blank.

2.4 A Technical Comment: Because the purpose of this paper is presentation of the PINF method, it abstains from making excessively technical statistical points. We illustrate such omissions with one subtlety. In an actual course such subtleties would, of course, be mentioned. Table 1 requires ascertaining whether a sample is *large*. Typically, textbooks will suffice with classifying a sample as *large* if it has 30 or more elements. The reason for this is that for samples of 30 or more elements, the

student *t* and normal distribution are very close in numerical value; hence, using either one is appropriate.

But this argument is only valid when the desired significance level is the typical 5%, that is, when one wishes to be 95% confident that the sample is predictive of the population. For some applications, a 99% or even a 99.99% confidence level may be desired. For these applications, the cutoff point for classifying a sample as large would be bigger than 30. However, as remarked, this is a very technical point and need not concern us further in this paper.

3. ALTERNATIVE FORMULATIONS

To defend the superiority of the PINF teaching delivery method, alternate approaches to the decision rule for sampling were randomly obtained, in March 2023, by a simple Google search, using the search phrase "when to use the normal vs. *t* distribution" (including "parametric distribution" in the search phrase did not significantly change the search results). Several alternate approaches were obtained [2, 3, 7, 9, 13, 20], some from university websites, some from online tutorials, and some from expository articles in refereed journals; these sources were supplemented with two textbooks [5,18].

The alternate approaches were qualitatively inferior; they frequently omitted cases, omitted parameters, or presented the decision rule in stages leading to unintended contradictory statements of the decision rule.

Rather than review each source by itself, we summarize several repeating issues.

Issue #1: A Contrastive Narrative Style: A contrastive style is easy to retain but may omit information. Two examples of contrastive styles are the following:

- (1) For large samples use normal; for small samples use *t*.
- (2) When the variance is known use normal; if unknown use *t*.

Although (1) and (2) are useful rules of thumb, they are not complete. For example, both formulations leave out the critical information that one should not use the *t*-distribution unless the population is known to be normal.

Issue #2: A Development Style: Some narratives *develop* the complete set of decision rules over several pages. This development may begin with a contrastive style like (1) or (2) and then, in a later paragraph, remark that other requirements (such as normalcy of a population) are needed.

While such a development style is easier to read than a table, it presents multiple statements which, if read alone, are contradictory, the initial statement being too simple and the final statement being correct, albeit technical. This can easily confuse a student that has before him or her two formulations.

One simple remedy to this is to *supplement* narrative development styles with a summary such as Table 1. This has the advantage of providing a one-stop complete set of rules (the table) but developing the ideas at a leisurely pace which helps weaker students.

Issue #3: Confusing Logical Connectives: The *exportation* law of classical logic states that the following two formulations of

an abstract rule are equivalent.

(3) If both (A) and (B) are true then do (C)

(4) If (A) is true then we consider further cases. If (B) is true, then do (C).

Formulation (4) is appealing when presenting rules using a nested bulleted list. The main (outer) bullets could present *variance known* and *variance unknown*. The sub-bullets of *variance unknown* could then present the cases of the *sample large* or *not large*.

But formulation (4) which fits in with a nested-bulleted-list presentation is harder to read than formulation (3). In fact, one point of the exportation law is that very often a reader will *understand* (4) by first reformulating it as (3).

An additional point in comparing nested bulleted lists with tables, is, as pointed out earlier, that tables are superior since they facilitate comparisons and contrasts [10, 11, 17].

Issue #4: Lack of Completeness: One should be careful in a critique of lack of completeness. A textbook or handout could, for example, argue that its purpose is to discuss particular methods such as normal and *t*. In such a case, an omission of mention of parametric methods may appear defensible.

We therefore formulate completeness as *completeness relative to the parameters the narrative introduces to describe the decision rule*. Table 1 illustrates this approach: The table requires consideration of three issues, i) whether the underlying population is normal, ii) whether the population variance is known, and iii) whether the sample size is large. Consequently, *completeness* of a decision rule requires that the decision rule lays down what happens in each combination of these three requirements. It immediately follows that, *based* on its choice of parameters, the narrative explicitly requires a discussion of the non-parametric approach: when the sample size is small, and the population is not normal.

It is interesting that some undergraduate textbooks or courses, *by design*, omit parametric methods from introductory statistics courses. Fortunately, some recent textbooks remedy this problem by providing appropriate material [18].

The author's practice, when teaching from a curriculum not requiring teaching parametric methods, is to point out that the correct response to a question where the population is not normal and the sample size is small is, "This question cannot be answered by the methods of this course."

It is noteworthy, that even though students are explicitly told that at least one question on examinations cannot be approached through the normal and *t* distributions, weaker students, typically get these questions incorrect; they approach these problems using the normal and *t* distributions without first applying the decision rules presented in Table 1 to ascertain what method should be used. This anecdote points to the challenge in teaching material based on multiple parameters: such material lends itself to avoidance of certain cases by weaker students.

In summary, the PINF has a variety of nice attributes:

- ✓ It is complete
- ✓ It is brief and compact

- ✓ It is readable
- ✓ It does not contain any redundant information.

The author's experience with the PINF is that it is superior for instruction, retention, and learning. While flowcharts are also complete [5], the flowchart is somewhat overwhelming, lacks compactness, and cannot easily be learned. Flowcharts are typically only useful when considering one path in the flowchart. Additionally, the author has found the PINF approach useful for remediation. The author explains to a weaker student who confuses rules that their problem is not mathematical but logical. Many of these students have never seen a multiple-parameter rule. Such a remediation approach can help some of the weaker students.

4. RELATIVE PRONOUNS

This article includes examples from disparate disciplines, Mathematics and English, in order to emphasize the cybernetic nature of the material presented. Cybernetics is intrinsically multi-disciplinary, since in its essence, it refers to the flow and organization of information *independent of content* [21]. The cybernetic flavor of this article helps the reader focus on the abstract Boolean nature of the PINF format advocated.

4.1 Rules Governing the Five Definite Relative Pronouns:

The topic of *definite relative pronouns* was selected for this paper's second example for a variety of reasons. i) There are only five definite relative pronouns in English: *that*, *who*, *whom*, *which*, *whose*. (Occasionally, but not always, *where*, *when*, *why* can also function as relative pronouns. There are also indefinite relative pronouns: *whoever*, *whomever*.) ii) Despite the small number of definite relative pronouns, the theory is rich and nuanced; even experienced native speakers can get caught in errors.

4.2 The Rules and Their PINF: Table 3 compactly presents i) the rules, ii) the parameters driving them, and iii) illustrative examples. The following explanatory comments clarify further:

- For purely formatting reasons the following abbreviations are used in order to fit the table to the page: *sub* refers to a case where the relative pronoun is the *subject* of the clause it heads; *obj* refers to a case where the relative pronoun is the *direct object* of the verb of the underlying sentence; *prep.* refers to a relative pronoun in a *prepositional* clause. Similarly, the *who* and *who(m)* rules in the row for *object with preposition at end*, are combined (again for purely formatting reasons).
- Table 1 listed questions in the column headers and responses to these questions, yes or *no*, in the cells. Because of the complexity of the relative pronoun rules a slightly different format is used here. For example, Row 1 presents two rules: *if the subject of the sentence is a person*, then the rule requires using *who* or *that*, while *if the subject of the sentence is an impersonal object* the rule requires using *which* or *that*. This reflects the fact that the question or issue, *what is the type of the subject?* is answered with the two possibilities *people* or *objects*.
- Illustrative examples follow each rule. For example, the sentences *I praised the student who got A*, *I praised the student that got A*, and *I praised the student getting an A* are all examples where the relative pronoun (*who*, *that*, or *blank*) is the subject of the sentence clause it is connected with (*The student got A*).

| Case | For People | Examples (people) | For Things | Examples (Things) |
|-------------------------|------------------------------|--|------------------------|--|
| Sub. | WHO THAT | 1) I praised the student WHO earned A 2) I praised the student THAT earned A | WHICH THAT | 1) I praised the grades WHICH were all A 2) I praised the grades THAT were all A |
| Obj | WHO THAT BLANK | 1) I praised the student WHO got A 2) I praised the student THAT got A 3) I praised the student ___ getting A | WHICH THAT BLANK | 1) The grades WHICH I praised were A-s 2) The grades THAT I praised were A-s 3) The grades ___ I praised were A-s |
| Obj., Prep. at end | WHOM WHO THAT BLANK | 1-2) This is the student WHO(M) I gave A TO 3) This is the student THAT I gave A TO 4) This is the student ___ I gave A TO | WHICH THAT BLANK | 1) This is the report WHICH I recorded A-s on 2) This is the report THAT I recorded A-s on 3) This is the report ___ I recorded A-s on |
| Obj., Prep. at begin | WHOM | This is the student TO WHOM I gave A | WHICH | This is the report ON WHICH I placed A |
| Possessive | WHOSE | This is the student WHOSE grade is A | WHOSE | This is the report WHOSE grades are all A-s |

Table 3: The decision table, with examples, for definite relative pronouns.

• As can be seen, the rules are similar for some columns (for example, *who*, *that*, and *blank* (pronoun absence) occur with variations in several rows). Understanding such associations facilitates student learning, retention, and avoidance of error. As indicated in Section 1, *table format*, is superior to the *list format* in communicating such associations.

4.3 Comparisons with Alternative Rule Presentations: As done for the statistics rule presented in Section 3, a Google search, using the search phrase “the rules governing relative pronouns” was made in March 2023 leading to a variety of online sources, from universities and online tutorials [4, 6, 14, 15, 16]. These, sources, supplemented with one textbook, [1], were compared and contrasted. Rather than review each source, certain general tendencies are summarized.

- **Use of Tables vs. lists:** Both list and table formats are used.
- **Incompleteness:** Certain minutiae in the table are overlooked by some sources. For example: i) the use of *whom* and *who* for the case of *object of a verb* is overlooked in some sources; contrastively, some sources correctly note that use of *whom* vs. *who* corresponds to proper usage in formal vs. conversational English; ii) The *blank* rule (permissibility of absence of a relative pronoun) is sometimes omitted; and iii) The dependency for the object-preposition case on whether the preposition is placed prior to the relative pronoun or after it is also sometimes omitted. In general, rules that require introduction of extra parameters tend to be omitted.
- **Integrated Rules:** Table 2 assumes student familiarity with identifying the relative pronoun as being a subject, object, or indirect object (object of a preposition). Contrastively, some sources integrate the rules for syntactical recognition with the relative pronoun usage. Integration of modules, particularly, when there is a review and reference to a prior module, is good pedagogical practice and facilitates avoidance of silo effects where each rule stands by itself without its relationship to other rules.
- **Integration Presentation of Examples and Rules:** Table 2 integrates the presentation of rules and examples. This is a superior pedagogic practice. Some sources adopt this practice; other sources give preference to spreading out the statement of rules by studying examples after each individual rule statement.
- **Additional Elaborations:** One source explicitly notes that pronouns that refer to animals are treated the same way as pronouns referring to inanimate things. It is a matter of taste, and dependent on the target student population, to what extent an instructor wishes to emphasize these subtleties.

5. CONCLUSION

This paper has presented best practices of teaching delivery when a multi-parameter rule is present. These best practices are formulated with the mathematical logic concept of the Prime Implicant Normal Form, PINF. Examples using PINF are presented from disparate disciplines and compared to a variety of alternative presentations currently being used. The comparative analysis shows that the PINF technique: i) facilitates completeness of rules without omissions, ii) avoids narrative styles that are not conducive to presenting multi-parameter rules, iii) provides clearer logical statements, and facilitates student learning and retention, and iv) is easy to learn, master, and apply.

It is hoped that this modest presentation will suffice to inspire instructors to use this technique in their courses.

Acknowledgements: Acknowledgement is given to Professor Michael Krach for a careful reading of the manuscript.

6. REFERENCES

- [1] Azar, Betty & Hagen, Stacy, **Fundamentals of English Grammar Workbook with Answer Key**, (5th ed), N.Y., NY & London, UK: Pearson Education ESL, 2019
- [2] Bevans, R., “T-Distribution | What It Is and How To Use It (With Examples)”, **Scribbr.**, 2022, Retrieved March 13, 2023, from <https://www.scribbr.com/statistics/t-distribution/>
- [3] Brereton, Richard G., “The t-distribution and its relationship to the normal distribution,” **Chemometrics**, 29(9), 2015, 481—483
- [4] Collins Dictionary, “How do you use the relative pronouns who, whom, which, and that?”, **Easy Learning Grammar**, retrieved from <https://grammar.collinsdictionary.com/us/easy-learning/how-do-you-use-the-relative-pronouns-who-whom-which-and-that> on March 14, 2023
- [5] Daniel, Wayne, W. & Cross, Chad L, **Biostatistics: A Foundation for Analysis in the Health Sciences**, (11 ed.), Hoboken, NY: Wiley, 2018.
- [6] Davidson, Misty, “Relative Pronouns In English, Who, Whom, Whose, That, And Which,” **Learning English**, 2018, Retrieved from <https://commongroundinternational.com/learning-english/relative-pronouns-who-whom-whose-that-which/> on March 14, 2023
- [7] DePaul University, **When to Use the t-Distribution vs. the Normal Distribution for Confidence Interval and Hypothesis Testing Problems for Means**, Retrieved from <https://condor.depaul.edu/ntomuro/courses/IT403/notes/NormalVersusTdistribution.pdf> on 3/14/2023
- [8] Ferdjallah, Mohammed. 2011. **Introduction to Digital Systems Modeling Synthesis and Simulation using VHDL**, (Chapter 6), Hoboken, NJ: John Wiley & Sons.
- [9] Hayes, Adam, “What Is t-Distribution in Probability? How Do You Use It?” **Investopedia**, 2022, Retrieved from <https://www.investopedia.com/terms/t/distribution.asp>, on 3/14/2023
- [10] Hendel, Russell Jay, “Goal Setting and Executive Function Using Matrix Graphic Organizers,” **Journal of Systemics, Cybernetics and Informatics (JSCI)**, 18(6),2020, 8--14.
- [11] Hendel, Russell Jay, “Enhancing the Pedagogical Utility of Tables in Actuarial Teaching,” **Expanding Horizons**, June 2021 Accessible at <https://www.soa.org/sections/education-research/education-research-newsletter/2021/june/ehn-2021-06-hendel/>
- [12] Instructional Design Central, **Instructional Design Definitions**, retrieved from <https://www.instructionaldesigncentral.com/whatisinstructionaldesign> on March 14, 2023
- [13] JMP (John’s Macintosh Project), “The t-Distribution“, **Statistics Knowledge Portal**, retrieved from https://www.jmp.com/en_us/statistics-knowledge-portal/t-test/t-distribution.html on 3/14/2023
- [14] LessonsforEnglish.Com, **Relative Pronouns Who, Whom, Which, Why, When, Where, Whose**, Retrieved from <https://lessonsforenglish.com/pronouns/relative-pronouns-who-whom-which-why-when-where-whose-that/> on March 14, 2023
- [15] MyEnglishPages.Com, **What’s The Difference Between Who, Whom, And Whose?**, Retrieved from <https://www.myenglishpages.com/english/grammar-lesson-difference-between-who-whom-whose.php> on March 14, 2023
- [16] Purdue University Online Writing Lab, **Introduction and General Usage in Defining Clauses**, Retrieved from https://owl.purdue.edu/owl/general_writing/grammar/relative_pronouns/index.html on March 14, 2023
- [17] Robinson, Daniel H., and Kenneth A. Kiewra, “Visual Argument: Graphic Organizers Are Superior to Outlines in Improving Learning from Text”. **Journal of Educational Psychology**, 87(3), 1995. 455–467. <https://doi.apa.org/doiLanding?doi=10.1037%2F0022-0663.87.3.455>
- [18] Schinzai, Rinaldo B., **Probability with Statistical Applications** (3rd ed.) Basel, Switzerland: Birkhauser, 2022
- [19] Statology, **Normal Distribution vs. t Distribution: What’s the difference?** Retrieved from <http://statology.org/normal-distribution-vs-t-distribution>, on 3/14/2023.
- [20] Datascience Stackexchange, “**When to use t-distribution instead of normal distribution?**” Retrieved from <https://datascience.stackexchange.com/questions/62958/when-to-use-t-distribution-instead-of-normal-distribution>, on 3/14/2023
- [21] Umpleby, Stuart. **Definitions of Cybernetics**, 2000, Retrieved from <https://asc-cybernetics.org/definitions/> on March 14, 2023

Refining the Art of Judgment Education: Evaluation of an educational case study on making judgments about the pros and cons of COVID-19 vaccination during the pandemic

Ariyoshi KUSUMI

Faculty of Liberal Arts and Sciences, Chukyo University
Nagoya, Aichi 4668666, JAPAN

Yasukazu HAMA

Independent Scholar
Sagamihara, Kanagawa 2520143, JAPAN

ABSTRACT

We discussed the form of education that fosters rational judgment based on the selection and prioritization of a large amount of information. Specifically, we developed a lesson plan for fostering judgment skills focused on the theme of the pros and cons of COVID-19 vaccination for prevention. We sorted out the twelve requirements for classes from three perspectives: education for fostering judgment, risk education, and critical thinking education. Based on the extent to which the twelve requirements were reflected in the course design, the course was evaluated on two aspects: "A: education that promotes subjective judgment without scientific or logical errors" and "B: education to achieve desirable judgment through communication." As a result, it was evident from the questionnaire survey evaluation that B was sufficiently achieved. On the other hand, the effectiveness of A resulted in different outcomes between student questionnaire survey evaluations and instructor assessments of the reports. In other words, while the student survey indicated sufficient achievement, the instructor evaluation indicated that it was not sufficient. From this, it is inferred that some simplification is important at least as an educational practice in this university.

Keywords: education to foster judgment skills, COVID-19, critical thinking, risk education

1. INTRODUCTION

In modern society, we are exposed to a vast amount of information and are required to make judgments based on our understanding and selection of that information. To make a judgment that aligns with our desired results, we now need to understand a significantly larger amount of information than before, to choose or discard information and then to make decisions. Artificial intelligence (AI), such as ChatGPT, can help in information-gathering and, in some cases, its selection. However, individual judgment, which includes personal subjectivity, naturally requires each individual's ability and cannot be replaced by AI. Moreover, since AI is now expected to replace more human roles, the ability to make appropriate judgment is likely to be increasingly valued as a human role that is not so easily replaced by AI.

Education that fosters rational judgment based on the selection and evaluation of large amounts of information is not well developed today. Since the easiest form of judgment involves choosing between two options, our focus will be on educating about such binary scenarios. Some approaches to making decisions in such cases have been demonstrated by one of the authors, Kusumi [1]. While there is no single correct method for

such approaches, the methods proposed by Failing et al. [2], Hammond et al. [3], and Quist et al. [4], as well as Kusumi's method, generally agree. These authors express nearly the same ideas, though with different order and emphasis.

In exploring educational methods centered around making decisions between two options, we have designed and published a judgment education program that focuses on the topic of the pros and cons of vaccination, using the COVID-19 pandemic as the subject matter. This program fosters the ability to make rational judgments based on the selection and evaluation of large amounts of information. The aforementioned approach to judgment can be described as an educational method that specializes in organizing information, particularly to enhance the understanding of the pros and cons of choices. The aim of this paper is to evaluate the effectiveness of this course, identify its limitations and potential, and discuss the future direction of judgment education.

2. THE OUTLINE OF THE PROPOSED EDUCATIONAL CONTENT

We discussed the requirements for the desired educational approach from three perspectives: judgment education, risk education, and critical thinking (CT) education. Here are the twelve requirements we extracted from the discussion:

- 1) Foster the ability to make appropriate choices from large amounts of complex information
- 2) Address issues that present binary choices
- 3) Teach an understanding of risk and risk comparison
- 4) Foster an understanding of uncertainty
- 5) Handle topics that absolutely require judgment
- 6) Foster risk communication skills
- 7) Foster expression and logic
- 8) Foster the ability to minimize bias
- 9) Foster trade-off understanding
- 10) Foster natural scientific literacy
- 11) Foster critical thinking (CT) skills
- 12) Make efforts to create effective meta-critical-thinking (MCT) skills.

We designed and implemented the course to meet the twelve requirements. Details are documented in Kusumi et al. [5], so here we report only the essential elements necessary for the evaluation.

The content of the class centers around teaching a "Simple Story" and a "Detailed Story" that could serve as prototypes for the logical structure used to evaluate the pros and cons of vaccination. The main focus of the class is to allow each student to build their

own argument and refine it through discussion. As a prerequisite for teaching the "Simple Story" and "Detailed Story," we taught students the way to think about risk and risk comparison.

The "Simple Story" involves calculating the risk of death from COVID-19 and the risk of death from the vaccine, and making a judgment about the vaccination based on the comparison of these values. While omitting the detailed explanation as described in Kusumi et al. [5], it shows that the death risk from COVID-19 is estimated to be between 2-35 and the death risk from the vaccine is estimated to be between 0.1-2. Based on this, it was considered that getting vaccinated is better than not getting vaccinated.

On the other hand, the "Detailed Story" is more cautious in judging the necessity of vaccination, taking into account the uncertainty of the underlying assumptions of the "Simple Story." The "Detailed Story" explains various uncertain factors from the "Simple Story" and has students themselves think about what other uncertain factors exist. Based on these findings, even if the quantitative assessment in the "Simple Story" is highly reliable, it is not necessarily a perfect decision to endorse vaccination based solely on the "Simple Story." This explanation takes into account the uncertainties and limitations of the "Simple Story" approach. In other words, the "Detailed Story" added an explanation that because of many uncertain factors, it can be difficult to make a judgment, and a negative judgment regarding vaccination cannot be considered a mistake.

The actual class was conducted in the course "Environmental Science B" at Chukyo University. We taught the same content in four classes per week of "Environmental Science B" at Chukyo University. Out of the 15 sessions of 90 minutes each, six sessions were dedicated to the actual class. In the first class, the focus was on teaching the previously-mentioned risks and the concept of risk comparison. In the second class, the focus was on teaching the "Simple Story" and the "Detailed Story." In the third class, the focus was on developing and refining individual arguments for and against vaccination. In the fourth class, we conducted group debates in teams based on the arguments each student had built and polished in the previous classes, further promoting a deeper understanding of the topic. In the fifth class, based on the arguments each student had polished in the debate during the fourth class and turned into a written report, the students checked and reviewed each other's reports. To make the classes more effective, we minimized lectures and instead used cooperative learning techniques. For reasons mentioned later, an additional sixth class was held to address areas of insufficient comprehension identified through the evaluation of the submitted reports.

In the sixth class, we presented typical arguments both for and against vaccination to serve as examples of possible stances on the topic. One argument in favor of receiving vaccination is that "based on a simple comparison of the risk of death, it can be said that receiving the vaccine is preferable. Quantitative risk assessment cannot make definitive judgments due to uncertainties such as unknown future circumstances, but organizing currently available information leads to the conclusion that there is no better overall judgment than this." The example of an argument stating that it is better not to receive the vaccine is as follows: "Even though a comprehensive judgment based on a "Simple Story" of comparing the risk of death can be considered valid, focusing on the subjectivity of vaccine side effects and prioritizing uncertain circumstances cannot refute the idea that not receiving the vaccine may be better." I also said

these are just some examples of answers from the second class, and there could be other types of correct answers.

3. TWELVE REQUIREMENTS AND TWO EVALUATION PERSPECTIVES

To evaluate education that fulfills the twelve requirements outlined in chapter 2, we identified two perspectives that reflect these requirements: A) "Education that promotes subjective judgment without scientific or logical errors" and B) "Education to achieve desirable judgment through communication."

Of the two perspectives, the first one, A, reflects requirements 1, 2, 3, 4, 5, 8, 9, and 10.

First, requirement 1 was a requirement to be included by the instructors during the design phase. Since requirement 1 was itself difficult, the instructor performed it on behalf of the students, and it was an important premise for the framework of perspective A. Requirement 2 was originally an important requirement for designing a relatively simple framework for education aimed at fostering judgment skills. And it was also an important requirement for constructing the framework of A. In other words, it was originally a requirement that needed to be fulfilled when designing the course. Requirement 3 was also important for A's "scientifically correct" judgment. Regarding requirement 4, the instructor clarified all aspects that could be made clear and organized the uncertain elements into a form that requires individual judgment based on personal preference. By doing this, the "understanding of uncertainty" required was made in a form that did not require specific situations. Therefore, requirement 4 was an important requirement for deriving A's scientifically accurate judgment. Requirement 5, just like Requirement 2, was an important requirement for constructing the framework of A, and it was a requirement that needed to be fulfilled when designing the course. Requirement 8 was also an important requirement as it helped to build the framework of A by fulfilling it. Requirements 9 and 10 were also important in the same way.

On the other hand, the second perspective, B, succinctly reflects requirements 6, 7, 11, and 12.

Requirement 6 is indeed an important element of B in this course. The same applies to requirement 7. This course is inherently important for demonstrating critical thinking ability, and requirement 11 is an element of B. Requirement 12 is a slightly different element, but it is also a B-element in the sense that it is a requirement to facilitate smooth communication.

Based on the above, in this paper, we will evaluate this course from two perspectives: A and B.

4. EVALUATION OF THE TEACHING PRACTICE

Perspective A: Education that promotes subjective judgment without scientific or logical errors

A questionnaire survey was conducted after the classes. A total of 71 students took the course, and for the debate, the number of participants on the affirmative and negative sides was adjusted to be equal. As a result, some students conducted debates taking a position that was different from their own. The number of students who responded to the questionnaire survey was 57. A six-point Likert scale was used in the questionnaire. The option that most closely corresponded to the question received a score

of 6, and scores decreased in one-point increments for each subsequent option. For example, "Strongly Agree" or "Completely Satisfied" would be given a score of 6, and "Strongly Disagree" or "Completely Dissatisfied" would be given a score of 1. The results of the questionnaire obtained in this way are summarized in Table 1.

In t-tests, a meaningful numerical value (threshold) for comparison is required. Therefore, for the overall educational effect, a threshold was considered assuming that the respondents followed a standard normal distribution (refer to Figure 1).

In the case of the standard normal distribution, the mean is 0 and the standard deviation is 1, and 66.6% of respondents fall within the range of -1 to 1. If x is less than -1, it was judged as "low", and if x is greater than 1, it was judged as "high" score. Furthermore, since 95% of respondents fall within -2 to 2 in a standard normal distribution, we judged that a score below -2 corresponds to "very low" and a score above 2 corresponds to "very high".

Table 1. Results of questionnaire survey on judgment ability

| Highest score: 6 Median:3.5 Lowest score: 1 | Were you satisfied enough with your own judgment? | Do you think you could explain the validity of your judgment adequately enough to others? | Do you think your ability to compare risks has improved by taking this class? |
|---|---|---|---|
| Average | 4.61 | 4.30 | 4.82 |
| standard deviation | 0.90 | 0.78 | 0.89 |
| t-test result | *Statistically significant at the 1% level *high | *Statistically significant at the 1% level *high | *Statistically significant at the 1% level *high |

The educational effectiveness questions were scored on a scale ranging from 1 to 6, with a median value of 3.5. Therefore, we divided the range as shown in Figure 1, set a threshold, and used t-tests to determine how significantly lower or higher the average score was for each question.

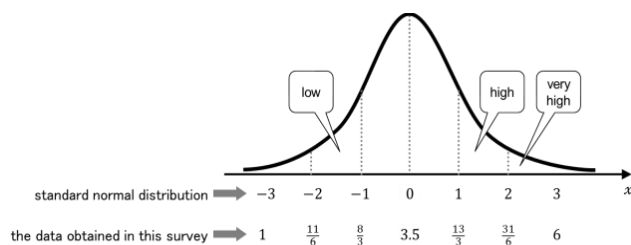


Figure 1. Correspondence of t-test values in this study to standard normal distribution

As shown in Table 1, all three questions, namely "Were you satisfied enough with your own judgment?", "Do you think you could explain the validity of your judgment adequately enough to others?" and "Do you think your ability to compare risks has

improved by taking this class?" received significantly "high" evaluations. The results of the t-test were also high. Based on the students' own evaluations, their ability to compare risks improved and they were satisfied enough with their own judgment.

Next, we conducted an evaluation from the perspective of the instructor. After the fifth class, one of authors assigned a report that required students to discuss their views on the "pros and cons of COVID-19 vaccination." The students were asked to choose whether they thought it was better to get vaccinated or not, and then list their reasons for their decision on the report form.

Fifty-four students submitted the report, but few of them were able to provide "subjective judgment without scientific or logical errors" with appropriate reasons. From the instructor's perspective, it was not yet possible to achieve the goal of providing education that helps students make subjective judgments without scientific or logical errors. The effectiveness of such a course is influenced by the level of the university that offers the class. At Chukyo University, a mid-tier private university, because of the many students who are weak in the field of science, technology, engineering, and mathematics (STEM), the abilities to make scientific or logical judgments are lacking in the first place. In this context, it seems that despite the challenges, education is being provided and many students feel they have made significant progress, although we as educators feel it is not sufficient.

In response to results noted above, an additional explanatory session was added, which was held in the sixth class. The questionnaire survey was conducted after this session. One possible factor for the higher self-evaluations compared to external evaluation could be attributed to this additional session.

From the instructor's perspective, this course did not achieve sufficient effectiveness until the fifth class, according to external evaluation. However, considering the high self-evaluation after the sixth class, one of the reasons for the higher self-evaluation may have been the effect of the supplementary explanations provided in the sixth class, even if the level of achievement was not as high as the instructor's goal. There are two possibilities: one is that the supplementary explanations provided in the sixth class were effective, and the other is that even though the students did not achieve the level of education the instructor aimed for, they still felt a sufficient educational effect. It is unlikely the sixth class had no effect at all, so it is reasonable to consider both possibilities.

From this point on, at least in the case of Chukyo University, education with more realistic goals should be implemented. The goal of the course discussed in this paper was quite difficult, and it was found that courses with lower-level goals are needed in order to achieve it.

Perspective B: Education to achieve desirable judgment through communication

This perspective is aimed at confirming whether communication within the class contributed to desirable judgments, so it was difficult to obtain external evaluations, and therefore only self-evaluation results were presented.

Table 2. Results of questionnaire survey on classroom communication and judgment

| | | | | | | | |
|---|---|--|--|--|---|--|---|
| Highest score: 6 Median:3.5 Lowest score: 1 | Did the preparation for the debate serve as an opportunity to gather various information on COVID-19? | Do you think your preparation and participation in the debate increased your knowledge about COVID-19? | Did writing down your thoughts during debate preparation help you organize your ideas? | Did having others point out the issues with your own opinions help in summarizing your own opinions? | Did you find it difficult to properly assert your own opinions? | Were you able to provide constructive criticism to the other person's opinion? | Were you able to modify (adjust) your own opinion by listening to the opinions of others? |
| Average | 5.19 | 5.19 | 5.09 | 5.40 | 5.02 | 4.00 | 4.42 |
| standard deviation | 0.88 | 0.81 | 0.76 | 0.68 | 0.81 | 0.73 | 0.80 |
| t-test result | *Statistically significant at the 1% level *high | *Statistically significant at the 1% level *high | *Statistically significant at the 1% level *high | *Statistically significant at the 5% level *very high | *Statistically significant at the 1% level *high | *Statistically significant at the 1% level *high | *Statistically significant at the 1% level *high |

We conducted a questionnaire survey using the same method as in the previous section in the same place. The questionnaire survey results obtained are summarized in Table 2.

All seven items in the table received significantly high evaluations. The results of the t-test were also high. It was found that communication within the class significantly contributed to desirable judgment.

Discussion

In recent years in Japanese education, it has become increasingly difficult to conduct education in large classrooms where students' logical errors in what they express are pointed out and corrected. This is because students have become more sensitive to criticism and may file harassment complaints, and because the university administration tends to respect students' opinions to the fullest extent possible.

Considering these circumstances, we have been exploring an education approach to promote judgment based on communication among students. This includes our requirement 12 as well. This educational practice, which promotes judgments based on such communication, can be considered successful overall, as described in the previous section. On the other hand, as mentioned in the previous section, the level of educational effectiveness achieved by this class was insufficient, at least according to external evaluation.

There are a couple of things that can be done to enhance education effectiveness. First, teach challenging topics over an extended period of time, and second, refine the teaching methodology of the course. Although the subject matter varies, I, as the author, have repeatedly assessed the application of the techniques employed in this course, and I have implemented several enhancements since the design phase of the trial version of this course several years ago. Further refinements of the teaching methods are still being considered.

One could argue that the subject matter may have been overly challenging, and for this style of education, it is important to allocate additional time and develop an educational program that is divided into smaller parts to meet various requirements.

5. CONCLUSION AND SUMMARY

First, according to self-evaluations by the students themselves, the education introduced as a whole has yielded generally positive results. This course has achieved sufficient results in "education to achieve desirable judgment through communication", and sufficient results have also been achieved in "education that promotes subjective judgment without scientific or logical errors".

Second, according to external evaluations by instructors, the level of achievement in "education that promotes subjective judgment without scientific or logical errors" was insufficient. Therefore, some kind of effort, such as allocating more time for explanation and discussion, or simplifying certain aspects of the course content, would be important in improving the educational practice at the target university.

On the other hand, it is still important to educate university students -- future decision-makers in society -- in developing rational judgment based on the selection and evaluation of the vast amounts of information available in contemporary society. Today, when AI such as ChatGPT is advancing, the consideration of educational practices that enable individuals to make decisions and act based on their own thinking and judgment is just beginning. It is my hope that this paper will serve as a catalyst for the development of such judgment-based education.

6. REFERENCES

[1] A. Kusumi, **Hajimete no Genpatsu Guidebook (Nuclear Power Guidebook for Beginner)**, revised version, Soseisha (in Japanese), 2019
 [2] L. Failing, R. Gregory, G. Long, B. Moore, **The Decision Playbook: Making Thoughtful Choices in a Complex World (Teachers' Edition)**, GutsNHeads Project, 2019
 [3] J. S. Hammond, R. L. Keeney, H. Raiffa, H. **Smart Choices: A Practical Guide to Making Better Decisions**. Harvard Business Review Press, 1998
 [4] A. Quist, & R. Gregory, Teaching Decision-Making Skills in the Classroom. The Arithmetic of Compassion. Retrieved from

<https://www.arithmeticofcompassion.org/blog/2019/5/1/teaching-decision-making-skills-in-the-classroom>

[5] A. Kusumi, Y.Hama, “Education to Foster Judgement Skills Regarding Life with the COVID-19: Discussion of its Desirable Characteristics”, **Japanese Journal of Environmental Education**, Vol.32, 1, 2023, pp.85-94

Roma youth's right to education (case studies: Greece and Hungary)

Kleanthis KYRIAKIDIS

College of Security and Global Studies, American University in the Emirates
Dubai Silicon Oasis, Dubai 503000, United Arab Emirates

Evgenia KOIKAS

Independent Researcher,
Dubai Silicon Oasis, Dubai 503000, United Arab Emirates

ABSTRACT

Romani youth's right to education both in Greece and Hungary is explicitly and implicitly violated despite the abundance of international, European, and national legislation. Consequently, Greece has been found guilty of violating thrice the European Union Convention of Human Rights by the European Court of Human Rights, whereas Hungary only once despite its institutionalized antigypsyism. Unfortunately, Roma, Europe's most substantial ethnic minority, are discriminated against in every domain, which in turn impacts their schooling. Evidently, the tangible results of anti-discriminatory legislation addressing the marginalization and discrimination of Roma students remain negligible. It becomes apparent that antigypsyism cannot be eradicated by legal action alone but has to be combined with measures addressing the socio-economic status of Roma and offering development opportunities for the Roma communities in both Greece and Hungary. A Gordian knot like that needs unflappable political will and in-depth individual and societal changes.

Keywords: Roma, right to education, Antigypsyism, Greece, Hungary

1. INTRODUCTION: ROMA AND ANTI-GYPSYISM

Roma, the world's most populous marginalized community, is Europe's most substantial ethnic minority, with an estimated population of ten to twelve million [1] "Roma" is an umbrella term for numerous groups that live in several European countries, including Greece and Hungary. The term encompasses a wide range of different people of Romani origin such as: Roma, Sinti, Kale, Romanichels, Gitan, Zigeuner, Cigan and Boyash/Rudari. It also encompasses groups such as Ashkali, Yenish, Dom, Lom, Rom and Abdal, as well as traveller populations, including ethnic travellers or those designated under the administrative term "gens du voyage" and people who identify as Gypsies, Tsiganes or Tziganes, without denying their specificities. Roma were thought to be originally from Egypt, hence the name Gypsy (the French word 'gitan' and Spanish 'gitano' also originate from this etymology), but the truth is that they migrated from India and entered Europe through the Byzantium in the Middle Ages. The German word Zigeuner and Slav tsigan or cigan come from the Greek word athinganos, meaning "heathen" or 'untouchable' referring to their Indian origin as they came from the lowest Hindu caste, contact with whom was traditionally believed to defile members of higher castes. In Greece the terms Gyftoi and Athinganoi have fortunately become obsolete in the public sphere succeeded by Tsiganoi and Roma, used interchangeably even though the latter is gaining more and more traction. [2]. Formerly nomadic, the majority are now sedentary but are still

ostracized due to their cultural and ethnic background. As a norm, they live in shantytowns and remain pariahs.

Antigypsyism is a form of racism targeting Roma. It is a historically rooted structural phenomenon that appears at institutional, social and interpersonal levels. It has its origins in how the majority views and treats those considered 'gypsies'. It is rooted in a process of 'othering' that builds on negative stereotypes. While there is consensus about the understanding of antigypsyism among proponents of the need to reinforce the fight against it, there has been a debate about the term. The European Parliament (in its 2015, 2017 and 2019 and 2020 resolutions), the European Commission (in its annual communications between 2015 and 2019, and its 2018 conclusions paper), the European Council (in its 2013 recommendation and 2016 conclusions) and the Council of Europe have recognized antigypsyism as a barrier to inclusion, and hence the importance of tackling it. The Commission uses the narrative proposed by the "Alliance against Antigypsyism", while accepting that different terms might be appropriate in different national contexts. Undoubtedly, the peak of the Roma persecution was during World War II, along with other ethnic, religious or racial groups, more notable the European Jews. The Romani Holocaust, when more than half of Europe's Roma population was exterminated, was recognized by Germany only in 1982 and the Roma Holocaust Remembrance Day is commemorated annually on the 2nd of August. "In the end, the fact that the Roma are historically and structurally subjected to discrimination and racism may appear to be their most defining characteristic from which the multiple social problems flow." [3]

Regrettably, covert indirect institutionalized discrimination, limited opportunities for participation in many facets of society, and inadequate access to good-quality education are pan-European phenomena. Furthermore, not sufficient progress has been made concerning Roma's integration, as a 2018 European Commission report observes that Roma people are often "victims of prejudice and social exclusion" [1] [4].

Nevertheless, everyone is entitled to good school education, irrespective of their racial, cultural, religious, and ethnic background, while every effort should be made for inclusive education that embraces underprivileged groups. Therefore, in this paper, we will look into Roma youth's, namely kindergarten to junior high school students, right to education in Greece and Hungary from a legal perspective. It will be argued that despite the abundance of legal frameworks, directives, and initiatives at European and national levels, Roma youth's right to education is frequently violated explicitly or implicitly. Thus, they are condemned to remain outcasts.

Roma have a strong sense of relative deprivation by virtue of having no home. Politically, they tend to be relatively passive or disengaged, except for occasional outbursts of rage when something that appears to be a direct threat to them sparks collective anger. Moreover, they have a limited range and depth

of civil, cultural, social, political and economic rights, experiencing rights insecurity and increasingly denied what Hannah Arendt called “the right to have rights,” an integral component of citizenship.

2. THE SOCIOPOLITICAL CONTEXT

Roma settlements have existed in Greece since the 14th century and remain ubiquitous. However, there are no precise figures concerning their actual population; only estimations that they are between 200,000 to 300,000. According to Greek Roma own estimations, their total population in Greece is close to half a million. Their numbers cannot be accurately calculated, because Roma are recorded as Greek citizens in the national censuses without any other denotation. Large settlements with over 1,000 families are found in four regions: Thrace, Thessaly, Western Greece and Central Macedonia. There are also some large settlements in the outskirts or outer suburbs of Athens in Agia Varvara, Liossia, Zefyri, Aspropyrgos and outer suburbs of Thessaloniki in Dendropotamos, Eleftherio-Kordelio, Evosmos, Menemeni, Nymphopetra. Hence, most Greek Roma are sedentary, having lived in the same location for decades.

Furthermore, the Roma in Greece are not a homogeneous cultural and linguistic entity. Instead, they comprise an amalgam of quarreling Roma tribes. Roma in Greece consist of the following categories: a minuscule number of domestic nomadic Roma; long-term sedentary distinct Roma communities which, however, are impoverished and ostracized by local communities; very long-term settled distinct Roma communities, several of which are almost entirely unproblematic; recent Roma migrants from the new E.U. Member States - primarily Bulgarian and Romanian Roma; completely integrated/assimilated Roma who may even not identify themselves as Romani; Roma Muslims in Thrace - who benefit from the minority protections available under the peace treaties between Greece and Turkey following the Treaty of Lausanne. In addition, there are recent Roma migrants who are not E.U. nationals, predominantly from Albania but also from Kosovo and North Macedonia, and thus are considered migrants. Concerning religion and national identity, the majority of the Greek Roma “tribes” such as the Medvedara (Bear-leader), Katsiveli, Fitsiria, Mandopolini are Orthodox Christian and identify as Greeks. To understand the differences and intra-roma quarrels, Ftzirion Roma live in a ghetto within the Roma settlements. Moreover, a 2015 study conducted by “Antigone”, an anti-racism information center in Thessaloniki, reports that discrimination is also prevalent within the Roma communities concerning varying educational attainment, financial status, religious beliefs, gender, and cultural practices.

Their degree of social integration or marginalization is impacted by geography and local particulars. On the one hand there are exceptions of relative success such as the Roma community in Florina but on the other hand several municipalities have attempted to evict Roma, despite a court decision that explicitly states that no eviction of Roma can take place if a suitable place for relocation has not been found. Given that their actions are closely monitored by non-governmental organizations and the Ombudsman's office, they tend to camouflage their attempts to evict the Roma as “cleaning operations”, disregarding the impact such operations have on the Romani families living there.

The preponderance of Roma communities have a restrictive patriarchic family and societal structure and thus remain introverted and endogamous, which in turn impedes their inter and intra-community relations. Also, Roma women are discriminated against within their community due to their gender

and honor-related perceptions, while early marriage, a measure to control adolescent sexuality and safeguard the family honor, causes early school leaving, obstructs their self-realization, and constitutes a violation of their rights.

Concerning Roma's integration into the Greek society, the pernicious effect of centuries-long ingrained prejudice constitutes an insurmountable obstacle. Negative stereotypes and exclusionary logic prevent this disenfranchised community from asserting their rights. To this day the word “gypsy” in Greek alludes to filth, crime, garish clothing, and anti-social behavior. Roma are also portrayed as untrustworthy, dishonest, lazy, violent, and often as thieves, or kidnappers. Frequently when a Romani person is a suspect for committing a crime the media emphasize the ethnicity of the suspect as a reaffirmation of these stereotypes [5]. Ergo, Roma have been subjected to persecution and widespread discrimination by local authorities, law enforcement, and the justice system. The case of Andreas Kalamiotis vs. Greece exemplifies this. On July 24, 2008, the United Nations Human Rights Committee determined that the Greek government had violated Article 2, paragraph 3 regarding the right to an effective remedy, along with Article 7 concerning the prohibition of torture of the International Covenant on Civil and Political Rights. The Committee, given the apparent lack of an effective investigation into allegations of police brutality against Andreas Kalamiotis, a Roma male, on June 14, 2001, ruled that Greece must provide the victim with an effective remedy and appropriate reparation, as well as take measures to prevent similar violations in the future.

Furthermore, Roma are also denied access to adequate healthcare, housing, and education and are segregated in many vital sectors such as housing, education, employment, and healthcare. However, the public turns a blind eye to their plight or denies, due to racialism, the level of discrimination and racism against them. One in three is unemployed, and 90% live below the poverty line [6] [7]. Is it all bad? Not really. In 2004 a government circular banned the use of derogatory references to Roma by the police. Moreover, “Gypsy musicians” have always been popular, including the singers Manolis Aggelopoulos, Kostas Hatzis, George Magas, Vasilis Paiteris, Kostas Pavlides, Zafeiris Melas, Irene Merkouri, Makis Christodouloupoulos, Eleni Vitali, and the clarinetist Vasilis Saleas. A top-rated television soap opera titled “Whispers of the Heart” transformed public attitudes towards the Roma for a short time in 1998. Chronicling the love story of an upper-class Greek architect and a young Romany woman, it was one of the most successful shows ever on Greek television. On the 9th of February 1998, it achieved a record 66.1% percentage of viewership that has not been surpassed yet [8].

This of course does not change the fact that the vast majority of the Greek Roma live in ghetto neighborhoods, attend segregated schools or classrooms, and are the subject of frequent racial profiling by police. Moreover, they are caught in a vicious circle as their lack of skills translates into a lack of employment opportunities, poor housing, and poor access to healthcare. Simultaneously, their participation in the formal economy is inadequate, so comparatively large numbers of the Roma lack the financial resources to pay the social security taxes needed to fund social security benefits. Hence, baiters accuse them of “asymmetrical” participation in social welfare systems and being free riders at the expense of “law-abiding” people [9].

Inequalities are also maintained due to clientelism, political affiliations, and voting coalitions between local actors and the Roma elites. Roma communities still lack water, sanitation and hygiene (WASH) infrastructure and facilities like public transport access to their villages and settlements, due to Roma's

perennial segregation and social exclusion, thus afflicting the younger generations' integration and empowerment [10].

Concerning education, common fallacies persist plaguing them. Early approaches were strongly influenced by either a strong belief in their unchangeable nature (the dubitable "Roma soul") that rendered any educational attempts futile or a conviction that if approached as "homines educandis", i.e., being "correctable" through education, there was hope for correction through schooling. The goal of the latter approach, though, was assimilation and abandonment of their lifestyle and culture [2]. Actually, instead of identifying the sociopolitical root causes of Roma students' academic struggles and finding ways to alleviate them, other stakeholders resort to victim-blaming. Roma children's education had been neglected for decades regarding the official Greek educational policymaking. However, in the last two decades, long scale nationwide programs, with multiple regional implementations per local needs and priorities, aiming to boost Roma enrollment in school, prevent school abandonment, and support children to succeed academically have had limited success. Evidently, the current educational policymaking considers Roma education as part of a broader issue that needs confronting, namely the harmonization of the Greek National Curriculum with the demands of the emerging multicultural educational reality in Greece.

A step towards the right direction, considering the importance of preschool education, especially for children from minority communities, was the introduction of two- year kindergarten, which will pave the way to a smoother integration into primary school as they will have the opportunity to catch up with their classmates [11]. Furthermore, the Greek educational authorities have launched a series of pedagogical initiatives which aim at supporting the role of both teachers and parents. Under the name "Education and Counseling Support for the families of Roma, repatriate populations and immigrants", the Ministry of National Education and Religious Affairs has formed an ambitious project aiming at creating inclusive educational environments in the early stages of basic education, mainly in nursery and primary schools. However, Roma children and adolescent students have a diverse array of linguistic, academic, and emotional needs that need to be met to fulfill their potential. On the one hand, Greece struggles with inadequate funding for teacher training and teacher resources while exogenous factors such as widespread antigypsism plays havoc with implementing action plans. A whole-child and whole-school approach are imperative to be adopted to create supportive learning environments that facilitate optimal learning outcomes [12].

In that milieu, Roma mothers are progressively becoming agents of change, seeking a better future for their children via education. Thus, they are willing to go beyond the call of duty and advocate for their children. However, similarly to migrants and refugees, they have to overcome the notorious Greek red tape and bureaucracy, even for the simplest tasks, such as registering their children. They have also to overcome abject poverty, social exclusion, and information poverty due to the poor educational background of Roma parents to stem the dissemination across generations of the negative connotations that mainstream education carries for them. Characteristically, the vast majority of requests (63.4%) for help concerned bureaucratic issues such as the acquisition of birth certificates, registration to local municipalities and the like while 10.2% of the requests regarded mediation between Roma families and various state authorities due to linguistic lack of confidence concerning Greek. They are also, consistent with trends in other countries, suspicious of schools, the quality of education their children receive and attribute any lack of facilities and equipment to the presence of

their children in the particular school. It should also be emphasized that low rates of literacy among community members result in Roma children's lack of factual knowledge and everyday involvement in educational contexts, which leads to underachievement [13] [14]

Undeniably, Roma children face serious conflicts concerning, inter alia, bilingualism and boundary identities in the formal schooling context. Moreover, typical top-down teaching practices and monolingual processes reaffirm the marginalization of their cultural and learning identities. Roma students' low and inconsistent attendance in compulsory education and their high dropout rates along with their minimal motivation and performance in mainstream education, illustrate their discontent with the Anti-Roma atmosphere at school and in their neighborhoods. Moreover, often knowledge learned at school is considered unimportant and irrelevant to their reality. Additionally, contrasting fears of losing touch with their ethnic group in tandem with fear of failing to integrate affect them psychologically. Also, the lack of the necessary factual knowledge and the need to acquire learning skills may appear overwhelming, and rarely a helping hand is extended. Teachers' low expectations of Roma children perpetrate racist stereotyping within the classroom framework [15].

There is however a significant number of educators who have built inclusive, culturally responsive, learner-centered learning environments. By encouraging students to utilize and develop their home language and culture and build on their prior experiences, they jointly challenge the ubiquitous perception that those features are inferior or insignificant compared to the dominant language and culture. An effective teacher is a facilitator by expanding their zone of proximal development through collaborative interaction and inquiry [16]. Schools and teachers alike have become their students' advocates and strive to stop perpetuating Roma's marginalization in their educational structures and teaching practices. For instance, two primary school educators Ms. Batsara and Ms. Pikla, cooperated with their students in the 9th Primary school of Thebes to compile a small dictionary of Greek Romani.

Ms. Vasiliki Arseniou, a primary school teacher in a village called Sofathes in the prefecture of Karditsa even wrote a book to address the specific educational needs of her Roma students. Ms. Matina Vavouli, another educator who teaches in the same school in New Zoe in Aspropyrgos for the last 28 years has managed to reverse the trend of early school leaving. Furthermore, educators with Romani background like Ms. Vivi Vilanaki are becoming role models for the Roma youth. Nevertheless, specific teacher training is imperative as usual teacher practices and beliefs translate into not recognizing background knowledge and not exploiting Roma students' orality during teaching processes. Also, a tenacity in maintaining stereotypical views about Roma students' potential for school learning has been observed. Actually, Greek school practices steered by an assimilationist ideology appear to disregard or devalue fundamental characteristics of Roma children's cultural identities. Their culture is usually considered insubstantial and insignificant, and most teachers presume that non- Greek home languages do not contribute or even present obstacles to their school performance. Teachers are also highly unlikely to use the home language as a teaching resource [17].

3. THE LEGAL FRAMEWORK IN GREECE

Until 1955, when the first pertinent degree established the Nationality Code for Roma, they were considered stateless and were issued a special identity card that had to be renewed every

two years by the Department of Aliens. However, the 1955 legislative decree did not have a retroactive effect, thereby leaving a sizeable number of Roma without proper documentation. The Compulsory Law 481/1968 tried to rectify this by extending the Nationality Code's scope to those born before the Nationality Code came into effect.

As it is clear from the aforementioned, the principal issue until the 1970s was the acquisition of Greek nationality and citizenship. In 2001, 46 associations, members of the Panhellenic Federation of Greek Roma Associations, issued a statement concerning their ethnic identity. In contrast to the International Romani Union, they identified themselves as Greek of Romani background. In 1971, Roma from various countries founded the International Romani Union to empower and protect Roma communities and act as a representative of the Roma Nation whose definition was amended in 2000 as Roma a Stateless Nation.

Moreover, issuing the General Order 212, contained in document Ref. No. 69468, by the Nationality Directorate of the Ministry of the Interior and Administrative Reorganization, on October 20, 1978, was deemed necessary to resolve persistent problems concerning Roma's statelessness. Also, with General Order 51, contained in document Ref. No. 16701, dated March 12, 1979, the Nationality Directorate provided additional guidance to the various prefectures that encountered problems in implementing General Order 212. Nevertheless, several Roma, even now, have no proof of nationality and live in Greece with a status similar to that of aliens.

At this point we need to highlight that Article 19 of the Greek citizenship code, which was in effect until 1998, was in stark contrast to Article 8 of the U.N. Convention on the Reduction of Statelessness, which stipulates that a state must not deprive a person of their nationality if that would render him stateless. Likewise, Article 9 of the same convention mandates that a state must not deny any person or group of persons their right to nationality on racial, ethnic, religious, or political grounds. Similarly, Article 4(b) of the European Convention on Nationality specifies that "statelessness shall be avoided." Greece has signed both Conventions, but until now, it has not ratified either of them [18].

Greek policies concerning Roma housing have twice been found to violate the European Social Charter by the European Committee of Social Rights. Also, the apparent government inaction and the widespread militant public antigypsyism of local communities perpetuate infringement on Roma's right to shelter. However, according to Baris and Alexopoulos [19], 91% of the primary school teachers interviewed in the prefecture of Achaia firmly believe that permanent housing would improve Roma youth's school attendance and academic achievement. A manifestation of institutional and public antigypsyism is the apparent lack of interest concerning the welfare of Roma. For instance, the disappearance of 502 Albanian Roma children, between 1998-2002, from the Greek Foundation for children Agia Varvara was not investigated by the Greek authorities until the European Union forced them to do so and led to the recovery of four children. According to the relevant report submitted by the Greek government to the European Commission, the vast majority of those children were presumably sold to human traffickers for sexual slavery or organ harvesting.

Muslim Roma, being one of the groups that comprise the Muslim minority in Northern Greece, have to learn Turkish as it is falsely considered to be the home language of the whole Muslim minority. Romani is not considered a minority language, and consequently, it is not taught in the minority schools, which makes Greek the second language Muslim Roma have to learn

beyond their home language. Ergo, they are further minorized in the context of the broader Muslim community [20]. As a parenthesis, for those who are not familiar with the Greek Muslim minority in Western Thrace, it is a legal entity that consists of three groups, namely Turkish-origin and Turkish-speaking Muslims, Pomac Muslims who speak the Pomac language, and Roma Muslims who speak Romani. Concerning education, Article 40 and 41 of the 1923 Treaty of Lausanne inform all aspects of schooling. However, the religious aspect as all are Muslims supersedes linguistic rights as Turkish is imposed on the other two groups. Neither the Pomac language nor Romani are regarded as minority languages and, consequently, they are not taught in the minority schools. Moreover, as a measure of appeasement towards Ankara, the Greek state signed education protocols in 1951 and 1968, which paved the way to establishing the Turkish language as the exclusive minority language. Consequently, the absolute linguistic Turkification of both Roma and Pomacs is in progress. Recently the Muslim Roma have become a bone of contention between the two countries [21]. Hence, Roma youth's linguistic rights and their linguistic identity are compromised by the lack of recognition and use of the Romani language within the school context as prescribed by the Universal Declaration of Linguistic Rights (1996), the European Charter for Regional or Minority Languages (1992) and the Convention against Discrimination in Education. Thus, language policies are not merely a sociolinguistic issue but also a human rights one [22].

Every Greek's right to education is enshrined in Article 16 of the revised Constitution of 1975. Law 1566/1985 describes the structure and operation of primary and secondary education. Law 3879/2010 (article 26, par. 1a and 1b) (GG 163 A/2010) introduced the "Educational Priority Zones" (ZEPs) to promote the equitable access of all learners who have little or no knowledge of Greek in the compulsory education system and improve learning outcomes. Roma students can benefit from the reception classes ZEP to achieve age-appropriate literacy skills. Moreover, according to articles 6 and 7 of Presidential Decree 79/2017 (G.G. 109/A), school principals must not only encourage Roma children to enroll and attend school but also seek Roma children living in their catchment area and ensure their enrolment and attendance. Furthermore, all Roma children must be admitted to school, irrespective of whether they have registered in the official population registers or not.

However, it took three European Court of Human Rights' convictions for relative progress to be made. The first case, *Sampani et al. vs. Greece*, concerned the lack of schooling for Romani children from the Psari area of Aspropyrgos during the 2004-2005 school years and the subsequent placement of over 50 Roma children in special classes located in the annex to the main building of the 12th Primary School School. Only Roma children were assigned to those so-called preparatory classes without, however, an initial objective assessment of their abilities nor any formative assessment to review their progress. The main issue is that those classes had been created as a compromise in light of non-Roma parents' violent protests against the admission of Roma children to the school [23]. The Court ruled, on June 5, 2008, that the segregation of Roma children into these special classes constituted "indirect discrimination" in education under Article 14 of the ECHR. The second case, *Sampani et al. vs. Greece*, concerned the same school as the first case. The 140 applicants from 38 Roma families, some of whom were plaintiffs in the first case, faced the same discriminatory ostracism and, on December 11, 2012, were vindicated by the Court.

The third case, *Lavida et al. vs. Greece*, concerned the segregation of 23 Romani schoolchildren from the town of

Sofades in the central mainland region of Thessaly. The almost 400 Roma families constitute half the town's population, and nearly all live in two areas known as the old and new Roma housing estates. The fourth primary school of Sofades was built on the old Roma estate, which translated into catering almost exclusively to the Romani schoolchildren living on the estate. Nevertheless, the catchment area for that school included, according to local authorities, the new Roma estate, despite being closer to another school. Thus, the offspring of its residents were also sent there. The Ministry of Education was informed about this blatant case of ethnic segregation via two letters sent by a Greek Helsinki Monitor (GHM) delegation after a visit to Sofades in 2009 but no anti-discriminatory measures were taken. Once again, the ECHR, with a unanimous ruling against Greece, on May 30, 2013, condemned its persistent discriminatory practices against Roma. Thus, Greece was found guilty of infringing Roma youth's right to quality education thrice. Consequently, law 4368/2016 (Article 82) (G.G. 21 A/2016) redefined the objectives of inclusion classes to cater to the needs of children with special education needs and disabilities so as their inclusion in the class environment to be achieved. Thus, learners would not be discriminated against by being pulled out of mainstream classes to attend inclusion classes for other reasons.

4. THE INTERNATIONAL AND EUROPEAN LEGAL FRAMEWORK

The international legal framework is abundant in provisions firmly outlawing direct or indirect racial discrimination. Article 26 of the 1948 Universal Declaration of Human Rights (UDHR), categorically states that "Everyone has the right to education". The right to education is also enshrined, *inter alia*, in UNESCO's Convention against Discrimination in Education (1960), and the International Covenant on Economic, Social, and Cultural Rights (ICESCR). It has also been reaffirmed in: the International Covenant on the Elimination of All Forms of Racial Discrimination (1965), the International Covenant on Economic Social and Cultural Rights (1966), the Convention on the Elimination of All Forms of Discrimination against Women (1979), the Convention on the Rights of the Child (1989), the International Convention on the Protection of the Rights of All Migrant Workers and Members of their families (1990), the Declaration on the Rights of Persons Belonging to National or Ethnic, Religious, and Linguistic Minorities and the Framework Convention for the Protection of National Minorities (1988), and the International Covenant on Civil and Political Rights (1966). Likewise, the United Nations' fourth Sustainable Development Goal seeks to provide "inclusive and quality education for all and promote lifelong learning." The Article 14 of the EU Charter of Fundamental Rights also stipulates the universality of the right to education. Furthermore, the broad language of Article 14 has allowed it to evolve, responding to changes in the understanding of discrimination, and providing increased protection against it [24].

Furthermore, apart from the European Union Directives on Racial and Employment Equality, the European Commission issued, on October 7, 2020, a reinforced and restructured E.U. Roma strategic framework. On March 12, 2021, the Council of the European Union adopted a recommendation on Roma equality, inclusion, and participation in all Member States. Moreover, most E.U. countries with significant Roma populations have enacted laws guaranteeing their human rights and have transposed the E.U. Racial Equality Directive into national law. The Council of Europe issued the ECRI General

Policy Recommendation no 3: Combating racism and intolerance against Roma Gypsies in 1998, followed by the Council of Europe Committee of Ministers Recommendation CM/Rec (2012)9 to member states on mediation as an effective tool for promoting respect for human rights and social inclusion of Roma and Recommendation CM/Rec (2009)4 on the education of Roma and Travellers in Europe. The European Platform for Roma inclusion brings together national governments, the E.U., international organizations, and Roma civil society representatives to facilitate closer cooperation and sharing of expertise and good practices among all stakeholders [4] [24]. Moreover, the strict accession requirements for E.U. candidate countries, *i.e.*, the Copenhagen Criteria, stipulate, *inter alia*, respect, and protection of minorities' rights. Consequently, the E.U. applicant countries, while lagging behind concerning implementing comprehensive anti-discrimination legislation based on pertinent E.U. directives, have introduced crucial, yet not always complete, anti-discrimination legislation [22] [24].

5. COMPARISON TO HUNGARY

The Council of Europe estimates that approximately 700,000 Roma live in Hungary (7.05% of the population) but similarly to Greece, it is not a homogeneous entity. For instance, more than 70% of the Hungarian Romani speak Hungarian as a home language. Up to 15% speak Romani, mainly the Vlach Lovara dialect, and another perhaps 15% of Roma/Gypsies speak, apart from Hungarian, *Beash*, an archaic form of Romanian. However, some of the prominent Kelderara families in Hungary, France, and Spain actively support the idea of an independent Gypsy state [8].

Furthermore, Roma are disproportionately poorer, endure bigotry in schools and workplaces, and have been victims of intimidation and sporadically deadly violence by far-right terrorists. High rates of unemployment among Roma (more than 70% in some parts of the country, particularly the northeast) are commonplace. Due to the restructuring of the Hungarian economy from heavy industry and full employment policies, since the mid-1980s, a vastly disproportionate number of Romani employees have been laid off. Nowadays, towns in Hungary's northern industrial belt, such as Miskolc, Ózd, and Salgotarjan, have large populations of chronically unemployed Roma [25].

The school segregation of Roma children in Hungary has reached such proportions that the European Commission, under Council Directive 2000/43/E.C. of June 29, 2000, the 'Racial Equality Directive' initiated infringement procedures against Hungary (along with Czech republic and Slovakia). Moreover, the current chauvinistic, xenophobic and racist government, under the rule of prime minister Victor Orban, has escalated against the very core of the E.U.'s values, the anti-Roma populist rhetoric, and acts of aggression. For instance, despite a court ruling, which determined that the historic ethnic segregation of Roma pupils in the town of Gyöngyöspata was unlawful, Orbán blocked the payout of the compensation and vilified the victims as "aggressors against the majority" [26] [27].

Since the 1989 collapse of the communist regime, there has been a renewed wave of anti-Romani sentiment. At this point it is worth noting that the anti-Romani sentiment is deeply ingrained in Hungarian psyche. In 1758, Hungary introduced new laws demanding Gypsies to settle down and assimilate or leave the country. They had to become land workers or become apprentices to learn a craft. It was also forbidden to wear their distinctive colorful clothes, speak their language, marry other Gypsies, or ply their traditional trades. Thus, since the 18th century, invasive state policies against Romani families have

contributed to Roma's deep hostility toward state officials, especially social workers, and generated the fallacy that non-Roma "steal children". Intrusive practices continued with much zest under communism, and many Roma lost entire families because social workers considered them incapable of caring for their own children [8].

Consequently, Roma in Hungary have suffered from high levels of police abuse, racially motivated crime, and mob violence. In many cases, the latter has been perpetrated by paramilitary "Quasi-fascist groups", called "civil guards," which are local chapters of a nationwide umbrella non-governmental organization that ostensibly provides rudimentary policing. However, its members are not constrained by standards of training or disciplinary codes expected of the police [28] [29].

The first legal provision that could be used against racially motivated crime (Article 174B of the Hungarian penal code) was added as late as 1996. Even after this year, it has rarely been applied. Regarding non-violent discrimination, Hungary lacks adequate legal provisions, and thus, few have been sentenced, although there are extensive allegations of discrimination and segregation in education, housing, employment, and the provision of social services and health care. For instance, according to a law concerning squatters that went into effect in May 2000, local authorities were no longer required to seek a court order before evicting illegal occupants but could be ordered by a notary, an assistant to the mayor. Police must implement notary-ordered evictions within eight days and appeals against them do not stay the expulsion. The law includes provisions to rehouse evicted furniture, but not evicted people. The Constitutional Court adding insult to injury, decreed in late 2000 that the right to shelter is not a fundamental right in Hungary. Therefore, the new law was not in violation of the Constitution. In 2015, the Municipality of Miskolc began to systematically terminate the social housing tenancies of persons living in a highly segregated, less well-off part of the town called the "Numbered Streets" without taking any measures to provide the tenants with alternative housing and thus rendering them homeless. In July 2015, the Equal Treatment Authority ruled that the practice constituted discrimination based on social status, financial situation, and Roma origin. The Authority ordered the Municipality to create two action plans for the relocation of the tenants to suitable housing and to stop the discriminatory practice until the action plans were adopted. Moreover, the Municipality was fined HUF 500,000 (EUR 1,670) by the Authority [26].

Even the 2004 Equal Treatment Act [26] did not make much difference. Consequently, because of prevalent antigypsyism and persecution, Hungarian Roma, since 1997, have fled to Canada and applied for asylum, and around 20% have been recognized as deserving refugee status [30] [31].

Concerning education, Hungary adopted children's rights legislation harmonizing Hungarian law to international standards in 1997, and thus, legislative amendments to national acts on education that aim to decrease segregation were made. However, in practice, they have led to a rise in segregated schools and classes. The discriminatory character of these amendments is challenging to prove based on a strictly legal analysis, as they are worded in a positive manner, but when they are interpreted within Hungary's national legal and societal contexts, serious concerns arise. For instance, the legal framework for providing education based on both religious convictions and national minority status has led to more segregation [31] [32].

The 1993 Minority Law, which was amended several times before being replaced by the 2011 Law on the Rights of Minorities, has facilitated the establishment of minority self-governments as part of a system of nonterritorial autonomy

(NTA). Any of Hungary's 132 recognized minorities can establish local, regional, and national self-governments, and thus, 1,118 local Romani MSGs have been created. These elected bodies, parallel to mainstream institutions, have the right to make decisions concerning local education, language use in public institutions, printed and electronic media, and the protection of their traditions and culture. Moreover, the local MSG representatives have the right to offer input on all public policy issues through guaranteed access to local council committee meetings. However, they have no other rights, and thus it can be argued that all the aforementioned legal frameworks offer an illusion of political power and autonomy instead of genuine inclusion [26] [31]. Hence, in reality they have little leverage. Article 29 of the Minorities Act states that, in issues relating to local public education, media, culture, and language, decisions can be made only with the consent of the local minority self-government. However, there is no effective legal recourse if a local government does not comply. Moreover, the National Minority Self-Government, can only offer observations and comments on legislation of relevance to the minority [22].

Regarding the ECHR, the Horváth and Kiss vs. Hungary case concerned two young Roma men whose education in schools for the mentally disabled resulted from misplacement and antigypsyism. The Court's decision on January 29, 2013, established that there had been a violation of Article 14 of the E.U. Convention and emphasized Hungary's 'indirect discrimination' given the country's long history of misplacement of Roma children in special schools [33].

6. CONCLUSION

Evidently, the tangible results of anti-discriminatory legislation addressing the marginalization and discrimination of Roma students remain negligible. It becomes apparent that antigypsyism cannot be eradicated by legal action alone but has to be combined with measures addressing the socio-economic status of Roma, offering development opportunities for the Roma communities in both Greece and Hungary. A Gordian knot like that needs unflappable political will and in-depth individual and societal changes.

7. REFERENCES

- [1] European Commission, **Report on the evaluation of the EU Framework for National Roma Integration Strategies up to 2020**, 2018.
- [2] E. Skourtou, **Investigating Literacy Issues on Roma Education**. In Skourtou, E. Kourtis- Kazoullis, V., Aravosittas, T., Trifonas, P.P. (eds). *Language Diversity in Greece-Local Challenges with International Implications*, pp.157-168. Springer, 2020.
- [3] E. Hemelsoet, **The Roma people: problem or mirror for Western European societies? An exploration of educational possibilities**. In M. Miskovic (Ed.), *Roma education in Europe: Practices, policies and politics*, pp. 59-70. Philadelphia: Routledge, 2013.
- [4] I. Ulasiuk, **To segregate or not to segregate?: educational rights of the Roma children in the case law of the European Court of Human Rights**, EURSCAS, 2014/29, Global Governance Programme-89, European, Transnational and Global Governance, 2014.
- [5] P. Malamou, **Social and educational stereotypes for Gypsies and non-Gypsies in Gypsy fairytales in Greece**. Masters' Thesis, University of Ioannina Repository, 2020.

- [6] UNICEF, **Deep Dive on Child Poverty and Social Exclusion in Greece**, UNICEF Europe and Central Asia Regional Office, Geneva, 2021.
- [7] A. Abdikeeva, A. Minority Rights Group partners, **Roma Poverty and the Roma National Strategies: the Cases of Albania, Greece and Serbia**. MRG, 2005.
- [8] D. Kenrick, **Historical Dictionary of the Gypsies (Romanies) (2nd ed.)** Scarecrow Press, 2001.
- [9] Doctors of the World – Greek Delegation, **Inception Report-Empowering the Roma Community**, 2020.
- [10] M. Pavlou, **Racism and Discrimination against Immigrants and Minorities in Greece: the State of Play**, HLHR-KEMO Annual Report, 2007.
- [11] S. Mitakidou, S. & C. Gavrielidou, **The culture and the home language as a learning bridge in kindergarten**, Educational Sciences (in Greek), 2015.
- [12] N. Nikolaou, **Teacher training on Roma education in Greece: a discussion about the results of INSETRom experience in two Greek schools**, InterculturalEducation, 20:6, pp. 549-557, 2009.
- [13] D. Kassis, **Underachievement of Roma Children in Greece**. In Skourtou, E. Kourtis- Kazoullis, V., Aravosittas, T., Trifonas, P.P.(Eds). *Language Diversity in Greece-Local Challenges with International Implications*, pp. 183-194. Springer, 2020.
- [14] K. Bhopal, **Gypsy and Traveller mothers as agents of change in their children's education in England, UK**. In S. Mitakidou (Ed.), *The Education of Roma Children*. Epikenton, 2015.
- [15] E. Gana, C. Stathopoulou, & C. Govaris, **Expanded Pedagogical Spaces: Enhancing Roma Students Involvement in School**. In Skourtou, E. Kourtis-Kazoullis, V., Aravosittas, T., Trifonas, P.P.(Eds). *Language Diversity in Greece-Local Challenges with International Implications*, pp.169-182 London: Springer, 2020.
- [16] J. Cummins, **Language, power, and pedagogy: Bilingual children in the crossfire: Multilingual Matters**, Bilingual Research Journal 25(3), pp.405-412, 2001.
- [17] I. Noula, S. Cowan & C. Govaris, **Democratic Governance for Inclusion: a Case Study of a Greek Primary School Welcoming Roma Pupils**. *British Journal of Educational Studies*, 63(1):47-66, 2015.
- [18] UNHCR, **Country Reports on Human Rights Practices – Greece**, 2013.
- [19] T. Baris, & H. Alexopoulos, **The educational problem of Roma children. Reality and emergent prospects** (in Greek). In Pantelis Gerogiannis(Ed). 5th International conference of Intercultural Education, Patras, 12-14 July, pp. 321-327, 2002.
- [20] G. Mavrommatis, **Nationalism and history of educational policy: The education of the Muslim minority of Thrace**, (in Greek), PhD Thesis, Department of Political Sciences and History, Panteion University, 2007.
- [21] M. Alevizopoulou, & A. Zenakos, **Geopolitical identities: Roma of Thrace between two nationalisms**. Reporters United, May 30, 2021.
- [22] C. Delcour & L. Hustinx, **Discourses of Roma Anti-Discrimination in Reports on Human Rights Violations**. *Social Inclusion*, 3(5), pp.90-102, 2015.
- [23] ECHR, 1st sect. **Sampanis and Others v. Greece**. Appl. No. **32526/05** (final since September 5, 2008).
- [24] I.E. Koch, **The Right to Education for Roma Children under the European Convention on Human Rights**. Right to Education Initiative, 2011.
- [25] C. Cahn, **Smoke and Mirrors: Roma and Minority Policy in Hungary**. European Roma Rights Centre, 2001.
- [26] Advisory Committee on the Framework Convention for the Protection of National Minorities (FCNM) , **Fifth opinion on Hungary**. Council of Europe, 2020.
- [27] Z. Jovanovic, **European leaders' silence over Orban's anti-Roma rhetoric shames the EU**. Euronews. <https://www.euronews.com/2020/06/17/european-leaders-silence-over-orban-s-anti-roma-rhetoric-shames-the-eu-view>, 2020.
- [28] P. Cain, **Hungary nationals whip up anti-Roma feelings**. BBC News, <https://www.bbc.com/news/world-europe-19439679>, 2012.
- [29] S.R. Maeso, **"Europe" and the Narrative of the "True Racist": (Un-)thinking Anti- Discrimination Law through Race**. *Oñati Socio-legal Series* [online], 8 (6), pp. 845-873, 2018.
- [30] C. Levine-Rasky, **Designating Safety, Denying Persecution: Implications for Roma Refugee Claimants in Canada**. *Journal of Refugee and Migrant Studies*, 16(3), pp.313-330, 2018.
- [31] J.K. Kinga, B. Gábor & S. Jenő, **Roma in Hungary: The Challenges of Discrimination**. Minority Rights Group Europe Report, 2021.
- [32] I. Chopin, C. Germaine, C. & J. Tanczos, **Roma and the enforcement of anti-discrimination law**. European Union-European Commission, 2017.
- [33] V. Todorova, **Discrimination in education of children in central and eastern Europe in the jurisprudence of the European Court on Human Rights**. *De Jure Law Journal*, pp. 580-596, 2019.

Building Bridges to Gen Z in Online Coursework in Teacher Education

Amy PACIEJ-WOODRUFF

School of Education, Marywood University
Scranton, PA 18509, United States

Tammy BROWN

School of Education, Marywood University
Scranton, PA 18509, United States

ABSTRACT

A qualitative study of 93 students enrolled in online or hybrid Education courses explored what students value in the online course environment. Open-response comments on course strengths and weaknesses as recorded on university course evaluation forms were analyzed according to a thematic process. Results suggest that Gen Z students value course content that they perceive as interesting and well-organized, assignments that are easy to understand, and instructor responsiveness. They want coursework that is neither too difficult nor too easy with clearly defined relevance to their future teaching practice. In addition, they look to instructors to lessen perceived stressors caused by course demands. This article explores the tensions between the expectations of Gen Z students and faculty who are mindful of the demands of the profession. In addition, ways to scaffold the development of appropriate professional dispositions are considered.

Keywords: Teacher Education, Professional Dispositions, Online Learning, and Gen Z.

1. WHAT FACULTY KNOW STUDENTS NEED: PROFESSIONAL DISPOSITIONS

Though the development of teacher dispositions in preservice teacher education programs is not without controversy, it is widely understood that effective teaching requires more than knowledge and skills [18]. The notion of teacher dispositions originated with Dewey [9] who viewed dispositions as underlying organizers for behavior. More recent literature defines dispositions as “a cognitive or affective habit of mind that enhances a teacher’s character or competence to perform teaching-related tasks in a professional and effective manner” [26]. The Council for the Accreditation of Teacher Educator Programs [6;7] includes a moral imperative in addition to the “habit of mind.” Dewey [10] argued that dispositions result from experiences, a belief that has been adopted by various accrediting bodies for teacher education programs and incorporated into the professional standards for teacher education [2;7].

Dispositions identified as important for teacher educators typically fall into the following categories: motivation, self-efficacy, teachability, personal responsibility, and communication skills [24]. Though the dispositions of preservice

teachers vary with the experiences of the individual, many preservice teachers tend to be somewhat idealistic in their views of schooling and naïve in their views about educational policies and how such policies may impact them professionally [21]. The development of appropriate dispositions could, potentially, enable the novice teacher educator to persevere and experience continued professional growth in the face of unforeseen professional challenges.

2. GEN Z SPEAKS: WHAT THEY SAY THEY NEED

Generation Z is composed of people born between 1997 to 2012 [13]. Understanding the general characteristics of the generation of students who are the majority of current college students can lead to strengthening teaching and learning which may result in improved retention and satisfaction.

GenZ students wish to make a difference in the lives of others and to society as a whole. They want to solve problems. Instead of defying authority, they wish to work with authority figures to solve problems. At the same time, they see themselves as uncreative [17]. GenZers share characteristics with the Silent Generation who also came of age after major global turmoil. Now that the global pandemic is behind them, they may have a tendency to play it safe and not “rock the boat” [14]. Another result of having survived the pandemic is that they maintain a positive outlook for their futures [1]. GenZers value collaborative relationships and are more open-minded than older generations; more open and supportive of diversity, different lifestyles, and to listening to both sides of a situation. At the same time, they like to work alone. They seek choice and freedom [17], as well as customization to their individual preferences [20].

While the commonly-stated eight-second attention span sources are difficult to find [15], we have learned that GenZers regularly consume long videos on topics in which they are interested (i.e. gaming videos, videos about shows). GenZers first find items of interest in a short, perhaps eight-second, video format (like TikTok) that look interesting. Then they seek longer, in-depth videos on those new topics of interest about which they care [25]. For example, rates for binge watching television shows, as well as movie theater attendance are up to rates higher than other generations [8]. Another example of GenZers diving deep is that they watch short videos on #BookTok, a subgroup within TikTok, and therefore read more books (CNN Business). Adult fiction connected to #BookTok grew by 25% and then 8% in the

last two years [3].

Because they use YouTube as a main source of information where they can learn anything quickly and get lost in the vast amount of information [4], GenZ students need help sifting through information. They need help to avoid getting lost in the vast amount of it. Therefore, assignments that require finding information online should also include clear and structured instructions, as well as guidance on how to decide what information to trust [17].

GenZ students have more anxiety than past generations of college students [20]. Stress management directly impacts students' academic success. For instance, better grades are correlated with students who have lower stress and who seek solutions to their problems instead of avoiding problems. Especially for younger college students, high stress levels are correlated with lower grades [11]. Additionally, GenZers have not yet developed the coping tools to manage stress effectively at this point in their lives compared to other generations [12; 22]. Perhaps that is the reason they are confrontation-avoidant (for example, ghosting). The lack of self-regulation strategies may also be the reason that they display lower emotional intelligence at work. Simon Sinek [22] calls it "emotional professionalism." Examples provided by Sinek [22] describe how GenZ employees find the most empathetic person at work and treat them as their confidant not only for work-related issues, but also for everything else happening in their lives; or, GenZ employees may pout at team meetings because they are in a bad mood that day [22].

3. FINDINGS

A qualitative study of 93 students enrolled in online or hybrid Education courses explored what students value in the online course environment. Open-response comments on course strengths and weaknesses as recorded on university course evaluation forms were analyzed according to a thematic process. Results suggest that students value course content that they perceive as interesting and well-organized, assignments that are easy to understand, and instructor responsiveness. They want coursework that is neither too difficult nor too easy with clearly defined relevance to their future teaching practice.

Students' sense of mattering emerged as a dominant theme. They value an instructor that they like and one they perceive as kind and caring toward them as an individual. They want the instructor to understand that coursework is not always their first priority, as they have competing obligations. To this end, they value instructors who are flexible with regard to assignments and due dates. In addition, they value instructors who flexibly meet student needs, such as being available outside of normal school hours.

Student stress emerged as another dominant theme. Consistent with the literature that indicates GenZers experience greater anxiety than previous generations [20] and that they have fewer strategies for managing stress [12;22], the data suggests that students look to instructors to lessen the course-related stress they experience, rather than assuming responsibility for managing the stressors in their lives.

4. DISCUSSION

Though the teachability of dispositions has been questioned, Dewey's [10] claim that dispositions are shaped by experiences is supported by various teacher preparation accreditation bodies [2;7]. Thus, instructors play a crucial role in supporting the development of key dispositions in preservice teachers. Course design and the ways instructors respond to student needs can help to scaffold the development of professional dispositions.

Some disconnects between what Education students value in an online course and the professional dispositions their professors deem crucial for success in the field are apparent, particularly with regard to the dispositions related to personal responsibility. Future classroom teachers need to meet certain deadlines, such as submitting grades, lesson plans, and assessment data. In addition, teachers need to prioritize their classroom responsibilities and meet the learning needs of their students regardless of the stressors they may be experiencing in their personal lives.

Furthermore, the preservice teachers' sense of mattering seems to align with the research suggesting that preservice teachers tend to be naive about the impact of educational policies [21]. Novice teachers, in particular, may find that they have much less say in their day-to-day practice than they anticipate.

Tensions exist between preservice teachers' expectation of flexibility with regard to assignments and due dates, as well as looking to professors to lighten course-related stress conflicts and the dispositions related to a sense of personal responsibility. Also, preservice teachers' sense of mattering may conflict with dispositions related to teachability. However, such tensions can serve as "teachable moments" during which professors can take steps to scaffold students' growth in the dispositions needed to succeed in the field.

5. BEST PRACTICES TO BRIDGE THE GAP

A discussion of two examples of strategies follows. Strategies examine ways to design courses, address professor responsiveness, and utilize scaffolding. The goal is to bring to light how to bridge a connection between the disposition of personal responsibility in the form of deadlines, managing competing priorities and self-awareness of interdependent relationships with students' need for flexibility and mattering.

The first strategy involves group assignments. Course group work is valued by students as GenZers seek collaborative relationships and enjoy solving problems [17]. From the faculty perspective, group work is a strategy that can help students strengthen their dispositions, specifically personal responsibility. Faculty welcome assignments that connect students to each other and also develop student awareness of their own impact on the group [24]. Simultaneously, course group work seems to add to students' stress at an exaggerated level more so than past generations due to GenZ students' underdeveloped coping skills [19]. A simple adjustment to the project's rubric can avoid compounding the already existing anxiety in group work assignments without the loss of academic rigor. Perhaps individual work in group projects can be weighted as equal to or more than the group as a whole. Perhaps a metacognitive component can be added to group work projects to allow students

to reflect on their own learning including how they believe their own behaviors and attitudes impacted their peer group members throughout the experience. In this way, group work can provide a low stakes arena for students to develop their emotional intelligence or strategies to manage stress and their dispositions. Additionally, individual grading will meet GenZ students' needs for customization [20]. Designing assignments while meeting students where they are will be appreciated by students because they may feel cared about individually by the instructor. Students perceive specific faculty teaching practices as a strong signal about the faculty member's care for the student [16] without the need for exceptions. The use of the Gradual Release of Responsibility process fits perfectly in the above-described group project, reinforcing students' development of dispositions [23].

The second example focuses on planning the course calendar. Due dates and time management are popular stress points for students. This study's findings showed student appreciation for instructor understanding and flexibility as a result of an award of extra time to complete projects. Instead of entertaining requests for exceptions at due date time, instructor attention can be paid to proactively planning the course calendar with the students' macrocosm in mind. Deliberate planning with an awareness for the student as a whole being with additional responsibilities outside of higher education demonstrates care to the student. Due dates chosen with consideration to campus events, community or world events is a strategy that can set students up for success while at the same time eliminate some excuses for missing deadlines. For example, avoid due dates in the third week of the semester or the few days prior to a long break as that is typically the time when most faculty assign due dates. Be aware of specific regional community festivals and traditions when students will be expected to be with family. Avoid due dates the day after a presidential election or, depending on the part of the world you are in, a major athletic championship. Even when utilizing this proactive strategy, life will continue to present plenty of opportunities that will require students to learn to prioritize their time and effort. Another possible strategy designed to meet students where they are is to build into the course a few days of lighter material to allow a small timeframe for anyone to catch up if needed. This will allow students to manage their own circumstances without asking for exceptions. For those who do not need to catch up, a small break can be a natural consequence and reinforcement for successfully managing their time and priorities.

Finding a bridge between the needs of Generation Z students and an instructors' teaching practices may result in higher satisfaction from the students' perspective as well as from the instructors'. Finding a way for students to finish their course having grown and learned to their highest potential will have far reaching benefits that can potentially positively impact the future of our educational system.

6. REFERENCES

[1] Abrams, S.J. (2021, January 30). Op-Ed: Generation Z's surprising optimism should give the rest of us hope. The Los Angeles Times. <https://www.latimes.com/opinion/story/2021-01-30/generation-z-politics-optimism-activism>

[2] Association for Advancing Quality in Educator Preparation (AAQEP) (2022). Standard 1:

Candidate/Completer Performance. <https://aaqep.org/standard-1>

[3] Bennett, G., Corkery, A., Boulter, M. (2023, March 19). *How #BookTok is giving authors and booksellers a much-needed boost*. PBS News Weekend Video. [Video]. <https://www.pbs.org/newshour/show/how-booktok-is-giving-authors-and-booksellers-a-much-needed-boost#transcript>

[4] Briggs, E. (2022, December 12). Gen Z Is Extremely Online. Morning Consult. <https://pro.morningconsult.com/instagram/gen-z-social-media-usage>

[5] CNN Business. (2022, October 7). *How 2022's most popular TikTok community can help you read more in 2023*. [Video]. <https://www.cnn.com/videos/business/2022/10/07/booktok-tiktok-trend-helps-book-sales-orig-ht.cnn-business?cid=other-eml-mtg-mip-mck&hlkid=51b1011a6a9e40258116d04b2cf8150e&hctky=1926&hdpid=4d9c8095-c80b-4a07-ba46-5f1edb2e4dad#:~:text=With%20more%20than%2080%20billions,book%20sales%20in%20physical%20stores.>

[6] Council for the Accreditation of Educator Preparation (CAEP). (2016). Mission, vision, and goals. <http://caepnet.org/about/vision-mission-goals>

[7] Council for the Accreditation of Educator Preparation (CAEP). (2022). Standard 1: Content and Pedagogical Knowledge. <https://caepnet.org/standards/2022-1/standard-1>

[8] D'Alessandro, A (2022, November 17). 'Avatar: The Way Of Water' Most Want-To-See Pic For Gen Z This Holiday; Moviegoing A Top Three Activity For Demo – Fandango Study. <https://deadline.com/2022/11/avatar-the-way-of-water-gen-z-moviegoing-fandango-study-1235175172/>

[9] Dewey, J. (1922). Human nature and human conduct: An introduction to social psychology. Henry Holt.

[10] Dewey, J. (1938). Experience and education. Collier.

[11] Gustems-Carnicer, J., Calderón, C. & Calderón-Garrido, D. (2019) Stress, coping strategies and academic achievement in teacher education students, European Journal of Teacher Education, 42:3, 375-390, DOI: [10.1080/02619768.2019.1576629](https://doi.org/10.1080/02619768.2019.1576629)

[12] Harari, T.T., Sela, Y. & Bareket-Bojmel, L. (2022). Gen Z during the COVID-19 crisis: a comparative analysis of the differences between Gen Z and Gen X in resilience, values and attitudes. *Curr Psychol* (2022). <https://doi.org/10.1007/s12144-022-03501-4>

[13] Hecht, E. (2022, September 9). What years are Gen X? A detailed breakdown of when each generation was born. <https://www.usatoday.com/story/news/2022/09/02/what-years-gen-x-millennials-baby-boomers-gen-z/10303085002/>

[14] Lynch, A. (2015, July 8). Gen Z Kids Are Like Their Great-Grandparents. Here's Why. <http://www.generationedge.com/blog/posts/genz-like-grandparents#:~:text=They%20tend%20to%20play%20it,like%20McCarthyism%20and%20civil%20rights.&text=Silents%20>

[were%20shaped%20by%20the.of%20Americans%20lost%20th
eir%20jobs.](#)

[15]Maybin,S. (2017, March 10). Busting the attention span myth. BBC News.

<https://static1.squarespace.com/static/60eb7f14f46b2d2b9ab95b82/t/642f424ea02fd800d85fe8eb/1680818791567/Busting+the+attention+span+myth+-+BBC+News.pdf>

[16]Miller, A.C., & Mills, B. (2019). 'If They Don't Care, I Don't Care': Millennial and Generation Z Students and the Impact of Faculty Caring, *Journal of the Scholarship of Teaching and Learning*, v19 n4 p78-89 Oct 2019. ISSN: EISSN-1527-9316.

[17]Mohr, Kathleen A. J. and Mohr, Eric S. (2017) "Understanding Generation Z Students to Promote a Contemporary Learning Environment," *Journal on Empowering Teaching Excellence*: Vol. 1 : Iss. 1 , Article 9. DOI: <https://doi.org/10.15142/T3M05T>

[18]O'Neill, J, Hansen, S., Lewis, E. (2014). Dispositions to teach: Review and synthesis of current components and applications, and evidence of impact. [Report to the Schooling Policy Group, Ministry of Education, Wellington, New Zealand. Massey University. <https://www.education.govt.nz/assets/Uploads/DispositionsReportFinal100914.pdf>

[19]Pefanis Schlee, R. , Blakney Eveland, V., & Harich, K.R. (2020) From Millennials to Gen Z: Changes in student attitudes about group projects, *Journal of Education for Business*, 95:3, 139-147, DOI: [10.1080/08832323.2019.1622501](https://doi.org/10.1080/08832323.2019.1622501)

[20]Pichler, S., Kohli, C., & Granitz, N. (2021). DITTO for Gen Z: A framework for leveraging the uniqueness of the new generation, *Business Horizons*, Volume 64, Issue 5, Pages 599-610. ISSN 0007-6813, <https://doi.org/10.1016/j.bushor.2021.02.021>.

[21]Saultz, A., Lyons, A. I., Aronson, B., Sander, S. A., & Malin, J. R. (2021). Understanding Preservice Teacher Dispositions : Implications for Social Justice and Educational Policy. *Teacher Education Quarterly*, 48(1), 7–32.

[22]Simon Sinek. (2022). *How Gen Z Deals With Stress* [Video]. YouTube. <https://www.youtube.com/watch?v=uUYUQxfUSNo>

[23]Webb, S., Massey, D., Goggans, M., & Flajole, K. (2019). Thirty-Five Years of the Gradual Release of Responsibility: Scaffolding Toward Complex and Responsive Teaching. *The Reading Teacher*, 73(1), 75– 83. <https://doi.org/10.1002/trtr.1799>

[24] West, C., Baker, A., Ehrich, J. F., Woodcock, S., Bokosmaty, S., Howard, S. J., & Eady, M. J. (2020). Teacher Disposition Scale (TDS): Construction and Psychometric Validation. *Journal of Further and Higher Education*, 44(2), 185–200. <https://doi.org/10.1080/0309877X.2018.1527022>

[25]Zeitoune, R. (2022, August). New trend: Long attention spans for long-form videos. Think with Google. <https://www.thinkwithgoogle.com/intl/en-gb/consumer-insights/consumer-trends/gen-z-long-form-videos/?cid=other->

[eml-mtg-mip-
mck&hlkid=aa0e0a735b684837838ae25ad24b9cd5&hctky=192
6&hdpid=4d9c8095-c80b-4a07-ba46-
5f1edb2e4dad#:~:text=In%20many%20instances%2C%20the%
20simple.on%20short%2Dform%20video%20apps.](#)

[26]Zhang, Q., Hayes, J., TeHau-Grant, R., Skeoch, R., France, L., Jiang, K., & Barnes, R. (2022). Positioning dispositions in initial teacher education: An action research project. *Australian Journal of Teacher Education*, 47(4). <http://dx.doi.org/10.14221/ajte.2022v47n4.3>

Teacher Professional Development in Inclusive Education in Chile: A New Perspective

Solangela SÁNCHEZ-MONTECINOS

Instituto de Enfermería, Universidad Austral de Chile
Valdivia, 5090000, Chile

Jaime HUINCAHUE

Centro de Investigación de Estudios Avanzados del Maule, Universidad Católica del Maule
Talca, 3480005, Chile

Claudio GAETE-PERALTA

Departamento de Matemáticas y Ciencias de la Ingeniería, Universidad Bernardo O'Higgins
Santiago, 8320000, Chile

ABSTRACT

This review analyses and describes the current trends in inclusive education identified in higher education in Chile, specifically in teachers at universities that are self-declared as inclusive. For that purpose, it recognises the development of inclusive pedagogical competences in the teacher, reflecting the transformation that occurs when inclusive education is placed in an institution, positioning the teacher as a key actor in its functioning from both an educational and a social dimension. The teacher is the one who mediates between the inclusive policy at their disposal and contrasts it with their own conceptions in order to lead to a direct implementation in the students. From a literature review, it has been possible to identify that the focus of development of the emerging trends in recent years has been the continuous training of teachers, based on the impulse and stimulation of institutional investment in human capital that promotes inclusion competences, together with multiple implementation mechanisms. It is concluded that, in this new perspective, teachers must be motivated to create inclusive learning environments. At the same time, inclusive education is a quality imperative for higher education.

Keywords: Pedagogical competences, Professional development, Higher education, Inclusion, Teachers.

1. INTRODUCTION

In recent decades, the processes of continuous improvement in a higher education institution involve the measurement of compliance indicators in educational quality, quality conceived from the inclusive educational paradigm, representing a tool of interest for such indicators. Chilean universities have aligned themselves with state policy, promoting a trend towards the formation of increasingly inclusive educational communities, with almost two decades of experience, for which the focus on rights in higher education has been substantial and at the same time challenging for those who begin the journey.

The foundations of inclusive policies in Chile affirm that advances in legislation and in the concept of quality are “insufficient to support and guide the construction of a higher education system based on an approach of rights and inclusion”

[1, p.9], expressing the need to continue with the challenge of paving the way towards an inclusive higher education that responds to the conditions demanded by students, overcomes obstacles and, at the same time, solves visible and overlapping nodes.

In higher education, an inclusive university requires an “inclusive culture” [2], as well as developing the capacity to foster the creation and growth of an inclusive culture within the university community and showing this approach to society. This is on the understanding that an inclusive culture values differences between people and sees these differences as opportunities for deepening knowledge and collaborative learning.

The increase of educational inclusion in universities expresses a constant demand to the teaching staff, encouraging diversification in the planning, implementation and evaluation of the teaching process, in response to the diversity of realities and conditions. This diversification implies executing strategies that enhance the learning experience of students, favouring their participation and promoting the development of skills without disguising differences [3].

Avoiding the standardisation of teaching is part of the challenge; however, it may sound contradictory to standardisation mediated by quality indicators. This is where the role of a new view of an inclusive culture underpinned by a fair policy provides the space to analyse obstacles that condition participation, using resources efficiently to support student learning from practice in diverse contexts. In short, teachers must create pedagogical conditions that stimulate the inclusive process, contributing to the continuous improvement of the quality of education.

The National Network for Inclusive Higher Education states that inclusive education is a set of processes, both individual and collective, that are installed within educational institutions with the aim of promoting the development of all people [4]. The response to the diversity of university students necessarily involves directing all efforts towards a series of objectives ranging from raising awareness in the university community, access to higher education, institutional support in the curricular trajectories, to guidance for labour market insertion. This path

in itself denotes the necessary articulation of global-local policy applied to different contexts.

Facilitating accessibility to university is a step forward, however, the challenge is to ensure that people with specific educational support conditions can join and remain within the institutional structure, with no more difficulties than anyone else might have. In this point, the teaching staff has a key role to play from the point of view of educational otherness, stimulating inclusive educational environments in their teaching practice, mediated by quality indicators.

Despite the above, it is possible to identify concerns among teachers and administrators when incorporating students with special educational conditions into the regular classroom system, given the possibility of a decrease in quality associated with levels of academic demand. In view of this, Ainscow [5] states that it has been demonstrated by far that inclusive education leads to excellence in educational quality, quality declared by universities, highly valued in institutional accreditation processes, so there is nothing to fear. From this analysis, the following question arises: How can teachers contribute to the creation of quality inclusive universities in Chile?

2. THE CONTRIBUTION OF THE EDUCATIONAL POLICY FRAMEWORK AND ITS QUALITY-INCLUSION RELATIONSHIP

Chile has a consistent educational policy framework and, at the same time, universities as autonomous institutions delimit their micro-policy on inclusive education, where they freely adhere to one or more of the three dimensions of inclusive education declared by the Ministry of Education: interculturality, diversity/gender and disability. This freedom of affiliation heterogenises the inclusive education offer, which could strain the discussion in terms of rights and justice.

This regulatory framework is governed by the current Chilean constitution, which establishes the right to education for all people without distinction, guaranteed by the sovereign state for all sectors of the nation. In particular, Law 21.901 establishes that this level of education must be available to all citizens, according to their abilities and merits, without discriminatory or arbitrary acts, and considers inclusive education as a right. Article 2 describes the principles of the higher education system, highlighting inclusion, and states that the higher education system “will promote the inclusion of students in higher education institutions, ensuring the elimination of arbitrary discrimination” [6, p.2], being proposed as basic and common elements to all higher education institutions in the national territory. It seeks to favour the access, permanence and graduation of students, considers talents, special abilities, trajectories and promotes the graduation of university students.

The trajectories and graduation are a constant concern for universities. Although admission is a relevant point, it does not guarantee a quality process in the university experience; expectations, desires and talents must be taken into account. At the same time, the teacher's awareness and motivations imply involvement in decision-making in order to contribute to inclusive processes under quality standards. Institutional support for teaching teams is crucial in the implementation of macro- and micro-policy in the field of inclusion. Collaborative

work contributes to this task and sets a roadmap for the processes underlying inclusive education.

This regulatory framework addresses educational quality explicitly (art. 81 of Law 20.129, [7]), in the establishment of a National Quality Assurance System for Higher Education, which incorporates various governmental entities that ensure the development of policies that promote quality, relevance, articulation, inclusion and equity in the development of the functions of higher education institutions. Likewise, article 49 details those acts that violate the dignity of the members of the university community, establishing prohibitions for both academic and non-academic staff of Chile's state universities. This support delimits quality criteria to which the institutions and their corresponding areas and courses freely submit themselves, with the aim of monitoring internal processes and their different improvement strategies based on the results. In other words, the concept of continuous improvement is strongly rooted, the self-evaluation processes are communal within the universities and have established a culture of quality, which leads to an inclusive culture in higher education.

The education policy reform considers the School Inclusion Law, which declares inclusive education as a social right guaranteed by the state, describing that “it is the duty of the state to ensure inclusive quality education for all” [8, p.3]. With this law, changes in the structure of the education system are evident from the reform, it gives clear signals in favour of opening social nodes, since it offers opportunities, installs and regulates mechanisms for admission to education, eliminates shared financing and prohibits profit-making. This clarity enhances fair action, eliminates all forms of discrimination that impede student learning and participation, and allows universities to be a meeting place for people of different socio-economic, cultural, ethnic, gender, nationality or religious backgrounds.

Based on this regulatory framework, in 2017 the document *Bases for the construction of an Inclusive Policy in Higher Education* was created, worked on by the 18 Chilean State Universities, pointing out that within the initiatives implemented, there are university communities where the inclusive education policy still does not mutate to a multidimensionality, but rather focuses on the conceptual reductionism of the deficit. In addition, they propose to systematise strong ideas, including professional teacher training with an inclusive approach and the use of relevant materials for inclusive practice, as a concrete milestone in the creation of inclusive universities.

Despite the strong policy framework presented, it is of little value to reproduce laws and articles if it is not possible to visualise the framework of a network that regulates quality in Chilean higher education and its positioning from the perspective of inclusive education with a focus on teachers. Similarly, it will be insufficient to elaborate on the concept of educational quality without relating it to the need for teacher professional development in terms of educational inclusion, recognising the supremacy of diversity.

3. TOWARDS QUALITY FROM AN INCLUSIVE PERSPECTIVE

The altruistic genesis of Chilean universities implies rethinking the concept of inclusion and the dimensions it embraces. At the same time, pedagogical practice challenges the role of the teaching staff, challenges their scientific acumen, academic freedom and vast disciplinary experience. University teachers possess attributes that enhance them within the educational community, so if they lack training in inclusive pedagogical competences and work in an institutional context that claims to be inclusive, they need to rethink inclusive education and the competences they need to work on from a new perspective.

Questioning and investigating how teachers can contribute to the creation of quality inclusive universities is central to this review, from the new perspective of the inclusive approach to education. Inclusive university education implies the institutional public declaration of being an inclusive university, however, the question arises: How do teachers contribute to this project? A possible answer to this question can be found in the words of Ainscow [5], who conceives inclusive education in a broad way as a radical political project, which requires approaching the feelings and knowledge of oppressed people, and presents it as an intentional continuous process. This implies that teachers work on developing their competences to make more room in their classrooms.

The conceptualisation of inclusive education involves the whole of society where people are challenged to contribute to the transformation of the education system. The principles of equity and equality, the right to quality education and equal opportunities for inclusive education are highlighted [9]. Gómez, [10] proposes the term inclusive education seen as a social model for transformation, which ratifies the view of Ainscow [5].

Inclusion implies providing effective opportunities so that students have the possibility to enter, learn and make progress in their university education pathway, in order to finally graduate from the institution. For this, it is essential that teachers have inclusive pedagogical competences.

4. TEACHER PROFESSIONAL DEVELOPMENT AS A CONTRIBUTION STRATEGY

This section analyses the main nodes that can be resolved in order to foster the development of inclusive teaching competences by university teaching staff and how this progress contributes to quality in inclusive education processes. As mentioned in the previous sections, inclusive education underlies quality in education and for this it is substantial to invest in human capital.

Studies carried out in Europe by Benet et al. [11] and Garabal et al. [12] have focused on the conceptualisation of inclusive universities, highlighting the practices and attitudes of teachers as a key element to be constituted, in a broad way visualising the relevance of the teacher's experience as a person and as a professional in the face of the inclusive mission.

In Latin America, research by Maldonado [13] and Zárate et al. [14] has focused on analysing the competences that non-

teaching university educators need to cultivate in order to deal with diversity and how the inclusive demand challenges university teachers in their pedagogical practices. Along the same lines, in Chile, some groups of researchers with an international alliance have done the same, including Herrera et al. [15], who have contributed by reflecting on how the implicit theories of university teachers are related to the pedagogical practices developed to deal with the heterogeneity of the university students. The American and Chilean perspectives focus on situated practice and how it contributes to the training of competent teachers in a challenging area of education.

With regard to the concept of inclusive universities, Tenorio and Ramírez [16] emphasise that Chilean institutions must assume a leadership role in order to confront the inequalities that promote exclusion and inequality, alluding to the necessary articulation between the members of their community, which includes the teaching staff. Here, the need for collaborative teamwork with institutional authorities, the establishment of strategies for curriculum implementation and its possible diversifications is observed.

By visualising the possible nodes to be solved, professional development for teachers emerges as a strategy to contribute to inclusive university environments through the development of inclusive pedagogical competences on the part of university teachers. As long as teachers are involved in continuing education programmes, their pedagogical practices improve and thus the quality of the teaching they do. The latter is confirmed by Lorenzo-Lledó [17] who concludes that it is necessary to cultivate the area of in-service training in order to improve inclusive teaching practices.

When reviewing Latin American studies, Maldonado [13], presents the results of the application of a questionnaire to determine whether university teachers are prepared to deal with heterogeneous groups and implement measures established by higher education institutions. He highlights that it is necessary to design a teaching profile that integrates different competences, and proposes 10 inclusive competences to outline it, as well as stating that it is necessary to train them under a social justice approach.

Along the same lines, in Colombia, researchers Zárate et al. [14], present as findings; the institutional promotion of guidelines on inclusive education, articulation of participatory work with students with disabilities, highlighting the axes of accessibility and communication. They indicate that teachers report not having an institutional care route for this group of students, barriers are seen, which hinder the process of achievement towards inclusive education. They recommend that the guidelines should be established by faculty, school and programme, and at the same time that they consider didactic flexibility in teaching and evaluation. They characterise inclusive pedagogical competences as a factor of teaching success and therefore of quality. They state that there is a need for teachers competent in inclusive education, and for university institutions that have training programmes in inclusive didactics. In addition to this, the local study by Cornejo [18] indicates that teachers recognise a lack of preparation in competencies for dealing with diversity.

When analysing the pedagogical practices for dealing with diversity and how teachers' perceptions affect inclusive practices, the contributions of Benet et al [11], who highlight

the key elements for dealing with diversity such as: planning, teaching development and assessment, stand out. They propose more teacher training and more institutional commitment to guarantee inclusive and quality higher education. From the position of Hernández and Ainscow [19], reflection on the creation of an inclusive university culture, inclusive policies and the development of inclusive practices are vital in the promotion of inclusive education. Herrera et al. [15] also analyse the practices from the teachers' conceptions, grouping them into three teaching strategies: those that promote meaningful learning, those that favour co-agency and those that support students in dealing with diversity. They provide arguments about the significance of the possible contributions of university teachers as central to inclusive practices.

The evidence shows feasible issues that can be addressed through the development of inclusive pedagogical competences of university teachers. It addresses the gaps involved in teachers' motivations and pedagogical altruism, not limiting them to a didactic focus but allowing them to envisage broad and reflective approach strategies, from an institutional cultural adaptation given the pedagogical reality they experience to practice situated in real context.

5. DISCUSSION

As can be seen in the previous overview, inclusive education is a central axis in the quality processes of Chilean higher education. To achieve that, the tendency is to have university teachers who are competent in inclusive education and who are substantial in the planning, implementation and evaluation of the policies that regulate the inclusive mission.

The conception of inclusive education influences situated inclusive pedagogical practices, which highlights the axis of teacher professional development. In this sense it is worth mentioning that the findings ratify the need for continuous training of university teachers in the field of inclusive education, as evidenced by Plata et. al [20].

The motivation of teachers on inclusive education requires awareness of this subject in order to encourage their professional development as teachers, which contributes to the new paradigmatic and cultural perspective of inclusive pedagogical practices.

Universities are challenged to continue to make progress in improving their quality standards and to be inclusive educational communities by stimulating teachers' professional development as a substantial strategy for bringing about change and taking charge of guaranteeing access, permanence and support for all.

In short, in order to build quality inclusive universities, it is necessary to focus on teachers and their contributions based on an academic profile that develops competences that enable them to design and implement inclusive education policies, implementing global-local policy and moving from theory to practice.

There are a variety of models that propose guidelines on how to implement inclusion in higher education, although all of them move between poles that propose inclusion in a specific or transversal way. The former refers to defining explicit and

focused spaces for the promotion of inclusive education, exemplifying, disseminating and teaching strategies on how to carry out such practices in different university environments. The second points towards a transversal immersion in all the sectors of the higher education institution, looking for the globality of policies and actions within the institution. However, it is predominantly identified that the models documented in the world aim to develop both poles at the same time, which seems to be the right intention when presented together with permanent monitoring measures, so that the proposals are adapted to the context of the higher education institution and that inclusion measures can be permanently reviewed and improved according to the demands.

Finally, this review of the case of Chile invites to disseminate the experience of implementing an inclusive policy for higher education, showing successful features from a political-educational dimension, but also posing local challenges to higher education institutions, to monitor and improve their quality of education from the perspective of inclusion.

6. REFERENCES

- [1] Ministerio de Educación, **Bases para la construcción de una Política Inclusiva en Educación Superior**. División Educación Superior, 2017. <http://dfi.mineduc.cl/usuarios/MECESUP/File/2017/eventos/C/M/seminario-taller-inclusion/documentos/Bases-Politica-Inclusiva-en-ES-dic2017.pdf>
- [2] J. Fernández, "Capacidades y competencias docentes para la inclusión del alumnado en la educación superior", **Revista de la educación superior**, Vol. 41, No. 162, 2012, pp. 9-24.
- [3] C.Valencia & O. Hernández, "El diseño universal para el aprendizaje, una alternativa para la inclusión educativa en Chile", **Atenas**, Vol. 4, No. 40, 2017, pp. 105-120.
- [4] M. Fajardo & M. Stella, "La Educación Superior Inclusiva en Algunos Países de Latinoamérica: Avances, Obstáculos y Retos", **Revista latinoamericana de educación inclusiva**, Vol 11, No. 1, 2017, pp. 171-197.
- [5] M. Ainscow, **Desarrollo de sistemas educativos inclusivos. Las respuestas a las necesidades educativas especiales en una escuela vasca inclusiva**, 2003. https://sid-inico.usal.es/idos/F8/FDO6565/mel_ainscow.pdf
- [6] Ley 21.091, Ley de Educación Superior. <https://www.bcn.cl/leychile/navegar?i=1118991&f=2019-11-21>
- [7] Ley 20.129, Ley que Regula el Sistema Nacional de aseguramiento de la calidad de la educación superior. <https://www.bcn.cl/leychile/navegar?i=1118991&f=2019-11-21http:%2F%2Fbcn.cl%2F2cvms>
- [8] Ley 20.845, Ley de inclusión escolar. <https://www.bcn.cl/leychile/navegar?i=1078172&f=2019-04-25>
- [9] G. Echeita & M. Ainscow, "La educación inclusiva como derecho: marco de referencia y pautas de acción para el desarrollo de una revolución pendiente", **Tejuelo**, Vol. 12, 2011, pp. 26-46.
- [10] N. Gómez & G. Toledo, **La institución escolar en Argentina: de la igualdad a la inclusión**. https://ridaa.unq.edu.ar/bitstream/handle/20.500.11807/300/C2_Gomez_Toledo.pdf?sequence=3 - :-:text=Se encuentran quienes aceptan y.de diferentes etnias, o preferencias
- [11] A. Benet, A. Sales & O. Moliner, "Construyendo universidades inclusivas: elementos clave de las practicas docentes", **Revista de Educación Inclusiva**, Vol. 12, No. 2,

2019, pp. 78-100.

[12] J. Garabal, T. Pousada, P. Espinosa & J. Saleta, “Attitudes as a Key Factor for Inclusion al University”, **Revista Española de Discapacidad**, Vol. 6, No. 1, 2018, pp. 181-198.

[13] E. Maldonado, “Competencias del profesorado universitario para la atención a la diversidad en la educación superior”, **Revista latinoamericana de educación inclusiva**, Vol. 12, No. 2, 2018, pp. 115-131.

[14] R. Zárate-Rueda, S. Díaz-Orozco & L. Ortiz-Guzmán, “Inclusive Higher Education: A Challenge for Pedagogical Practices”, **Revista Electrónica Educare**, Vol. 21, No. 3, 2017, pp. 1-24.

[15] C. Herrera-Seda, C. Pérez-Salas & G. Echeita, “Teorías Implícitas y Prácticas de Enseñanza que Promueven la Inclusión Educativa en la Universidad: Instrumentos y Antecedentes para la Reflexión y Discusión”, **Formación universitaria**, Vol. 9, No. 5, 2016, pp. 49-64.

[16] S. Tenorio, M. Ramírez, “Universidad Pública y discapacidad: El caso de Chile”, **Revista Perfiles Educativos**, Vol. 43, No. 172, 2021, pp. 144-159.

[17] A. Lorenzo-Lledó, G. Lorenzo, A. Lledó & E. Pérez-Vázquez, “Inclusive methodologies from the teaching perspective for improving performance in university students with disabilities”, **Journal of Technology and Science Education**, Vol. 10, No. 1, 2020, pp. 127-141.

[18] J. Cornejo, “Inclusión educativa desde la óptica de los académicos responsables de la formación de profesores de la Universidad Católica del Maule-Chile”, **Educación**, Vol. 28, No. 56, 2019, pp. 27-58.

[19] A. Hernández & M. Ainscow, “Desarrollo de una guía para promover un e-learning inclusivo en educación superior”, **Perfiles Educativos**, Vol. 42, No. 168, 2020, pp. 60-75.

[20] M. Plata, M. Gozalo, C. Gómez, S. Barrios, “Los docentes que creen en la inclusión educativa ¿Tienen una actitud favorable hacia el alumnado de altas capacidades?”, **International Journal of Developmental and Educational Psychology**, Vol. 1, No. 1, 2021, pp. 381–390.

Efficiently Solving High School Timetable Scheduling Problems with Various Neighborhood Operators

Lijian XIAO

Department of Biomedical, Industrial and Human Factors Engineering, Wright State University
Dayton, OH 45435, USA

Xinhui ZHANG

Department of Biomedical, Industrial and Human Factors Engineering, Wright State University
Dayton, OH 45435, USA

Subhashini GANAPATHY

Department of Biomedical, Industrial and Human Factors Engineering, Wright State University
Dayton, OH 45435, USA

ABSTRACT

The high school timetable scheduling problem involves assigning lectures to students, faculty, and classrooms while meeting specific constraints. This study focuses on the challenging high school course scheduling problem in China, where subject choices and complex timetable rules make finding feasible and optimal solutions difficult. By successfully addressing this complex course scheduling problem, we hope to contribute to the improvement of education systems around the world. Simulated annealing, a novel algorithm that considers soft constraints and preferences, is proposed to address this problem. The algorithm utilizes different neighborhood operators to tackle various aspects of the problem, resulting in efficient and effective solutions. The research has important implications for similar timetabling problems in the academic and practical domains.

Keywords: High School Timetabling, Simulated Annealing, Multi-objective Model.

1. INTRODUCTION

High school timetables are highly structured, with fixed schedules of classes held on specific days and times, offering little flexibility or customization options for students. This is in contrast to university or exam scheduling, where students typically have more control over their schedules. The rigid structure of high school timetables provides predictability but may limit opportunities for exploration and experimentation.

In 2017, China's Ministry of Education announced a plan to reform the high school curriculum structure and national higher education entrance examination system by 2020. Students are now encouraged to choose courses that align with their interests, selecting three mandatory subjects and one or two comprehensive tests in either science or liberal arts, as well as a basic proficiency test. This shift from a fixed set of courses to a vast range of possibilities creates complex timetabling problems for high schools, involving more than 100 courses, tens of teachers, and classrooms. Two main challenges are the need to assign subjects to teachers and students to courses, and the complex rules and preferences that schools impose for creating "good" timetables, which often have not been studied in the literature.

These timetabling problems have been particularly challenging due to two aspects. Firstly, students do not choose individual courses but choose subjects, which requires the assignment of subjects to teachers and students to courses, adding another dimension to the already complicated timetabling problem. Secondly, the complex rules and preferences proposed by schools for creating "good" timetables have not been extensively studied in the literature, further complicating the problem.

With China having the largest population in the world, thousands of students in high school, and nearly 28,000 high schools, high school course scheduling becomes highly constrained and finding feasible, let alone optimal, solutions become difficult. This research proposes a simulated annealing-based meta-heuristic algorithm to solve the Chinese high school timetabling problem. The algorithm elegantly models preferences or soft constraints, utilizes several neighborhood operators, and incorporates enhancements such as probability selection and candidate listing to guide the search process. This design enables the algorithm to efficiently and effectively solve these complicated school timetabling problems, with significant academic and practical impact on similar problems in the literature.

The remainder of the research report is organized as follows: Section 2 provides a literature review on the solution approaches for the school timetabling problem, Section 3 presents the details of the problem, Section 4 introduces the solution representation and different neighborhood operators, and Section 5 provides an example of a faculty member's schedule and a student's schedule.

2. RELATED WORK

The course scheduling problem has been the subject of study for the optimization society for many decades, and researchers are interested in applying metaheuristic-based algorithms to course scheduling problems. This may be attributed to the characteristics of metaheuristic algorithms, which can be used for very large problem types as general-purpose algorithms. For early surveys of these studies, please refer to Yang et al. [1], Pillay [2], Lewis [3], Babaei et al. [4], and Bettinelli et al. [5]. The solution approaches mainly fall into two categories: exact methods and heuristic methods. For recent advances in exact methods, please see Hao et al. [6].

This section primarily focuses on studies related to metaheuristic algorithms for the course timetabling problem. Metaheuristics, as general algorithm frameworks, can be applied to different optimization problems with minimal modifications for a specific problem, making them suitable for solving timetabling problems. Thompson et al. [7] presented a simulated annealing approach with a robust implementation for solving examination scheduling problems. OuYang et al. [8] proposed a hybrid genetic algorithm combined with Tabu search and the coloring principle for solving course scheduling problems. Hao et al. [6] presented a partition-based approach for improving lower bounds for the curriculum-based course timetabling problem. Lach et al. [9] introduced an integer programming approach for solving curriculum-based university course timetabling problems.

While one-stage optimization is flexible and easy to implement, its weight evaluation function may lead the search away from attractive or fully feasible solutions [3]. In such cases, a two-stage optimization approach could be more effective. Santiago-Mozos et al. [10] presented a two-phase heuristic algorithm for personalizing course timetables. Chiarandini et al. [11] proposed a two-phase hybrid algorithm for the university course timetabling problem, combining various construction methods, and relying on an experimental methodology called racing procedure for algorithm configuration and proper parameter settings. Causmaecker et al. [12] presented a decomposed metaheuristic approach using tabu search with three different neighborhoods to solve university course timetabling problems with overlapping time slots and irregular weekly timetables. Müller introduced a two-stage hybrid approach for solving timetabling problems, using an iterative forward search algorithm [13] in the construction phase, a hill climbing algorithm in the second phase, and the great deluge technique [14] in the third phase. Lü et al. [15] proposed an adaptive tabu search algorithm for solving the curriculum-based course timetabling problem, which is a two-stage algorithm combining an intensification phase and a diversification phase based on an iterated local search in the second stage.

In recent studies, Kheiri et al. [16] presented a stochastic search with hyper-heuristic method for solving the high school course scheduling problem. Bellio et al. [17] proposed a simulated annealing method for solving the curriculum-based course timetabling problem and designed an extensive and statistically principled methodology for the parameter tuning procedure. Kiefer et al. [18] introduced an adaptive large neighborhood search approach for the curriculum-based course timetabling problem, also applying a dynamic weight adjustment mechanism. Song et al. [19] presented a simulated annealing-based iterated local search algorithm to find feasible solutions for the university course scheduling problem. The proposed algorithm successfully found 58 feasible solutions out of a total of 60 instances within a reasonable computational time.

3. PROBLEM DESCRIPTION AND DEFINITION

The Chinese High School Course Timetabling Process

To get a better idea of the course timetabling problem and its unique characteristics, it is necessary to first introduce the curriculum selection and course formation process. This process consists of several steps, is of critical importance to the course timetabling problem, and is presented below.

Step 1: Curriculum Selection: In the first step, each student selects a set of subjects of their own interest, based on analysis of their career goals. For example, a student could select {Math, Chinese, English, Physics, Chemistry, Biology }

Step 2: Course Formation: Based on student selections, the school administration determines the number of courses to open for each of its subjects, based on the number of instructors for each subject and the size of the classrooms.

The Chinese High School Course Timetabling Problem

Several terms used in the description of the problem are formally defined below.

Sets and Indices

T Set of topics indexed by t .

F Set of faculty members indexed by f , $F(t)$ represents the set of faculty members that teaches topics t .

K Set of repeated sessions indexed by k .

D Set of days indexed by d .

P Set of time periods indexed by p .

G Set of groups of students, $T(g)$ represents the set of topics selected for student group g .

R Set of rooms indexed by r .

Parameters

$NK(f, t)$ the number of sessions a faculty member f teaches topic t , given by preprocessing and managerial adjustments.

$Mtx(g, t)$ 1 if student in group g requires topic t , 0, otherwise.

$NG(g)$ Number of students in the group g .

$NL(t)$ the number of lectures (time slots) a course in topic should offer in a week, $n(t) = 1,2,3,4,5$.

$NS(t)$ Maximum number of students allowed in instructing topic t .

$NL(d, p)$ Maximum number of lectures on certain days.

$\alpha(t, d, p)$ Penalty for not assigning topic t to day d , period p .

$\beta(t, r)$ Penalty for not assigning topic t to be in room r .

$\gamma(f, d, p)$ Penalty for not assigning faculty f to be in day d , period p .

$UB(r)$ Upper bound of capacity of each room r .

Decision Variables

$x_1(f, t, k, d, p)$ Binary variable, whether a course (f, t, k) is offered on day d period p , where $k \leq NK(f, t)$, $f \in F(t)$.

$x_2(f, t, k, r)$ Binary variable, whether a course (f, t, k) is assigned to room r .

$y(g, f, t, k)$ Binary variable, representing whether group g that is assigned to course (f, t, k) .

$z(g, f, t, k, d, p)$ Binary variable, representing number of students in group g that is assigned to course (f, t, k) on day d period p .

Minimize

$$\sum_{f,t,k,d,p} x_1(f, t, k, d, p) \alpha(t, d, p) + \sum_{f,t,k,r} x_2(f, t, k, r) \beta(t, r) + \sum_{f,t,k,d,p} x_1(f, t, k, d, p) \gamma(f, d, p) \quad \text{Eq. (1)}$$

Objective (equation 1) is to minimize the weighted sum of violating the preferred assignments: Topic-to-Period, Topic-to-Room, Faculty-to-Period.

Hard Constraints

1) (H1) a student's topic t selected in the curriculum has to be satisfied through one of the courses (f, t, k) that cover the specific topic t .

- 2) (H2) a faculty member can only teach at most one cohort at any time.
- 3) (H3) a student can only belong to one cohort at any time.
- 4) (H4) the number of cohorts offered at any time cannot exceed the number of rooms.
- 5) (H5) a course must be assigned to a classroom that can accommodate the topic.
- 6) (H6) a course must meet the specific number of times across the time horizon.
- 7) (H7) the capacity of the classroom must be observed.

Soft Constraints

- 1) (S1) a course should be offered at the preferred time slots if possible.
- 2) (S2) the number of students in each course of the same topic should be balanced.
- 3) (S3) the number of courses a faculty member teaches should be evenly distributed across the week, such as “X0X0X” for three lectures or “X0XXX” for four lectures.
- 4) (S4) the set of students with the same or similar curriculum should be assigned to similar schedules throughout the week.
- 5) (S5) teachers of the same topic or a subset of teachers should not be assigned to the same time slots so that to increase the chance of substitution if a certain teacher is absent.
- 6) (S6) if a teacher is teaching multiple sessions, it would be preferable for these sessions to follow the same progress so that teacher can align his assignments etc.

4. THE PROPOSED APPROACH WITH VARIOUS NEIGHBORHOOD OPERATORS

Simulated Annealing for the Chinese High School Course Timetabling Problem

Simulated Annealing (SA) is an iterative search procedure that aims to approximate the global optimum of a problem. SA begins with a random solution and explores the solution space by randomly selecting a neighboring solution. It accepts worse moves based on a probability determined by the increase in the cost function and the temperature parameter. In previous studies, SA has been applied to solve course scheduling problems by incorporating constraints through the addition of a penalty term to the objective function. However, the selection of which constraints to maintain feasibility and which ones to penalize depends on the specific problem. Researchers such as Thompson et al., Bellio et al. [17], Chiarandini et al. [11], and Song et al. [19] have utilized simulated annealing methods to address course scheduling problems. For a more detailed understanding of simulated annealing, please refer to the early surveys conducted by Johnson et al. [20] and Johnson et al. [21].

Three structures are used to represent the various aspects of the course scheduling problem: the a) course timetable, b) curriculum group-to-course assignment, and c) number of students in the curriculum group-to-course assignment.

A *course timetable* is represented by a two-dimensional array where the rows represent rooms (r), the columns represent time slots (d, p), and the element in the array gives the unique ID of the course (f, t, k) assigned to the room (r) in time period (d, p). An example of this schedule is shown in **Table 1**. This structure allows a concise representation of $x(f, t, k, d, f, r)$, the assignment of course (f, t, k) to room (r) in time period (d, p).

Table 1: A Two-dimensional Array for a Course Timetable or Decision Variables $x(f, t, k, d, f, r)$

| Room/Period | 1 | ... | ... | ... | 40 |
|-------------|----------|-----|-----|-----|-----|
| 1 | Course 1 | ... | ... | ... | ... |
| 2 | Course 2 | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... |
| R | Course n | ... | ... | ... | ... |

The two-dimensional array for a course timetable guarantees a feasible solution of course assignments to time slots and to the rooms, i.e., a) a course appears exactly the number of times as the number of lectures required per week (H6), b) the number of courses at any time period would not exceed the number of available rooms (H4).

A *curriculum group-to-course assignment* is also a two-dimensional array where the rows represent the student group IDs, the columns represent the course IDs, and the elements in the array are either 1 or 0, representing whether a particular curriculum group g is assigned to the corresponding course (f, t, k) or not. An example of this schedule is shown in **Table 2**. This structure allows a concise representation of $y(g, f, t, k)$, and each row represents a feasible assignment of courses to meet the curriculum group course requirement. This two-dimensional array maintains the feasibility of curriculum requirement (H1) and course lecture requirement (H6).

Table 2: A Two-dimensional Array for Curriculum Group-to-Course Assignment or $y(g, f, t, k)$

| Group ID | Course 1 | Course 2 | ... | Course n |
|----------|----------|----------|-----|----------|
| G1 | 1 | 0 | ... | 1 |
| G2 | 1 | 1 | ... | 1 |
| G3 | 0 | 1 | ... | 1 |
| ... | ... | ... | ... | ... |
| Gn | 0 | 1 | ... | 1 |

The number of students in each curriculum group is represented by a one-dimensional vector where the length of the vector is the number of curriculum groups, and the summation of the numbers is equal to the total number of students.

Constraints Maintained Feasible in the Solution Representation and Various Neighborhood Operators

As can be seen, the above solution representation maintains the feasibility of several constraints, including a) room assignment (H4), b) course lecture requirement (H6), and c) curriculum requirement (H1). However, the above solution representation does not guarantee the feasibility of constraints such as student conflicts (H3), teacher conflicts (H2), course capacity (H7), course room restrictions (H5), and soft constraints (S1 – S6).

The violations of these constraints are treated as penalty terms in the objective function. Specifically, the penalty terms for violations include: a) student conflicts, b) teacher conflicts, c) course capacity conflicts, d) course preferences in time slots, e) teacher preferences in time slots, f) course capacity balance, g) course spread, etc. The above solution representation is highly flexible and allows for the inclusion of additional soft constraints. These soft constraints can be either incorporated into the definition of the solution space or penalized in the cost function.

While solution representations cannot guarantee feasible solutions for all hard constraints, the hard constraints are considered as penalty terms in the objective function. Both hard and soft constraints are reflected in the objective function, but with different penalty coefficients based on their importance. Generally, hard constraints are assigned higher weights or penalties, and the algorithm explores neighborhood solutions accordingly, prioritizing the importance and order of the constraints.

Multiple neighborhoods are defined to operate on the various aspects of a solution to the course timetabling problem.

N1: Swap-Courses-Between-Time-Period: In this neighborhood move, two different courses (f, t, k) (one can be empty) from two different periods (d, p) in the course schedule are swapped to form a new solution. This move affects a) student group conflicts, b) teacher conflicts, c) course preference, d) number of courses appearing in the same day; yet it does not affect course capacity (as it does not affect group assignment in these courses) or course composition conflicts such as student group incompatibility etc. The size of the neighborhood is number of rooms $(|R|)$ times number of periods $(|D| \times |P|)$. An example of this neighborhood move is shown in **Table 3**.

Table 3: An example of Swap-Courses-Between-Time-Period

| | Period 1 | Period 2 | ... | Period n |
|---------------|----------------------|----------------------|-----|--------------------|
| Room 1 | English Wang, D. | English Wang, D. | ... | GT Han, D. |
| Room 2 | English Zhong, L. | English Zhong, L. | ... | Music Hu, Y. |
| Room 3 | Math Liu, F. | Math Liu, F. | ... | Music Wang, F |
| Room 4 | English Fan, J. | English Fan, J. | ... | GT Zhao, R |
| Room 5 | English Liu, X. | Math Li, B. | ... | English Liu, X. |

N1 (Math, Room 3 Period 2) →

| | Period 1 | Period 2 | ... | Period n |
|--|----------------------|----------------------|-----|--------------------|
| | English Wang, D. | English Wang, D. | ... | GT Han, D. |
| | English Zhong, L. | English Zhong, L. | ... | Music Hu, Y. |
| | Math Liu, F. | GT Zhao, R | ... | Music Wang, F |
| | English Fan, J. | English Fan, J. | ... | Math Liu, F. |
| | English Liu, X. | Math Li, B. | ... | English Liu, X. |

N2: Swap-Group-Courses-Assignment: In this neighborhood, two courses (f, t, k) of a specific topic in a group, g , are swapped in an effort to reduce the course capacity. This move affects a) student group conflicts, b) course capacity (as they do not affect group assignment in these courses), c) course composition conflicts such as student group incompatibility; yet they do not affect a) faculty conflicts in these time periods, b) course preference in these periods, and c) number of courses appearing in the same day. The size of the neighborhood is number of groups $(|G|)$ times number of topics $(|T|)$. An example of this neighborhood move is shown in **Table 4**.

Table 4: An example of Swap-Group-Courses-Assignment

| | POL 1 | POL 2 | BIO 1 | BIO 2 | N2 (Group 2 POL 1, Group 2 POL 2) |
|-----------|-------|-------|-------|-------|---|
| G1 | 1 | 0 | 1 | 0 | → |
| G2 | 1 | 0 | 1 | 0 | |
| ... | ... | ... | ... | ... | |
| Gn | 0 | 1 | 0 | 1 | |

| | POL 1 | POL 2 | BIO 1 | BIO 2 |
|-----------|-------|-------|-------|-------|
| G1 | 1 | 0 | 1 | 0 |
| G2 | 0 | 1 | 1 | 0 |
| ... | ... | ... | ... | ... |
| Gn | 0 | 1 | 0 | 1 |

N3: Split-Groups-Resize: This neighborhood operation splits or merges groups, changing their size and cardinality. While not directly affecting the objective function, it impacts classroom sizes and balance, as well as the efficiency of other moves and the overall algorithm. An example of this neighborhood move is shown in **Table 5**.

Table 5: An example of Split-Groups-Resize

| | Selection | No. Students |
|----------------|---|--------------|
| Group 1 | HIS(1) GEO(1) POL(1) PHY(2) CHE(2) BIO(2) | 19 |
| Group 2 | BIO(1) PHY(1) CHE(1) POL(2) HIS(2) GEO(2) | 13 |
| Group 3 | HIS(1) GEO(1) PHY(1) CHE(2) BIO(2) POL(2) | 12 |
| ... | ... | ... |
| Group n | GEO(1) PHY(1) CHE(1) BIO(2) POL(2) HIS(2) | 10 |

N3 (Split Group 3) →

| | Selection | No. Students |
|--|---|--------------|
| | HIS(1) GEO(1) POL(1) PHY(2) CHE(2) BIO(2) | 19 |
| | BIO(1) PHY(1) CHE(1) POL(2) HIS(2) GEO(2) | 13 |
| | HIS(1) GEO(1) PHY(1) CHE(2) BIO(2) POL(2) | 8 |
| | | 4 |
| | ... | ... |
| | GEO(1) PHY(1) CHE(1) BIO(2) POL(2) HIS(2) | 10 |

N4: Swap-All-Courses-Between-Periods: In this neighborhood, the set of all courses (f, t, k) in a time period (d, p) is swapped with the set of courses in another time period (d', p') . These moves are designed to refine the faculty and student preference and course-in-the-same-day preference. An example of this neighborhood move is shown in **Table 6**.

N5: Swap-Courses-In-Period: In this neighborhood, the set of all courses (f, t, k) in a time period (d, p) are swapped with each other in the same time period. These moves are designed to refine the room preference and seem to be extremely effective as well. An example of this neighborhood move is shown in **Table 7**.

Table 6: An example of Swap-All-Courses-Between-Periods

| | Period 1 | Period 2 | ... | Period n |
|---------------|----------------------|----------------------|-----|--------------------|
| Room 1 | English Wang, D. | English Wang, D. | ... | GT Han, D. |
| Room 2 | English Zhong, L. | English Zhong, L. | ... | Music Hu, Y. |
| Room 3 | Math Liu, F. | Math Liu, F. | ... | Music Wang, F |
| Room 4 | English Fan, J. | English Fan, J. | ... | English Fan, J. |
| Room 5 | English Liu, X. | Math Li, B. | ... | English Liu, X. |

N4
(Period 2, Period n)
→

| Period 1 | Period 2 | ... | Period n |
|----------------------|--------------------|-----|----------------------|
| English Wang, D. | GT Han, D. | ... | English Wang, D. |
| English Zhong, L. | Music Hu, Y. | ... | English Zhong, L. |
| Math Liu, F. | Music Wang, F | ... | Math Liu, F. |
| English Fan, J. | English Fan, J. | ... | English Fan, J. |
| English Liu, X. | English Liu, X. | ... | Math Li, B. |

Table 7: An example of Swap-Courses-In-Period

| | Period 1 | Period 2 | ... | Period n |
|---------------|----------------------|----------------------|-----|--------------------|
| Room 1 | English Wang, D. | English Wang, D. | ... | GT Han, D. |
| Room 2 | English Zhong, L. | English Zhong, L. | ... | Music Hu, Y. |
| Room 3 | Math Liu, F. | Math Liu, F. | ... | Music Wang, F |
| Room 4 | English Fan, J. | English Fan, J. | ... | GT Zhao, R |
| Room 5 | English Liu, X. | Math Li, B. | ... | English Liu, X. |

N5
(Period 2)
→

| Period 1 | Period 2 | ... | Period n |
|----------------------|----------------------|-----|--------------------|
| English Wang, D. | English Wang, D. | ... | GT Han, D. |
| English Zhong, L. | English Fan, J. | ... | Music Hu, Y. |
| Math Liu, F. | Math Li, B. | ... | Music Wang, F |
| English Fan, J. | Math Liu, F. | ... | GT Zhao, R |
| English Liu, X. | English Zhong, L. | ... | English Liu, X. |

The search algorithm uses various neighborhoods, each designed to operate on specific solution structures. N1, N4, and N5 operate on the course timetable array, N2 operates on the curriculum-group-to-course assignment array, and N3 operates on the curriculum group vector. The neighborhood selection is dynamic, and dynamic schedules are used to adapt the search as it progresses. Detailed designs of these schedules are not included due to space limitations.

Cooling Schedule

A simulated annealing implementation requires generating a finite sequence of decreasing temperature values, along with a finite number of state transitions (iterations) for each temperature value. This sequence of temperature values is commonly known as the cooling schedule. Currently, the scheduling proposed by Strenski and Kirkpatrick [22] is adopted.

The schedule consists of three parameters: a) an initial temperature, which must be set high enough so that any new solution generated during a state transition has a high probability of being accepted (close to 1); b) a temperature decrease function, typically an exponentially decreasing function, such as $t_k = a * t_{k-1}$, where a is a constant smaller than 1 (usually between 0.8 and 0.99); and c) a stopping criterion, which typically specifies a certain iteration count or a predefined temperature value at which the algorithm should stop.

5. AN EXAMPLE OF FINAL HIGH SCHOOL SCHEDULE

Here is another example course schedule from a medium to large-sized high school. The high school has a total of 450 students, divided into 10 cohorts, and 10 classrooms are available. There are 13 subjects in total, with 6 of them having two subtopics, Level 0 or Level 1, resulting in a total of 19 topics. Each subtopic consists of a varying number of lectures, ranging from 1 to 7.

The school follows a 5-day week schedule, with 9 periods per day, amounting to a total of 45 time slots per week per room. The curriculum is divided into 16 different groups based on the 19 topics. An example of curriculum groups is shown in **Table 8**.

Table 8: An example of curriculum groups

| Selection |
|---|
| CNC PHE CHI MAT ENG COM MTH POL(1) HIS(1) CHE(1) GEO(0) PHY(0) BIO(0) |
| CNC PHE CHI MAT ENG POL(1) PHY(1) CHE(1) HIS(0) GEO(0) BIO(0) |
| ... |
| CNC PHE CHI MAT ENG GEO(1) PHY(1) CHE(1) POL(0) HIS(0) BIO(0) |

There are 46 faculty members available, each with certain preferences. For example, Faculty member 1 cannot be assigned to certain periods due to other commitments.

One hundred runs were conducted, with an average running time of around 5000 seconds. In all runs, 100% feasible solutions were obtained. An example of Faculty member 2, who prefers not to be assigned on Fridays is shown in **Table 9**. An example of a student who has 39 lectures per week is shown in **Table 10**.

Table 9: An example schedule of Faculty 2

| Faculty 2 schedule | | Monday | Tuesday | Wednesday | Thursday | Friday |
|--------------------|----------|--------------------|--------------------|--------------------|--------------------|--------|
| Morning | Period 1 | BIO (0) Room 03 | | | | |
| | Period 2 | BIO (0) Room 04 | | | | |
| | Period 3 | BIO (1) Room 07 | | BIO (0) Room 03 | BIO (0) Room 03 | |
| | Period 4 | | | | BIO (0) Room 04 | |
| | Period 5 | | BIO (0) Room 03 | BIO (0) Room 04 | | |
| Afternoon | Period 6 | BIO (0) Room 01 | BIO (0) Room 01 | | BIO (0) Room 01 | |
| | Period 7 | | BIO (0) Room 04 | BIO (0) Room 01 | | |
| | Period 8 | | | | | |
| | Period 9 | | | | BIO (1) Room 07 | |

Table 10: An example student schedule

| Student schedule | | Monday | Tuesday | Wednesday | Thursday | Friday |
|------------------|----------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Morning | Period 1 | MAT Faculty 14 Room 8 | GEO (0) Faculty 30 Room 8 | HIS (0) Faculty 26 Room 8 | ENG Faculty 20 Room 8 | CHE (1) Faculty 37 Room 8 |
| | Period 2 | BIO (1) Faculty 40 Room 8 | BIO (1) Faculty 40 Room 8 | ENG Faculty 20 Room 8 | MAT Faculty 14 Room 8 | PHE Faculty 10 Room 8 |
| | Period 3 | POL (0) Faculty 02 Room 8 | ENG Faculty 20 Room 8 | Meeting | POL (0) Faculty 02 Room 8 | CHE (1) Faculty 37 Room 8 |
| | Period 4 | PHY (1) Faculty 33 Room 8 | PHE Faculty 10 Room 8 | Meeting | HIS (0) Faculty 26 Room 8 | GEO (0) Faculty 30 Room 8 |
| | Period 5 | CHI Faculty 05 Room 8 | HIS (0) Faculty 26 Room 8 | Meeting | CHI Faculty 05 Room 8 | ENG Faculty 20 Room 8 |
| Afternoon | Period 6 | HIS (0) Faculty 26 Room 8 | Meeting | GEO (0) Faculty 30 Room 8 | Meeting | CNC Faculty 05 Room 8 |
| | Period 7 | ENG Faculty 20 Room 8 | Meeting | POL (0) Faculty 02 Room 8 | Meeting | POL (0) Faculty 02 Room 8 |
| | Period 8 | GEO (0) Faculty 30 Room 8 | CHI Faculty 05 Room 8 | PHY (1) Faculty 33 Room 8 | MAT Faculty 14 Room 8 | MAT Faculty 14 Room 8 |
| | Period 9 | CHI Faculty 05 Room 8 | ENG Faculty 20 Room 8 | MAT Faculty 14 Room 8 | Meeting | Meeting |

6. CONCLUSION

In this research, our aim was to tackle the challenging problem of high school course scheduling, which involves satisfying numerous hard and soft constraints. To find a solution, we proposed a simulated annealing-based metaheuristic algorithm

that utilizes several neighborhood operators.

To incorporate both hard and soft constraints into the objective function, we assigned a penalty value to each constraint based on its importance. While it may not always be possible to satisfy all hard constraints during the search process, we only considered

solutions feasible if they satisfy all of them. In some cases, we had to relax some constraints to find a solution that comes as close as possible to the ideal solution.

To represent a solution, we used three structures: a two-dimensional matrix for the course timetable, another two-dimensional matrix for curriculum group-to-course assignment, and a one-dimensional vector for the number of students in each curriculum group.

We proposed five neighborhood operators to explore the solution space: Swap-Courses-Between-Time-Period, Swap-Group-Courses-Assignment, Split-Groups-Resize, Swap-All-Courses-Between-Periods, and Swap-Courses-In-Period.

We tested our algorithm on a high school with 450 students, 10 cohorts, and 10 classrooms. On average, the algorithm took around 5000 seconds to run, and we obtained 100% feasible solutions in all 100 runs. By successfully addressing this complex course scheduling problem, we hope to contribute to the improvement of education systems around the world.

7. REFERENCES

- [1] X. F. Yang, M. Ayob and M. Z. A. Nazri, "An investigation of timetable satisfaction factors for a practical university course timetabling problem," in **2017 6th International Conference on Electrical Engineering and Informatics (ICEEI)**, Langkawi, Malaysia, 2017.
- [2] N. Pillay, "A survey of school timetabling research," **Annals of Operations Research**, vol. 218, 2014, pp. 261-293.
- [3] R. Lewis, "A survey of metaheuristic-based techniques for university timetabling problems," **OR Spectrum**, vol. 30, 2008, pp. 167-190.
- [4] H. Babaei, J. Karimpour and A. Hadidi, "A survey of approaches for university course timetabling problem," **Computers & Industrial Engineering**, vol. 86, 2015, pp. 43-59.
- [5] A. Bettinelli, V. Cacchiani, R. Roberti and P. Toth, "An overview of curriculum-based course timetabling," **Top**, vol. 23, no. 2, 2015, pp. 313-349.
- [6] J.-K. Hao and U. Benlic, "Lower bounds for the ITC-2007 curriculum-based course timetabling problem," **European Journal of Operational Research**, vol. 212, no. 3, 2011, pp. 464-472.
- [7] J. M. Thompson and K. A. Dowsland, "A robust simulated annealing based examination timetabling system," **Computers & Operations Research**, vol. 25, no. 7-8, 1998, pp. 637-648.
- [8] Y. OuYang and Y. Chen, "Design of automated Course Scheduling system based on hybrid genetic algorithm," in **2011 6th International Conference on Computer Science & Education (ICCSE)**, Singapore, 2011.
- [9] G. Lach and M. E. Lübbecke, "Curriculum based course timetabling: new solutions to Udine benchmark instances," **Annals of Operations Research**, vol. 194, 2012, pp. 255-272.
- [10] R. Santiago-Mozos, S. Salcedo-Sanz, M. DePrado-Cumplido and C. Bousoño-Calzón, "A two-phase heuristic evolutionary algorithm for personalizing course timetables: a case study in a Spanish university," **Computers & Operations Research**, vol. 32, 2005, pp. 1761-1776.
- [11] M. Chiarandini, M. Birattari, K. Socha and O. Rossi-Doria, "An effective hybrid algorithm for university course timetabling," **Journal of Scheduling**, vol. 9, 2006, pp. 403-432.
- [12] P. D. Causmaecker, P. Demeester and G. V. Berghe, "A decomposed metaheuristic approach for a real-world university," **European Journal of Operational Research**, vol. 195, no. 1, 2009, pp. 307-318.
- [13] T. Müller, R. Hana and R. Barták, "Minimal perturbation problem in course timetabling," in **International Conference on the Practice and Theory of Automated Timetabling**, 2005.
- [14] G. Dueck, "New Optimization Heuristics: The Great Deluge Algorithm and the Record-to-Record Travel," **Journal of Computational Physics**, vol. 104, no. 1, 1993, pp. 86-92.
- [15] Z. Lü and J.-K. Hao, "Adaptive tabu search for course timetabling," **European Journal of Operational Research**, vol. 200, no. 1, 2010, pp. 235-244.
- [16] A. Kheiri, E. Özcan and A. J. Parkes, "A stochastic local search algorithm with adaptive acceptance for high-school timetabling," **Annals of Operations Research**, vol. 239, no. 1, 2016, pp. 135-151.
- [17] R. Bellio, S. Ceschia, L. D. Gaspero, A. Schaerf and T. Urli, "Feature-based tuning of simulated annealing applied to the curriculum-based course timetabling problem," **Computers & Operations Research**, vol. 65, 2016, pp. 83-92.
- [18] A. Kiefer, R. F. Hartl and A. Schnell, "Adaptive large neighborhood search for the curriculum-based course timetabling problem," **Annals of Operations Research**, vol. 252, 2017, pp. 255-282.
- [19] T. Song, S. Liu, X. Tang, X. Peng and M. Chen, "An iterated local search algorithm for the university course timetabling problem," **Applied Soft Computing**, vol. 68, 2018, pp. 597-608.
- [20] D. S. Johnson, C. R. Aragon, L. A. McGeoch and C. Schevon, "Optimization by Simulated Annealing: An Experimental Evaluation; Part I, Graph Partitioning," **Operations Research**, vol. 37, no. 6, 1989, pp. 865-892.
- [21] D. S. Johnson, C. R. Aragon, L. A. McGeoch and C. Schevon, "Optimization by Simulated Annealing: An Experimental Evaluation; Part II, Graph Coloring and Number Partitioning," **Operations Research**, vol. 39, no. 3, 1991, pp. 378-406.
- [22] P. Strenski and S. Kirkpatrick, "Analysis of finite length annealing schedules", **Algorithmica**, vol.6, 1991, pp.346-366.

Trans-Disciplinary Communication in the ChatGPT Age: A Systems Perspective

Jasmin COWIN

Department of TESOL/Bilingual Education, Graduate School of Education
Touro University, NY, 10036, U.S.A.

Birgit OBERER

ETCOP Institute for Interdisciplinary Research,
Klagenfurt, Austria

Cristo LEON

Office of Research & Development, New Jersey Institute of Technology
Newark, NJ, 07102-1982, U.S.A.

ABSTRACT

In recent years, Trans-Disciplinarity (TD) has become increasingly recognized as a critical concept in contemporary scholarship and practice, especially in the emerging field of the metaverse. Despite its growing importance, however, the precise origins and meanings of the term remain somewhat elusive, and its relationship to systems thinking is still poorly understood. Consequently, further research is needed to clarify the definition and application of transdisciplinarity and explore its connections with related concepts such as systems thinking. By doing so, we can gain a broader understanding of how transdisciplinary approaches can be used to address complex problems in a variety of contexts and how they can contribute to advancing knowledge and innovation across disciplinary boundaries.

Keywords: Trans-disciplinary communication, digital age, metaverses, systems thinking, ChatGPT, transformative technologies

1. INTRODUCTION

Trans-disciplinary communication is gaining increasing recognition as a critical concept in contemporary scholarship and practice, particularly in the context of the digital age and the emergence of the metaverse. As the boundaries between disciplines continue to blur, there is a growing need to explore new approaches to address complex problems and advance knowledge across disciplinary boundaries. However, transdisciplinarity's precise origins, meanings, applications, and relationship to systems thinking remain somewhat elusive. Additionally, the advent of transformative technologies, such as ChatGPT and the metaverse, presents both opportunities and challenges for Trans-Disciplinary Communication (TDC). To provide a clearer understanding of TDC and its significance in the Open AI age, this paper aims to investigate and clarify the origins and meanings of the term "Trans-Disciplinary (TD)" and its relationship to the concept of systems. By examining the term's evolution and tracing its roots in various disciplines and fields of study, we can gain insights into how it transcends disciplinary approaches and promotes integration and collaboration. Moreover, the paper will explore the relationship between trans-disciplinarity and systems thinking, highlighting the role of TDC in creating a unity of intellectual frameworks

beyond disciplinary perspectives. The authors of this paper bring diverse disciplinary lenses to the conversation. Jasmin Cowin, from the Department of TESOL/Bilingual Education at the Graduate School of Education, Touro University, NY, USA, brings insights from the field of education and the importance of considering the social sciences lens in understanding human behavior and societal structures. Birgit Oberer, founder, and board member at the ETCOP Institute for Interdisciplinary Research, Austria, contributes expertise in interdisciplinary research, entrepreneurship education, and exploring emerging technologies. Finally, Cristo Leon, from the Office of Research & Development, NJIT, Newark, NJ, USA, contributes a perspective on research and development, further enhancing the trans-disciplinary nature of this paper. In our exploration, we will also discuss the potential of transformative technologies such as ChatGPT and the metaverse in facilitating TDC and knowledge integration. These technologies offer novel opportunities for collaboration, information exchange, and problem-solving across disciplinary boundaries. First, however, addressing concerns and ethical considerations surrounding integrating artificial intelligence and its impact on language and knowledge representation is essential. This comprehensive investigation aims to understand better trans-disciplinarity and its implications for contemporary scholarship and practice. Furthermore, by exploring the relationship between TDC, systems thinking, ChatGPT, and the metaverse, we can uncover new insights into how these approaches can effectively address complex problems and foster innovation in a rapidly evolving digital landscape. Overall, this paper calls for more research and exploration in TDC, highlighting the need to develop a coherent theoretical framework and practical methodologies to guide the integration of diverse disciplines and technologies.

1.1 The significance of transdisciplinary communication in the digital age

Much confusion arises when people fail to recognize that there is a theoretical transdisciplinarity, a phenomenological transdisciplinarity, and an experimental transdisciplinarity. The word "theory" implies a general definition of transdisciplinarity and a well-defined methodology (which must be distinguished from "methods": a single methodology corresponds to a significant number of different methods). The word "phenomenology" implies the construction of models that connect the theoretical principles with the previously observed experimental data to predict further results. The word

"experimental" implies the performance of experiments that follow a well-defined procedure, allowing any researcher to obtain the same results when performing the same experiments" [1]. In the digital age, where problems often cross disciplinary boundaries, transdisciplinary communication offers a way to approach challenges from multiple angles, incorporating different perspectives and expertise. Embracing the multiple dimensions of transdisciplinarity equips scholars and practitioners with powerful tools to navigate the ever-changing landscape of knowledge and innovation, fostering collaboration and synergy across disciplines to effectively address the multifaceted problems of the modern world [2].

1.2 The authors' disciplines and lenses in the conversation

Education focuses on disciplines such as the humanities, history, natural sciences, and social sciences. Among these, the social science lens is critical for educators to understand human behavior, institutions, and structures. The social sciences seek to explore various aspects of society, including how individuals interact, how organizations function, and how social and economic systems are interdependent. This educator's lens provides unique insights into the complexities of human behavior and places learners, parents, and educational systems within the broader social and cultural contexts that influence them. It is essential to recognize that each lens provides a different perspective for exploring and understanding education, the role of educators, learners, school systems, and their roles in a multilingual, demographically diverse society. Educators develop a more comprehensive understanding of education and its complex relationship with individuals and communities through a multidisciplinary approach integrating knowledge from multiple fields. Part of the educator's lens includes discussions and projections on the implementation of new technologies such as Generative Artificial Intelligence (GAI), ChatGPT, and Metaverses to prepare learners for the complexities of the 21st-century global economy. Such discussions require a transdisciplinary approach for substantive projections and integrations of GAI and other emerging technologies while addressing concerns "...because we fear that the most popular and fashionable strain of AI - machine learning - will degrade our science and debase our ethics by incorporating into our technology a fundamentally flawed conception of language and knowledge" [2]. This paper defines AI as: "systems that exhibit intelligent behavior by analyzing their environment and taking action - with some degree of autonomy - to achieve specific goals". The lens of interdisciplinary research and entrepreneurship education provides valuable insights into the collaborative nature of transdisciplinary communication and its potential to bridge the gaps between different fields of knowledge. The focus on entrepreneurship education underscores the importance of fostering innovative and creative thinking in the spirit of transdisciplinarity in the search for novel approaches to complex problems. In addition, the emerging technologies perspective will shed light on the impact of transformative technologies such as ChatGPT and the metaverse on communication, collaboration, and knowledge integration. By examining how these cutting-edge technologies intersect with the concept of transdisciplinarity, the paper can illuminate their potential role in facilitating knowledge-sharing and problem-solving across disciplinary boundaries. The transdisciplinary lens opens avenues for practical applications and innovative solutions by exploring how transformative technologies such as ChatGPT and the Metaverse can facilitate effective knowledge sharing and problem-solving across disciplinary boundaries. By understanding the potential of these technologies to foster

collaboration and information sharing, researchers and practitioners can explore new ways to address complex challenges and advance knowledge in diverse fields, leading to progress and innovation in the digital age [3], [4]. Building on the interdisciplinary lens, the concept of Trans-Disciplinary Communication (TDC) takes this further by fostering knowledge production through the integration and collaboration of diverse academic, non-academic, and community members. According to Misra and Lotrecchiano [5], TDC addresses far-reaching societal implications, such as environmental denudation, climate change, and health disparities, and produces knowledge that integrates a range of perspectives, theories, methods, and tools. Its foundation in Complex Adaptive Systems allows for a nuanced understanding of both interactive systemic complexities and structural, systemic complexities. Importantly, communication is viewed as the essence of TDC, enabling individual and team-level cognitive shifts and facilitating the iterative process of interaction, observation, and reflection. This approach promotes collective thinking and problem-solving, signifying its potential to drive innovative solutions in the rapidly evolving digital landscape.

2. ETYMOLOGY OF THE TERM TRANS-DISCIPLINARY

The term "Trans-Disciplinary" finds its origins in the Latin prefix "trans," meaning "across" or "beyond," and the word "disciplinary," which refers to a specific field of study or knowledge domain. Transdisciplinarity emerged as a response to the limitations of traditional disciplinary boundaries, where individual fields of study often operate independently, leading to fragmented approaches in addressing complex real-world problems. The use of the term transdisciplinarity can be traced back to the early 20th century, gaining more prominence in academic discourse in the latter half of the century. It was initially employed in discussions related to philosophy and epistemology, particularly in the works of French philosopher Jean Piaget and Swiss philosopher Jean Gebser [6], [7]. Transdisciplinarity aims to transcend the boundaries of disciplinary silos by fostering collaboration and integration across different fields of knowledge. As transdisciplinarity gained recognition, scholars from various disciplines began to explore its practical applications, integrating it into areas as diverse as environmental studies, urban planning, and health care. The term's etymology embodies the idea of crossing disciplinary boundaries and signifies the importance of thinking beyond the boundaries of singular fields of knowledge. In recent years, the emergence of the metaverse and transformative technologies has further underscored the need for transdisciplinary approaches. The interconnected nature of the metaverse blurs the boundaries between virtual and physical realities, requiring the collaborative efforts of experts in multiple fields to fully understand its societal, cultural, and ethical implications [8], [9].

2.1 Definition and transcendence of transdisciplinary

Transdisciplinarity is an approach that crosses disciplinary boundaries to address complex issues that cannot be adequately addressed within a single discipline. It involves the integration of knowledge, methods, and perspectives from different disciplines to gain a comprehensive understanding of the subject. Transdisciplinary research emphasizes collaboration among scholars from diverse backgrounds, promoting a holistic understanding of complex phenomena and fostering innovative solutions. As the term evolves in contemporary scholarship,

embracing transdisciplinarity allows scholars to overcome the limitations of traditional disciplinary boundaries, enabling transformative solutions in the rapidly changing digital landscape [1], [10].

2.2 The communication and communicative cycle

Effective communication plays a central role in transdisciplinary endeavors. The communication cycle within transdisciplinary projects involves a continuous exchange of ideas, knowledge, and perspectives among stakeholders from different disciplines. This cycle typically involves four key stages: information sharing, interpretation, integration, and co-creation. Information sharing involves exchanging disciplinary insights, data, and methodologies among team members to foster a common understanding of the subject matter. The interpretation phase consists in analyzing and synthesizing information from multiple sources and identifying patterns, commonalities, and divergences among disciplinary perspectives. In the integration stage, stakeholders combine and harmonize different knowledge domains, seeking connections and intersections that lead to a complete understanding of the research problem. Finally, co-creation involves developing novel solutions, frameworks, or methods that emerge from integrated knowledge and contribute to advancing transdisciplinary knowledge. Effective communication strategies are essential throughout the communication cycle to ensure that diverse stakeholders can share their expertise openly and respectfully. Active listening, empathy, and openness to different points of view are critical to fostering a collaborative and inclusive environment where ideas from various disciplines are valued and integrated. In addition, the communication cycle in transdisciplinary projects often involves iterative processes in which feedback and insights from team members continually shape and refine the collective understanding of the research problem. This iterative approach promotes continuous learning and adaptation, allowing the team to build on previous insights and discoveries, leading to more robust and innovative results. In addition, communication within transdisciplinary efforts extends beyond the boundaries of the research team to include engagement with external stakeholders such as policymakers, practitioners, and community members. By incorporating diverse perspectives from outside academia, transdisciplinary projects can more effectively address real-world challenges and ensure the relevance and applicability of their findings.

2.3 Theoretical framework

The concept of transdisciplinarity emerged in the latter half of the 20th century in response to the limitations of traditional disciplinary boundaries and the recognition of the need for a more integrated approach to study, analysis, and collaboration across disciplines to address and solve complex problems. Transdisciplinary approaches aim to bridge the gaps between disciplines to foster collaboration and knowledge sharing. The goal is to transcend the boundaries of individual disciplines and create a shared understanding of complex phenomena that cannot be adequately addressed from a single disciplinary perspective. The term "transdisciplinary" and its use and development can be traced back to several key thinkers and movements. Jean Piaget, a Swiss psychologist, educator, and philosopher, founded the International Center for Genetic Epistemology in 1955. He identified himself as a genetic epistemologist. Piaget stated in Genetic Epistemology, "...the second feature of genetic epistemology that we wish to emphasize is its interdisciplinary

character" [11]. Thus, the theoretical framework underpinning transdisciplinarity draws from various intellectual traditions, including philosophy, systems theory, and epistemology. Key theoretical elements include interconnectedness, holism, emergence, and complexity. Philosophically, transdisciplinarity aligns with a holistic worldview that recognizes the interconnectedness of all phenomena. It challenges reductionist approaches by considering the whole as more than the sum of its parts and emphasizes the importance of understanding relationships and contexts. Systems theory serves as a fundamental basis for transdisciplinary thinking. It posits that complex phenomena are best understood as systems with interrelated components. Transdisciplinary projects often employ systems thinking to analyze the interactions and interdependencies among disciplinary elements, facilitating a unified understanding of the research problem. Epistemologically, transdisciplinarity recognizes the diversity of ways in which knowledge is produced and valued. It identifies the value of both empirical and experiential knowledge and seeks to incorporate diverse ways of knowing into research and problem-solving processes. The theoretical framework of transdisciplinarity provides a robust basis for integrating knowledge and fostering collaboration across disciplinary boundaries, enabling scholars and practitioners to address complex challenges with innovative and comprehensive approaches.

3. The relationship between systems and transdisciplinary

A central concern of Nicolescu, a Romanian-born physicist, philosopher, and major proponent of transdisciplinarity, was the enforced separation between the material world studied by the natural sciences and the lived world experienced by human beings. He believed that this separation, coupled with the exclusion of spiritual and sacred dimensions, contributed to the alienation of individuals from their environment and a lack of meaningful connection to the world around them. By bridging the gap between the objective and subjective realms, transdisciplinarity aims to foster a deeper understanding of the interconnectedness and interdependence of all phenomena. In summary, Nicolescu's approach to transdisciplinarity addresses the separation of Human vs. Artificial Intelligence, Generative AI, ChatGPT as he speaks to and about the limitations of modern science, challenges the dominance of scientism, and seeks to integrate the material and lived worlds to create a more comprehensive and harmonious understanding of reality. In doing so, he hoped to offer a more sustainable and enriching vision of human existence that considered the physical aspects of the universe and the spiritual, ethical, and cultural dimensions. The "Transdisciplinarity wheel" [12], attempts to visualize the various components and levels of knowledge integration [13]. We need to challenge the widespread implementation of AI in our lives, just as Nicolescu challenges scientism. Understanding the broader implications of AI and its relationship to humanity, including the opaque nature of AI algorithms, requires a holistic approach, this will assist us in understanding the TDC space and its relation to cultural objects and real objects [14]. Transdisciplinarity can help us understand AI's societal, ethical, and philosophical dimensions. AI is a multidisciplinary field, and addressing its complex challenges requires collaboration and integrating insights from different disciplines. Ethical considerations are critical, and examining the impact of AI on society, education, privacy, employment, and human rights requires perspectives beyond the technical. In this endeavor, specialists from different fields can contribute to debates about human-machine interaction, including considerations of trust,

empathy, and the impact on human identity and cognition. As we navigate the age of AI, the transdisciplinary approach has significant relevance in addressing the spiritual, emotional, and cultural aspects affected by AI and human-machine interactions, as well as the potential neglect of spirituality and aesthetics in AI development. Overall, embracing transdisciplinarity can help us understand and navigate this multifaceted landscape of AI's impact on our lives.

3. THE ROLE OF TRANSDISCIPLINARY COMMUNICATION IN UNIFYING INTELLECTUAL FRAMEWORKS BEYOND DISCIPLINES.

Nicolescu in his *La transdisciplinarité, manifeste* states that there are three axioms of the methodology of transdisciplinarity [1], [15]:

"The ontological axiom: There are, in Nature and in our knowledge of Nature, different levels of Reality of the Object and, correspondingly, different levels of Reality of the Subject. ii. The logical axiom: The passage from one level of Reality to another is made possible by the logic of the included middle. iii. The epistemological axiom: The structure of the totality of levels of Reality is a complex structure: every level is what it is because all the levels exist at the same time"

1. The ontological axiom: This axiom posits that both in the natural world (Nature) and in our understanding of it (our knowledge of Nature), there exist various levels of reality for both objects and subjects. In other words, reality is not a singular, uniform entity; instead, it comprises different layers or levels. These levels can be seen as hierarchical or nested, with each level possessing its own distinct characteristics and properties. For instance, in the study of living beings, there are different levels of reality, such as subatomic particles, atoms, molecules, cells, organisms, and ecosystems. Similarly, in terms of knowledge, our understanding of these living beings exists on various levels of complexity, ranging from simple observations to sophisticated scientific theories.

2. The logical axiom: This axiom suggests that the transition or movement from one level of reality to another is facilitated by the principle of the "included middle." The principle of the included middle, also known as the law of excluded middle, is a fundamental logical principle that states that a statement is either true or false, with no middle ground or third option. In the context of these axioms, the principle of the included middle implies that there are no abrupt discontinuities between different levels of reality. Instead, there are intermediate steps or gradual progressions that allow us to move from one level to another. This logical connection between levels ensures coherence and consistency in understanding the world and its complexity.

3. The epistemological axiom: The epistemological axiom deals with the nature of knowledge and how it relates to the totality of levels of reality. It asserts that the structure of reality, with its different levels, is a complex and interconnected system. Each level of reality is influenced and shaped by the existence of all the other levels simultaneously.

In practical terms, this means that understanding any level of reality requires considering its interactions and connections with all other levels. No level exists in isolation, and each contributes to the overall understanding of the system. For example, studying how individual species interact within an ecosystem requires

considering the entire ecological network to grasp the complexity of their relationships, as shown in the "Trans-Disciplinary Communication (TDC) Logarithmic Spiral" [16]. The three axioms provide a philosophical framework for understanding the complex nature of reality and knowledge. They emphasize the existence of different levels of reality, the logical continuity between them, and the interconnectedness of all levels in shaping our holistic understanding of the world. The International Transdisciplinarity Conference which took place in Zurich, Switzerland, spanned from February 27 to March 1, 2000. This seminal conference served as an international gathering for sharing the most current knowledge within the emerging international transdisciplinarity community. According to the conference book *Transdisciplinarity: Joint Problem Solving among Science, Technology, and Society an Effective Way for Managing Complexity*.

"Transdisciplinarity is a new form of learning and problem-solving involving cooperation among different parts of society. Transdisciplinarity research starts from tangible, real-world problems. Solutions are devised in collaboration with multiple stakeholders. A practice-oriented approach, transdisciplinarity, is not confined to a close circle of scientific experts, professional journals, and academic departments where knowledge is produced. Ideally, everyone who has something to say about a particular problem and is willing to participate, can play a role. Through mutual learning, the knowledge of multiple participants is enhanced, including local knowledge, scientific knowledge and the knowledge of industries, businesses, and NGO's. The sum of this knowledge will be greater than the knowledge of any single partner. In the process the bias of each perspective will also be minimized." [17]. The notion of transdisciplinarity remains in constant flux, with diverse interpretations and variations persisting.

4. CHATGPT AND THE METAVERSE

ChatGPT, an AI-driven language model, can produce human-like text that serves various purposes within the metaverses: shared virtual worlds. "Another use of GPT in the metaverse is the creation of interactive experiences in virtual reality. GPT could record and generate responses to user input, allowing users to participate in virtual games, events, or movies where GPT could create unique responses and risks for each user." As we move into the 2020s, there is a growing trend across disciplines toward personalized and individualized instruction using multimedia technologies, AI, avatars, and simulations in metaverses or other 3D environments. The term "metaverse" was first coined by Neal Stephenson in his 1992 science fiction novel *Snow Crash*, which describes a vision of the physical universe merging with a virtual one. In the novel, the protagonist accesses the metaverse by donning goggles and headphones to appear in the digital world as a customized avatar. Today, virtual reality (VR) technology is defined as "a technical system through which a [single] user or multiple users can experience a simulated environment" [18]. VR is beneficial for transdisciplinary discussions and interactions as it can provide valuable context for configuring and contextualizing experiences [19]. History will show whether customized metaverses such as *Agora World* (see Figure 1) offer new possibilities for creating exclusive educational ecosystems tailored to personalized educational experiences.

Within metaverses, additional ChatGPT applications can create interactive experiences such as recording and generating individualized responses to user input, enabling the creation of personalized educational experiences, lectures, games, events, shopping, and training.

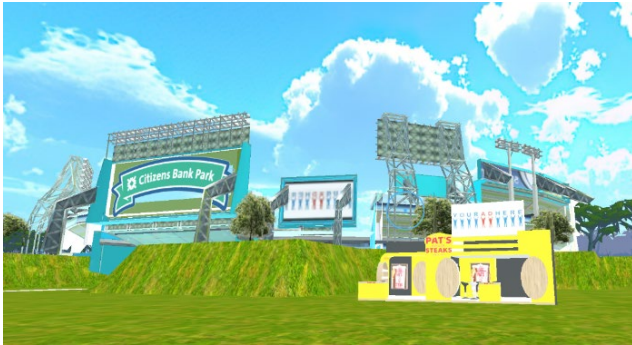


Figure 1.- Agora World Screenshot

4.1 ChatGPT as a meta-communication tool and its functions

While ChatGPT is increasingly being used as a meta-communication tool to facilitate interactions between individuals who generate human-like text, often enabling users to convey complex ideas, emotions, and information effectively, "we don't yet know the limits of these models. All of this could mean sweeping changes in how - and what - work is done in the near future." But ChatGPT can also hallucinate and generate inappropriate or inaccurate responses. "It literally doesn't know what it doesn't know, because it's not really an entity at all, but rather a complex algorithm that generates meaningful sentences." Because AI is devoid of ethos and pathos, it does not understand the nuances of human communication, leading to misunderstandings or misinterpretations that hinder the development of interpersonal and transdisciplinary communication skills. Dr. Malik Sallam in his article "ChatGPT Utility in Healthcare Education, Research, and Practice: Systematic Review on the Promising Perspectives and Valid Concerns" [20] states that concerns include ethical, copyright, and transparency issues, as well as potential legal issues. In addition, there were concerns about biased responses, plagiarism, potential lack of originality, inaccurate content that could lead to misunderstanding, limited knowledge, incorrect citations, cybersecurity vulnerabilities, and the risk of contributing to the "spread of misinformation" [21].

4.2 The potential of ChatGPT and the Metaverse for transdisciplinary communication and knowledge integration.

Transdisciplinarity can significantly impact education and educators in several ways, as educators should integrate diverse subjects and perspectives into their teaching, emphasize the interconnectedness of knowledge, and foster a deeper understanding of the world and its complexities. With an emphasis on critical thinking, educators can encourage students to explore different viewpoints and engage with different disciplines to find comprehensive solutions to real-world problems. Classrooms around the world are increasingly focused on solving real-world problems, such as climate change, that are inherently complex and interconnected. The need for students to empathize with others, to value diverse perspectives and cultures, to understand how events around the world are interconnected,

and to solve problems that transcend borders has never been greater," said Ariel Tichnor-Wagner, Senior Fellow of Global Competence at ASCD. "Because transdisciplinarity emphasizes the interdependence of different aspects of knowledge and existence, educators can inspire students to see the connections between different subjects and the world, fostering a sense of interconnectedness that promotes empathy and a broader worldview."

5. FUTURE OF TRANSDISCIPLINARY COMMUNICATION

The anticipated influence of transdisciplinary communication (TDC) on society and knowledge production emphasizes the importance of cross-disciplinary collaboration, particularly when addressing complex challenges. This section initially presents a discussion on the future of TDC, then shifts its attention to highlighting technology's role in fostering this form of communication. Specific focus is placed on artificial intelligence (AI), including models like ChatGPT, and the concept of the Metaverse. The discourse traces key technological milestones, starting from the Gutenberg press to the advent of the World Wide Web, and further explores the role of contemporary AI and virtual reality (VR) technologies. It underscores how these technologies can bridge the gaps between disciplines characterized by specialized knowledge and a group of practitioners, thereby enabling more personalized and individualized instruction and collaboration.

5.1 The future of transdisciplinary communication and how it can shape knowledge production and Problem-solving in Society

The future of transdisciplinary communication can profoundly impact knowledge production and problem-solving in society by bringing together researchers from different disciplines and stakeholders from outside academia to address complex, real-world problems. By fostering collaboration between experts from various fields, transdisciplinary approaches can lead to innovative solutions to pressing complex challenges. Such an integrative approach promotes a holistic understanding of problems and enables researchers and practitioners to address multifaceted issues that transcend disciplinary boundaries. In addition, the future of transdisciplinary communication is closely linked to advances in transformative technologies that can further enhance knowledge production and problem-solving. The integration of artificial intelligence, big data analytics, and virtual collaboration tools can facilitate seamless information sharing, analysis, and synthesis across disciplines, enabling researchers to explore complex issues with unprecedented depth and efficiency [22].

5.2 The role of ChatGPT and the Metaverse in shaping the future of Trans-Disciplinary Communication

Throughout history, technology has played an essential role in developing transdisciplinarity. The ancient abacus, the pencil, and the Gutenberg press were significant milestones in developing transdisciplinary technology and the resulting innovative solutions. The advent of the World Wide Web in the 1990s brought a new generation of digital tools that expanded transdisciplinary communication capabilities and personal enrichment. Wang and Pratt-Johnson [4] predicted that digital exploration would eventually replace the frustrating task of memorizing obscure phrases with collaborative, digital explorations of history, culture, and meaning across disciplines. However, as Ryszard Kapuściński warns in *Shah of Shahs*, "Development is a treacherous river, as anyone who plunges into

its currents knows." To begin the conversation about "disciplines," it is necessary to come to a common understanding of what "discipline" means. Examples of disciplines include English literature, dance, philosophy, physics, and computer graphics technology. According to Petrie's seminal article, "Interdisciplinary Education: Are We Facing Insurmountable Opportunities?" [3]. A discipline is now characterized by several factors, including the specialization of knowledge within a larger unit of cognitive endeavor, the use of common metaphors and concepts to define the field of inquiry, a particular set of categories of observation for structuring experience in the field, specialized methods of inquiry, a means of determining truth or justification for claims made within the field, and a sense of purpose for studying the field. In addition, a discipline comprises an organized group of people who study the field, train other practitioners, and form a social mechanism for arbitrating truth claims within the field. As we move into the 2020s, there is a growing trend across disciplines toward personalized and individualized instruction using multimedia technologies, artificial intelligence (AI), avatars, and simulations in metaverses or other 3D environments. Today, virtual reality (VR) technology is defined as "a technical system through which a [single] user or multiple users can experience a simulated environment" [18]. What is a virtual world? VR is useful for transdisciplinary discussion and interaction because it can provide valuable context for configuring and contextualizing experiences [18]. Dalgarno and Lee in "What are the learning affordances of 3-D virtual environments?" [19] identified five main benefits of VR for language learning, including expanding spatial knowledge of visual stimuli, allowing learners to experience tasks that would not be possible in the real world, increasing motivation and engagement, providing opportunities for contextualized learning, and facilitating collaborative learning.

6. CONCLUSION – THE ALPHA AND THE OMEGA?

The convergence of transdisciplinary communication, AI, ChatGPT, and metaverses can usher in an era of enhanced connectivity or a descent into the "realm ... of those who have rejected spiritual values of those who have rejected spiritual values by yielding to bestial appetites or violence, or by perverting their human intellect to fraud or malice toward their fellow man" The Alpha promises that knowledge, rather than being confined to disciplinary boundaries, will serve as a unifying element, driving progress and facilitating global problem solving on an unprecedented scale [23]. We are on the brink of a technological revolution that will fundamentally change how we live, work, and relate to one another. The transformation will be unlike anything humanity has experienced before in its scale, scope, and complexity. We do not yet know how it will unfold. Still, one thing is clear: the response to it must be integrated and comprehensive, involving all stakeholders in the global polity, from the public and private sectors to academia and civil society [23]. This symbiosis of technology and communication can transform our approach to complex global issues, fostering greater collaboration and cross-cultural understanding [23]. However, by rereading and reflecting on Dante Alighieri's 14th-century *Inferno*, we can connect the themes of human behavior, sin, and redemption that remain universal and relevant to the alpha and Omega of technological advancement. By considering the potential of technology and communication technology, GAI, ChatGPT, and metaverses can take us on a "Dantesque" Oppenheimer's allegorical journey toward the Omega, the tomb of our humanity. The future will show if our current trajectory of new technologies will be

adopted or go the way of the Skladanowsky Bioscope. In summary, we can draw parallels and interpretations to consider how technology and communication might impact societal and global transformations.

6.1 An urgent call to action and further research

Philosopher Yuval Harai warns in his keynote, "AI and the Future of Humanity" [24], that AI will become a "one-stop oracle" capable of creating intimate relationships with us while manipulating our deepest thoughts and emotions. Cultural dimensions play a role in interpreting and understanding contextual cues with gestures, symbols, or metaphors that have different meanings in different cultures. However, ChatGPT's ability to capture and accurately analyze cultural context depends on the diversity and representation of cultural data in its training. It is unclear whether ChatGPT's and GAI's "black box" model considers and respects the different perspectives, beliefs, and values of individuals from different cultures. "AI black boxes refer to AI systems with inner workings that are invisible to the user. You can feed them input and get output, but you cannot examine the system's code or the logic that produced the output." Therefore, ChatGPT's responses reflect cultural biases or norms embedded in its training data and algorithms.

The query in ChatGPT: Who trained ChatGPT answers obliquely:

ChatGPT

ChatGPT was trained by OpenAI. The training process involved a large team of researchers and engineers working on various aspects of the model, but the specifics of individual contributors have not been publicly disclosed. The model is based on the GPT-3.5 architecture, which is an improved version of the GPT-3 model. The training process typically involves using a massive dataset and computational resources to optimize the model's parameters and fine-tune its performance.

To use a metaphor, we do not want to build a bridge between disciplines because transdisciplinarity holds that everything happens in the space between fields. There are three tasks for transdisciplinary bridge-builders: 1. Build cultural bridges, 2. Use dialog and negotiation to build bridges, and 3. Use the bridge to challenge perceptions. Transdisciplinary communication facilitates a dynamic exchange of ideas, methods, and data across disciplines, promoting a comprehensive perspective that traditional approaches often overlook, such as "purposeful collaborative processes of knowledge production among researchers from different disciplines, inter- and transdisciplinary fields, and representatives of the private and public sectors, including civil society." In conclusion, when examining the ethical implications of a technology like GAI and ChatGPT in different nations, it is critical to consider the specific cultural values, norms, and legal frameworks that shape national landscapes' ethical and legal idiosyncrasies. These include factors such as privacy laws, cultural sensitivities, societal expectations, and individual rights. In Austria and Germany, for example, robust data protection laws play an important role in shaping ethical discussions and privacy and data handling practices. Overall, the authors believe there is a need for inter-, multi-, and transdisciplinary discussion to foster robust collaboration between technical, engineering, and social sciences and stakeholders to create meaningful guardrails for ChatGPT, GAI, and metaverses.

7. REFERENCES

- [1] B. Nicolescu, "Multidisciplinarity, Interdisciplinarity, Indisciplinarity, and Transdisciplinarity: Similarities and Differences," *RCC Perspectives*, no. 2, pp. 19–26, 2014.
- [2] N. Chomsky, I. Roberts, and J. Watumull, "Noam Chomsky: The False Promise of ChatGPT," *The New York Times*, Mar. 08, 2023. Accessed: May 10, 2023. [Online]. Available: <https://www.nytimes.com/2023/03/08/opinion/noam-chomsky-chatgpt-ai.html>
- [3] H. G. Petrie, "Interdisciplinary Education: Are We Faced with Insurmountable Opportunities?," *Review of Research in Education*, vol. 18, pp. 299–333, 1992, doi: 10.2307/1167302.
- [4] M. Wang and Y. Pratt-Johnson, "Using Historical Insight and Digital Tools to Teach Idioms to L2 Learners A Response to Carla Zimmerman-Edison's "Teaching and Learning English Idioms in the L2 Classroom," *NYS TESOL Journal*, vol. 4, no. 2, pp. 86–89, Jul. 2017.
- [5] S. Misra and G. R. Lotrecchiano, "Transdisciplinary Communication: Introduction to the Special Issue," *InformingSciJ*, vol. 21, pp. 041–050, 2018, doi: 10.28945/4079.
- [6] L. Apostel *et al.*, "Interdisciplinarity Problems of Teaching and Research in Universities," OECD Publications Center, Suite 1207, 1750 Pennsylvania Avenue, N, Paris: Organization for Economic Co-operation and Development., 1972.
- [7] J. Piaget, "The Epistemology of Interdisciplinary Relationships," in *Interdisciplinarity Problems of Teaching and Research in Universities*, OECD Publications Center, Suite 1207, 1750 Pennsylvania Avenue, N, 1972, pp. 127–139.
- [8] B. Nicolescu, "Methodology of Transdisciplinarity," *World Futures*, vol. 70, no. 3–4, pp. 186–199, May 2014, doi: 10.1080/02604027.2014.934631.
- [9] A. H. Toomey, N. Markusson, E. Adams, and B. Brockett, "Inter- and Trans-disciplinary Research: A Critical Perspective," Lancaster University, Lancaster Environment Centre, 2015. [Online]. Available: <https://sustainabledevelopment.un.org/content/document/s/612558-Inter-%20and%20Trans-disciplinary%20Research%20-%20A%20Critical%20Perspective.pdf>
- [10] R. C. Scharff and D. A. Stone, "Transdisciplinarity Without Method: On Being Interdisciplinary in a Technoscientific World," *Hum Stud*, vol. 45, no. 1, pp. 1–25, Mar. 2022, doi: 10.1007/s10746-021-09616-0.
- [11] J. Piaget, *The Principles of Genetic Epistemology: Selected Works vol 7*, Reprint of 1972 Edition., vol. 7. Routledge, 1972.
- [12] J. Cowin, "Transdisciplinarity Wheel," Open Science Framework, USA, Aug. 06, 2023. Accessed: Aug. 06, 2023. [Online]. Available: <https://osf.io/https://osf.io/daz6p>
- [13] A. W. Russell, F. Wickson, and A. L. Carew, "Transdisciplinarity: Context, contradictions, and capacity," *Futures*, vol. 40, no. 5, pp. 460–472, Jun. 2008, doi: 10.1016/j.futures.2007.10.005.
- [14] C. Leon, "Trans-Disciplinarity Communication Space," Open Science Framework, USA, Aug. 06, 2023. Accessed: Aug. 06, 2023. [Online]. Available: <https://osf.io/khv7s>
- [15] B. Nicolescu, *Manifesto of Transdisciplinarity*. SUNY Press, 2002.
- [16] J. Cowin, "Trans-Disciplinary Communication (TDC) Logarithmic Spiral," *Dr. J's Education Blog*, Aug. 04, 2023. <https://drcowinj.files.wordpress.com/2023/08/transdisciplinary-communication-spiral.jpg?w=1200> (accessed Aug. 06, 2023).
- [17] J. T. Klein, R. Häberli, R. W. Scholz, W. Grossenbacher-Mansuy, A. Bill, and M. Welti, Eds., *Transdisciplinarity: Joint Problem Solving among Science, Technology, and Society*. Basel: Birkhäuser Basel, 2001. doi: 10.1007/978-3-0348-8419-8.
- [18] C. Girvan, "What is a virtual world? Definition and classification," *Education Tech Research Dev*, vol. 66, no. 5, pp. 1087–1100, Oct. 2018, doi: 10.1007/s11423-018-9577-y.
- [19] B. Dalgarno and M. J. W. Lee, "What are the learning affordances of 3-D virtual environments?," *British Journal of Educational Technology*, vol. 41, no. 1, pp. 10–32, 2010, doi: 10.1111/j.1467-8535.2009.01038.x.
- [20] M. Sallam, "ChatGPT Utility in Healthcare Education, Research, and Practice: Systematic Review on the Promising Perspectives and Valid Concerns," *Healthcare*, vol. 11, no. 6, Art. no. 6, Jan. 2023, doi: 10.3390/healthcare11060887.
- [21] D. Caled and M. J. Silva, "Digital media and misinformation: An outlook on multidisciplinary strategies against manipulation," *J Comput Soc Sc*, vol. 5, no. 1, pp. 123–159, May 2022, doi: 10.1007/s42001-021-00118-8.
- [22] R. Frodeman, J. T. Klein, and R. C. D. S. Pacheco, Eds., *The Oxford Handbook of Interdisciplinarity*, 2nd ed. Oxford, United Kingdom: Oxford University Press, 2017.
- [23] K. Schwab, *The Fourth Industrial Revolution*, Illustrated edition. Geneva, Switzerland: Currency, 2017.
- [24] *AI and the Future of Humanity*, (May 14, 2023). Accessed: Aug. 02, 2023. [Online Video]. Available: <https://www.youtube.com/watch?v=LWiM-LuRe6w>

Codesign a Digital Mental Health Application to Promote Young People's Cyber-Behavioral Competence and Sustain their Wellbeing: A Literature Review

Areej ELSAYARY

College of Interdisciplinary, Zayed University
Abu Dhabi, United Arab Emirates

ABSTRACT

The global COVID-19 pandemic has increased the population's fear, anxiety, stress, and depression. Learners in schools and universities are the most affected as they face strict lockdown measures and have fewer resources to cope with it. After the traumas of the pandemic, well-being has assumed greater importance in individuals' work and social lives. In order to navigate this changing world, there is a need for an approach that tackles problems and generates successful outcomes. Young people and adolescents need positive thinking inspiration and sustain a well-being mindset. Technology is designed to influence and change human behavior with a focus on positive outcomes: promoting physical activity, healthy eating, quitting smoking, and coping with dementia, stress, anxiety, and depression. Accordingly, this paper discusses the literature on the impact of codesigning a digital mental health intervention on promoting young people and adolescents' positive thinking and sustaining their well-being mindset.

Keywords: Digital Mental Health Application, Well-being, Cyber-behavioral Competence

1. INTRODUCTION

In 2019, before the pandemic, it was reported in the Arab Youth Survey that 54% of young Arabs believe that it is difficult to access medical care for mental illnesses such as anxiety or depression [1]. In 2022, the Economist Impact report stated that neuropsychiatric disorders contribute an estimated 19.9% of the burden of disease in the UAE and 75% of these psychological conditions are associated with depression and anxiety [2]. A previous study mentioned that students are more likely to experience depression and anxiety than the general population [3]. World Health Organization WHO [4] stated that 50% of mental health problems start by age 14 and 75% by age 24. Given that 34% of the UAE population is under age of 25, mental health promotion, prevention, intervention, and treatment are on the agenda of government authorities [5].

One of the policy recommendations stated by Mohamed Bin Rashed School of Government in UAE is the use of digital intervention, prevention, or treatment for mental health problems to reduce stress, depression, and anxiety, as well as the usability and feasibility of mobile applications. In addition, digital interventions promote individuals' self-management, symptom monitoring, evidence-informed education [6], and opportunities for peer support and information sharing [7]. In order to navigate this changing world, there is a need for an intervention that tackles problems and generates successful outcomes. Some studies mentioned the importance of using the design thinking process to codesign a digital intervention to solve individuals' problems and improve their well-being [8, 9]. Previous studies suggested that when individuals were engaged in the codesign thinking process to design a digital intervention to solve their problems and maintain positive thinking, they were most likely to use this digital intervention [9, 10]. Therefore, students must

develop mindsets that enable them to solve their problems unconsciously, manage their mental health problems, and sustain their well-being [10]. Accordingly, students' input is essential in codesigning the digital intervention that meets their needs and allows them to monitor and improve their well-being as part of the positive education programs implemented in schools. This paper aims to discuss different literature on the impact of codesigning a digital mental health intervention on promoting young people and adolescents' positive thinking and sustaining their well-being mindset. The paper started by discussing the well-being in the United Arab Emirates (UAE), digital and cyber-behavior competence that needs to be acquired by young people, and elements of well-being. Finally, the Codesign Digital Mental Health Intervention App will be discussed to touch base on the design thinking process and the most suitable software to codesign mental health applications.

2. WELL-BEING IN UAE

One of the main goals of the United Arab Emirates (UAE) government is to become one of the happiest nations in the world by the 50th anniversary of its nationhood in 2021. Accordingly, policies, programs, and partnerships at the local and international levels were initiated to improve the well-being of all UAE's public and private sector industries. Within this context, the awareness and application of positive education have been implemented across the UAE's public and private schools. In 2017, the UAE adopted the National Policy for the Promotion of Mental Health, which aims to develop leadership effectiveness in the mental health field, developing and enhancing the scope of integrated mental health services for all community groups and ages. Furthermore, the Ministry of State of Happiness and Well-being undertook a pilot project in 2018 to train public school teachers in positive education practices. In 2019, the Ministry of Health and Prevention announced the launch of several digital solutions in the mental and psychological field to support and empower individuals through curative and awareness programs [11].

The National Strategy for Wellbeing 2031 [12] was launched with four principles design: (i) focus on individuals' wellbeing as a measure of sustainable and tangible societal progress, (ii) adopt a holistic governmental approach to individuals' wellbeing based on the integration of different sectors, (iii) enhance wellbeing by defining clear roles and responsibilities for government entities, and (iv) respond to the implications and finding of the future trends and challenges. In addition, the National Strategy for Well-being 2031 stated three main levels of the framework: flourishing country, connected communities, and thriving citizens, where the main objectives of this strategy are to:

- promote digital well-being and a positive virtual community,
- nurture and sustain good mental well-being,
- adopt a healthy and active lifestyle,
- inspire positive thinking as a core life value,

- develop good life skills,
- foster social cohesion and connectedness with families and communities,
- cultivate well-being environments for learning and working,
- support a giving, engaged, and altruistic society for community well-being,
- and advance UAE cities' and communities' livability, attractiveness, and sustainability.

3. DIGITAL AND CYBER-BEHAVIORAL COMPETENCE

Most definitions of competence refer to knowledge, ability, skills, personal characteristics, behaviors, and competencies related to organizational goals and play a key role in achieving goals [13]. The competency dimensions were outlined by the Institute of Project Management in 2004), as abilities to do something, skills and the number acquired, and attitudes that include stable feelings, beliefs, behavioral tendencies, issues, goals, and specific groups [14]. Behavior is the way in which people act in a particular situation. It encompasses attitudes (and actions), knowledge, and skills. Knowledge is a set of conceptual, factual, and systematic information that can be used directly in the performance of tasks. Skills are gained through an internship, experience, mastery of skills, and ease. Personality is a unique set of characteristics, tendencies, and traits that describe individuals and determine their interaction with the environment. Digital competency is the ability to technically use digital technologies to work, study, communicate, collaborate, and critically evaluate to participate and commit to the digital culture [15]. Digital competencies underpin the basic skills in Information and Communication Technology (ICT), including using computers to retrieve, assess, store, produce, present, exchange information, and communicate and collaborate via the Internet [16]. It is the efficient and effective use of technological resources to create an active learning environment where students are highly engaged in the learning processes [17]. In an educational context, digital competency is related to transferring information and creating innovative ideas [18]. In addition, digital competency involves the effective and efficient use of digital technology to access and store information, communicate with other users, and process program and data [19]. It also involves the confident and critical use of digital technology for education, work, home and etc. [20].

One of the main problems that parents, teachers, governments, and young people are concerned about is the reliance on digital technology and social media as it causes exacerbating feelings of anxiety and depression, disturbing sleeping patterns, leading to cyber-bullying and distorting body image [21]. Both the internet and social media networks can be used in an adequate way in the young people population [22]. However, a relationship was found between the amount of time using the internet and children's well-being. UNICEF [23] stated that a little bit of internet use could have a small positive impact on children and young people's well-being, while excessive use of the internet or not being online can have a small negative impact on well-being. Similarly, previous studies stated that the excessive use of digital technologies and social media is associated with mental illness [24]. Vannucci et al. [25] mentioned that greater social media use is associated with poorer sleep, and a significant correlation was found between playing video games in the evening and sleep deprivation [26]. Other problems occurred, such as the association between social media and body image concerns [27] and disordered eating [28]; evidence of a rise in cyber-bullying

due to the tools for cyber-bullying provided by digital platforms [29]. Cyberbullying is a harmful problem that occurs through exposure to online interactions [30, 31]. It is defined as "an international aggression repeated in time, perpetrated through electronic devices" (Marin-Lopez, et al., 32, p.2).

Adopting an approach that minimizes the risks without restricting the opportunities and benefits digital technologies and social media offer became crucial [21]. Children, young people, and their families should be empowered to be responsible for appropriate digital use and risks [21]. They should be encouraged to use relevant, appropriate, and accessible content and tools that provide prevention or early interventions for mental illness. Social and emotional competencies are defined as emotional knowledge, skills, and attitudes applied in prosocial interpersonal interactions and relationships [33] to manage young people's own emotions and others' emotions while maintaining desirable interpersonal relationships [34]. It includes management of expressions, perceptions, understandings, and emotions [35]. In previous studies, it was mentioned that social and emotional competencies protect children from involvement in cyberbullying [36, 37].

Zych et al. [38] stated that people use a wide range of cyber-behaviors related to emotional content online, such as online emotional content expression, online emotional content perception, facilitating the use of online emotional content and understanding and management of online emotional content, which is called "*E-motion*". Marin-Lopez et al. [32] mentioned that emotional content online could be relevant for cyber-behavior in general, where some people feel high emotional arousal from Facebook; positive relation between emotionally charged tweets and more retweets [39]. It was mentioned that emotions are related to high social and emotional competencies and the abuse of technology [40]. On the other side, cyberbullying perpetration and victimization were found to have an emotional impact, such as feeling frustrated, angry, rejected, sad, and scared [41, 42, 43, 44]. In cyberbullying, interpersonal interactions can cause opportunities for perpetrators to witness the emotional impact of their actions on others [45], while victims' emotions might not be easy to perceive in computer-mediated communication [32].

4. ELEMENTS OF WELL-BEING

Well-being is the combination of performing well and feeling well [46]. Well-being consists of three main components: emotional, social, and psychological [47]. Diener [48] clarified that well-being is a psychological construct that operates through rewards, positive relationships with others, feeling good or confident, and believing that life is meaningful and purposeful. Furthermore, the cognitive and affective appraisal of one's life is considered his/her reference in being satisfied [8]. Thus, the perceptions of the extent of life satisfaction could be a valid measure to assess a person's subjective well-being [48]. The PERMA model introduced by Seligman [50] is one of the most popular models to measure well-being among children, adolescence, and adults. The model proposes five main elements derived from the essence of positive psychology that can be incorporated into schools' curricula and promote students' well-being.

The five elements of well-being are positive emotions, engagement, relationship, meaning, and accomplishments. *Positive emotions* such as happiness, gratitude, contentment, and joy are connected to greater life satisfaction and well-being [49, 50]. Positive emotions bring remarkable resilience and a broader viewpoint of possibility and

even help us sleep better [49]. In other words, the positive emotions element of well-being is about having a pleasurable life [50]. Positive emotions motivate individuals to continue a certain course of action, whereas negative emotions may act as signals to change and improve behaviors [49]. *Engagement* is an activity in which we all are involved and are “in the zone” [50, 51]. Although the engagement activities seemed effortless, they contributed to the well-being. *Relationships* are essential to human thriving. Research has demonstrated that living and working in social isolation increases someone’s chances of early mortality at a much higher rate than smoking, alcoholism, or obesity [52]. From the perspective of human-centered designers (design thinkers), it is imperative to focus attention on others to have a life worth living [53]. In the long run, some sense of *meaning* is important as it involves living one’s values of meaning where one’s life makes sense, matters, and has a purpose even during the struggle [54]. *Accomplishment* is significant for human beings to flourish as individuals need to have goals, motivation to pursue them, and the ability to generate pathways to reach them [55]. The goals do not need to be long-term, but individuals need to be willing to try something new and risk failure to innovate [56]. This is because when people experience personal achievement, greater well-being occurs when they can capitalize on and savor the achievement and not just move on to the next project [57, 58]. This leads to a happier life and satisfaction.

Much research demonstrated the PERMA model's positive impact in promoting well-being in emotions, relationships, academic motivation, and skills [50, 59]. In addition, the PERMA model has demonstrated its applicability in genuine schools and classroom settings [8, 60, 61]. There are numerous ways of categorizing the primary elements of well-being. In this study, the five-model domain of well-being (positive emotions, engagements, relationships, meaning, and accomplishments) created by the father of this field Martin Seligman [50], will be used to measure students’ well-being.

5. CODESIGN DIGITAL MENTAL HEALTH INTERVENTION APP

Design Thinking (DT) is a human-centered approach to innovation and problem-solving. By applying design thinking principles, individuals will feel empowered to stretch creatively, understand problems and possibilities, and generate specific actions that have a real impact. The power of design thinking process is influenced by positive social psychology in understanding the strengths and limitations of the process, gaining greater insights into the individuals’ needs, and influencing their well-being.

In order to navigate this changing world, there is a need for an intervention that tackles problems and generates successful outcomes. Some studies mentioned the importance of using the design thinking process to codesign a digital intervention to solve individuals’ problems and improve their well-being [8, 9, 62]. Previous studies suggested that when individuals were engaged in the codesign thinking process to design a digital intervention to solve their problems, they are most likely to use this digital intervention to solve their problems [9, 10, 63]. Therefore, students need to develop mindsets that enable them to solve their problems unconsciously and manage their mental health problems [10]. Accordingly, this study aims to co-design a digital mental health application for young people that will offer interventions to improve their quality of life and well-being using Seligman’s well-being PERMA model: positive emotions, engagement, relationships, meaning, and accomplishments. The

COVID-19 pandemic has compounded the mental health challenge, depriving people of social relationships and fostering feelings of loneliness and sadness [64]. Although most of the relationship conflicts and problems affecting students begin with their peers, who play an essential role in their life and social relationships [65], the widespread use of digital communication devices such as smartphones, tablets, and access to the internet allowed for a new contribution of positive stimuli in the social life of adolescents [66]. Nowadays, students continue communicating and interacting through social networks, for good and bad, using their digital devices [65].

6. AGILE SOFTWARE PROCESS

Regarding the software of the digital intervention, it was stated in a previous study that the waterfall software development model is found to be best suited for the codesign of the digital mental health intervention [67]. However, the Agile software process and models have caught the attention of researchers and software engineers, and many studies consider the agile method because of its natural fit to the mobile app [68, 69]. Furthermore, the Agile approach is more flexible in developing software than a plan-driven approach, with the ability to change requirements in any phase of the software development cycle [70]. In addition, it focuses on the collaboration between customers and developers [71]. Accordingly, following the Agile approach in developing the digital mental health intervention is highly recommended. It was also stated that the Agile practices improve formal and informal communication during the software development process [72]. Some of these practices are open office space, product backlog, sprint planning, iteration planning meetings, iteration reviews, daily meetings, and iteration retrospectives [73, 74]. Sprint planning is the best method to share the information and Sprint reviews facilitate informal communication among developers. It also serves to facilitate communication among the team while using the design thinking process.

7. CONCLUSION

The COVID-19 pandemic has highlighted the need for digital mental health interventions to promote positive thinking and sustain well-being among young people and adolescents. The UAE has recognized this need and has recommended the use of digital interventions for mental health promotion, prevention, and treatment. Design thinking and the co-creation of mental health interventions with young people are effective strategies to ensure that digital interventions meet the needs of their intended users. In addition, the agile software development process is recommended for the development of digital mental health interventions to ensure that they are flexible and can be adapted to changing needs and user feedback.

Based on the literature discussed, the following recommendations can be made:

- Governments and healthcare organizations should prioritize the development and implementation of digital mental health interventions for young people and adolescents.
- The design thinking process should be used to co-create digital mental health interventions with young people to ensure that they meet their needs and are effective.
- Agile software development methodologies should be used to ensure that digital mental health interventions can be adapted to changing needs and user feedback.
- Digital and cyber-behavioral competence should be included in education and training programs for young

people to enable them to use digital mental health interventions effectively and safely.

- Elements of well-being, such as positive thinking and self-management, should be incorporated into digital mental health interventions to promote sustained well-being.

Overall, the co-design of digital mental health interventions with young people can lead to more effective interventions that promote positive thinking and sustain well-being. It is important to prioritize the development and implementation of these interventions to address the mental health challenges faced by young people, especially in the context of the COVID-19 pandemic.

8. REFERENCES

- [1] Emirates Youth Council, The trends shaping the UAE's youth sector after the COVID-19 pandemic. **Strategy & Part of the PwC network**, 2021
- [2] O.H. Mohamed Ibrahim, R.M. Ibrahim, N.K. Al-Tameemi, K. Riley (2020). Challenges associated with mental health management: Barriers and consequences. **Saudi Pharm J.**, Vol. 28, No. 8, 2020, pp. 971-976.
- [3] T.M. Evans, L. Bira, J.B. Gastelum, L.T. Weiss & N.L. Vanderford, "Evidence for a mental health crisis in graduate education", **Nature Biotechnology**, Vol. 36, No. 3, 2018, pp.282.
- [4] World Health Organization WHO, Child and adolescent mental and brain health. Geneva. **World Health Organization**. 2021.
- [5] Oxford Business Group. Dubai Seeking To Meet Needs Of GCC Youth Population. **Oxford Business Group**, 2021.
- [6] L. Ramey, C. Osborne, D. Kasitnon, & S. Juengst, (2019). Apps and Mobile Health Technology in Rehabilitation: The Good, the Bad, and the Unknown. **Phys Med Rehabil Clin N Am**, Vol. 30, No. 2, 2019, pp. 485-497.
- [7] S. Magasi, J. Banas, B. Horowitz, J.P. Reis, T. Kimbrerly, T. Wilson, & D. Victoson, D. WeCanConnect: development of a community-informed mHealth tool for people with disabilities and cancer. **Prog Community Health Partnersh**, Vol. 13, No. 5, 2019, pp. 49-59.
- [8] W.C. Au & K.J. Kennedy A Positive Education Program to Promote Wellbeing in Schools: A Case Study from a Hong Kong School. **Higher Education Studies**, Vol. 8, No. 4, 2018, pp. 9-22.
- [9] L.R. Thomas, R. Nguyen, A. Teherani, C.R. Lucey & E. Harleman Designing Well-being: Using Design Thinking to Engage Residents in Developing Well-Being Interventions. **Academic Medicine**, Vol. 95, No. 7, 2020, pp. 1038-1042.
- [10] S. Ma, M. Ruensuk, C. Kim, 'Design Interventions for Promoting the Mental Health of Young Academics', in **Proceedings of the 22nd International Conference on Engineering Design (ICED19)**, Delft, The Netherlands, 2019, pp. 5-8.
- [11] H. Hussein & T. Alfaham, **UAE marks World Mental Health Day**. WAM Emirates Agency, 2020.
- [12] UAE Government, **National Wellbeing Strategy 2031**. 2019.
- [13] S. Astereki, H. Mehrdad & M. Ghobadiyan, Components and Characteristics of the Professional Competency Model among Educational Administrators. **Special Number: Professional competencies for international university education**, Vol. 9, 2021.
- [14] M. Najafi, M. Qahramani, M. Abul Ghasemi & M. Arefi, Designing and explaining the model of professional competencies of preschool center managers. **Scientific Research Quarterly**, Vol. 9, No. 2, 2018, pp. 88-95.
- [15] L. Ilomaki, S. Paavola, M. Lakkala & A. Kantosalo, Digital competence – An emergent boundary concept for policy and educational research. **Education and Information Technologies**, Vol. 21, No. 3, 2015, pp. 655-679.
- [16] M.A. Pérez & A. Delgado, De la competencia digital y audiovisual a la competencia mediática: Dimensiones e indicadores [From digital and audiovisual competence to media competence: Dimensions and indicators]. **Comunicar**, Vol. XX, No. 39, 2012, pp. 25–34.
- [17] A. Mirete, B., Maquilon, J. J., Mirete, L., & R.A. Rodriguez, R. A. Digital competence and university teachers' conceptions about teaching: A structural causal model. **Sustainability**, Vol. 12, 2020, pp. 4842.
- [18] E. Ordóñez-Olmedo, E. Vázquez-Cano, S. Arias-Sánchez & E. López-Meneses, Las competencias en el uso de las tecnologías de la información y la comunicación en el alumnado universitario [Competencies in the use of information and communication technologies in university students]. **Pixel Bit Revista de Medios y Educación**, Vol. 2021, No. 60, 2021, pp. 153–167.
- [19] F.J. Desjardins, R. Van Oostveen, E. Childs & T. Blayone, **General Technological Competency and Use**, 2015.
- [20] European Union, Recommendation of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning, 2006.
- [21] OECD (2018). **Children & Young People's Mental Health in the Digital Age**. 2018.
- [22] I. Zych, R. Ortega-Ruiz, R. Muñoz-Morales & V.J. Llorent, Dimensions and psychometric properties of the Social and Emotional Competencies Questionnaire (SEC-Q) in youth and adolescents. **Revista Latinoamericana de Psicología**, Vol. 50, No. 2, 2018, pp. 98-106.
- [23] UNICEF, How does the time children spend using digital technology impact their mental well-being, social relationships and physical activity? **An evidence-focused literature review**, 2017.
- [24] N. McCrae, S. Gettings and E. Purssell, "Social Media and Depressive Symptoms in Childhood and Adolescence: A Systematic Review", **Adolescent Research Review**, 2017, pp. 315-330.
- [25] A. Vannucci, K. Flannery and C. Ohannessian, "Social media use and anxiety in emerging adults", **Journal of Affective Disorders**, 2017, pp. 163-166.
- [26] F. Billari, O. Giuntella & L. Stella, Broadband internet, digital temptations, and sleep", **Journal of Economic Behavior and Organization**, 2018.
- [27] J. Fardouly & L. Vartanian, **Social Media and Body Image Concerns: Current Research and Future Directions**, 2016.
- [28] G. Holland & M. Tiggemann (2016), **A systematic re-view of the impact of the use of social networking sites on body image and disordered eating outcomes**, 2016.
- [29] S. Livingstone, M. Stoilova & A. Kelly, **Cyberbullying: incidence, trends and consequences**, United Nations, 2016.

- [30] D. Olweus, (2012). Cyberbullying: An overrated phenomenon? **European Journal of Developmental Psychology**, Vol. 9, No. 5, 2012, pp. 520-538.
- [31] P.K. Smith, The nature of cyberbullying and what we can do about it. **Journal of Research in Special Educational Needs**, Vol. 15, No. 3, 2015, pp. 176-184.
- [32] I. Marín-López, I. Zych, R. Ortega-Ruiz, R., S.C. Hunter & V.J. Llorent, V. J. Relations among online emotional content use, social and emotional competencies and cyberbullying. **Children and Youth Services Review**, 2020, pp. 108
- [33] O. Gómez-Ortiz, E.M. Romera & R. Ortega-Ruiz, Multidimensionality of social competence: Measurement of the construct and its relationship with bullying roles. **Revista de Psicodidáctica**, Vol. 22, No. 1, 2017, pp. 37-44
- [34] Collaborative for Academic, Social, and Emotional Learning, **CASEL guide: Effective social and emotional learning programs: Secondary school edition**. Chicago, IL: Author, 2015.
- [35] P. Fernández-Berrocal, R. Cabello & M.J. Gutiérrez-Cobo, Avances en la investigación sobre competencias emocionales en educación. **Revista Interuniversitaria de Formación del Profesorado**, Vol. 88, No. 31.1, 2017, pp. 15-26.
- [36] V. Busch, L. Laninga-Wijnen, T.A. Van Yperen, A.J.P. Schrijvers & J.R.J. De Leeuw, Bidirectional longitudinal associations of perpetration and victimization of peer bullying with psychosocial problems in adolescents: A cross-lagged panel study. **School Psychology International**, Vol. 36, No. 5, 2015, pp. 532-549.
- [37] C.R. Cook, K.R. Williams, N.G. Guerra, T.E. Kim & S. Sadek, Predictors of bullying and victimization in childhood and adolescence: A meta-analytic investigation. **School Psychology Quarterly**, Vol. 25, No. 2, 2010, pp. 65-83.
- [38] I. Zych, D.P. Farrington, V.L. Llorent & M.M. Tfofi, (2017). **Protecting children against bullying and its consequences**. New York, NY: Springer. 2017.
- [39] S. Stieglitz & L. Dang-Xuan, Emotions and information diffusion in social media—sentiment of microblogs and sharing behavior. **Journal of Management Information Systems**, Vol. 29, No. 4, 2013, pp. 217-248.
- [40] E. Nasaescu, I. Marín-López, V.J. Llorent, R. Ortega-Ruiz & I. Zych, I. (2018). Abuse of technology in adolescence and its relation to social and emotional competencies, emotions in online communication, and bullying. **Computers in Human Behavior**, Vol. 88, 2018, pp. 114-120.
- [41] T. Beran & Q. Li, Cyber-harassment: A study of a new method for an old behavior. **Journal of Educational Computing Research**, Vol. 32, No. 3, 2005, pp. 265-277
- [42] S. Hinduja & J.W. Patchin, Offline consequences of online victimization: School violence and delinquency. **Journal of School Violence**, Vol. 6, No. 3, 2007, pp.89-112.
- [43] A.M.G. Gulado, S.C. Hunter, K. Durkin, P. Arnaiz & J.J. Maquilón, The emotional impact of cyberbullying: Differences in perceptions and experiences as a function of role. **Computers and Education**, Vol. 82, 2015, pp. 228-235.
- [44] B. Spears, P. Slee, L. Owens & B. Johnson, Behind the scenes and screens: Insights into the human dimension of covert and cyberbullying. **Zeitschrift für Psychologie/Journal of Psychology**, Vol. 217, No. 4, 2009, pp. 189-196.
- [45] J.J. Dooley, J. Pyżalski & D. Cross, Cyberbullying versus face-to-face bullying: A theoretical and conceptual review. **Zeitschrift für Psychologie/Journal of Psychology**, Vol. 217, No. 4, 2009, pp. 182-188.
- [46] F. A. Huppert & D. M. Johnson, A controlled trial of mindfulness training in schools: The importance of practice for an impact on well-being, **The Journal of Positive Psychology**, Vol. 5, No. 4, 2010, pp. 264-274
- [47] C. Keyes, Keyes's Model of Mental Health With Personal Growth Initiative as a Parsimonious Predictor, **Journal of Counseling Psychology**, Vol. 56, 2009.
- [48] Diener, E. (Ed.), **The science of well-being: The collected works of Ed Diener**. Springer Science + Business Media. 2009
- [49] M.A. Cohn & B.L. Fredrickson, Positive emotions. In S. J. Lopez & C. R. Snyder (Eds.), **Oxford handbook of positive psychology** (pp. 13–24). Oxford University Press. 2009
- [50] M.E.P. Seligman, **Flourish: A visionary new understanding of happiness and well-being**. New York, NY: Simon and Schuster, 2012.
- [51] M. Csikszentmihalyi, Flow: The Psychology of Optimal Experience, **Journal of Leisure Research**, Vol. 24, No. 1, 1990, pp. 93-94.
- [52] J. Holt-Lunstad, T.B. Smith, J.B. Layton, Social Relationships and Mortality Risk: A Meta-analytic Review. **PLoS Med**, Vol. 7, No. 7, 2010, e1000316.
- [53] C.W. Park, A.B. Eisingerich & J.W. Park, Attachment-Aversion (AA) Model of Customer-Brand Relationships. **Journal of Consumer Psychology**, Vol. 23, 2013, pp. 229-248.
- [54] S. Heintzelman & L. King, Life Is Pretty Meaningful, **American Psychologist**, Vol. 69, No. 6, 2014, pp. 1-26
- [55] C. R. Snyder, **The Psychology of Hope: You Can Get There from Here**. New York, NY: Free Press. 1994
- [56] M.D. Cannon & A.C. Edmondson, A. C. Failing to Learn and Learning to Fail (Intelligently): How Great Organizations Put Failure to Work to Innovate and Improve. **Long Range Planning: International Journal of Strategic Management**, Vol. 38, No.3, 2005, pp. 299-319.
- [57] F.B. Bryant & J. Veroff, **Savoring: A new model of positive experience**. Mahwah, NJ: Lawrence Erlbaum Associates. 2007
- [58] C.A. Langston, Capitalizing on and coping with daily-life events: Expressive responses to positive events. **Journal of Personality and Social Psychology**, Vol. 67, 1994, pp. 1112-1125.
- [59] L.S. Green & J.M. Norrish, Enhancing well-being in adolescents: Positive psychology and coaching psychology interventions in schools. In C. Proctor & P. A. Linley (Eds.), **Research, applications, and interventions for children and adolescents: A positive psychology perspective** (pp. 211-222). Springer Science + Business Media. 2013
- [60] M.L.Kern, L. Waters, A. Adler & M.A. White, A multidimensional approach to measuring well-being in students: Application of the PERMA framework.

- The Journal of Positive Psychology**, Vol. 10, No. 3, 2015, pp., 262-271.
- [61] A. Shoshani, S. Steinmetz & Y. Kanat-Maymon, Effects of the Maytiv positive psychology school program on early adolescents' well-being, engagement, and achievement. **Journal of School Psychology**, Vol. 57, 2016, pp. 73-
- [62] G. Panger, (2015). Reassessing the Facebook experiment: critical thinking about the validity of Big Data research. **Information, Communication and Society**, Vol. 19, No. 8, 2015, pp. 1108-1126.
- [63] M.J. Kreitzer, C. Kennita, D.S. Coffey, E. Goldblatt, C.L. Grus, P. Keskinocak, M. Klatt, T. Masima, Z. Talib, Z. & R.W. Valachovic, Utilizing a Systems and Design Thinking Approach for Improving Well-Being Within Health Professions' Education and Health Care. **National Academy of Medicine**, 2019.
- [64] A. Mailizar, Almanthari, S. Maulina, & S. Bruce, Secondary School Mathematics Teachers' Views on E-learning Implementation Barriers during the COVID-19 Pandemic: The Case of Indonesia. **EURASIA Journal of Mathematics, Science and Technology Education**, Vol. 16, No. 7, 2020.
- [65] R. Ortega-Ruiz, J.A. Casas & R.D. Rey, Towards the construct of cyberconvivencia / Hacia el constructo ciberconvivencia, **Infancia y Aprendizaje**, Vol. 37, No. 3, 2014, pp. 602-628.
- [66] R. Ortega, R. Del Rey & V. Sanchez, **Nuevas dimensiones de la convivencia escolar y juvenil. Ciberconducta y relaciones en la Red: Ciberconvivencia. Madrid: Ministerio de Cultura, Educación y Deporte**, 2012.
- [67] M.A. Job, Alseba, S.M. A Software Engineering Approach in Design and Development of a Mobile Application, **International Journal of Engineering Trends and Technology**, Vol. 69, No. 5, 2021, pp. 32-40
- [68] T. Asfour et al., "ARMAR-6: A collaborative humanoid robot for industrial environments," in **Proc. IEEE/RAS Int. Conf. Humanoid Robots (Humanoids)**, 2018, pp. 447-454.
- [69] P. Patil, J. Virdin, M. Diaz, J. Roberts, & A. Singh, **Toward A Blue Economy: A Promise for Sustainable Growth in the Caribbean; An Overview**. The World Bank, Washington D.C. 2016
- [70] D. Ghimire & S. Charters, The Impact of Agile Development Practices on Project Outcomes. **Software**, Vol. 1, 2022, pp. 265-275.
- [71] P. Ozkan, & S. Süer, I. Keser, & I. K. Deveci, The effect of service quality and customer satisfaction on customer loyalty: The mediation of perceived value of services, corporate image, and corporate reputation. **International Journal of Bank Marketing**. 2019
- [72] S. Dorairaj, J. Noble & P. Malik, Effective communication in distributed agile software development Teams. In **International Conference on Agile Software Development**; Springer: Berlin/Heidelberg, Germany, 2011; pp. 102-116.
- [73] R. Sandstø & C. Reme-Ness, Agile practices and impacts on project success. **J. Eng. Proj. Prod. Manag.** Vol. 11, 2021pp. 255-262.
- [74] C. Baham & R. Hirschheim, Issues, challenges, and a proposed theoretical core of agile software development research. **Inf. Syst. J.**, Vol. 32, 2021, pp. 103-129.

Is the Cyberwar on the Horizon or has it Already Begun? Russian Cyberattack Strategies Against Ukraine - Lessons Learned

Tarik ELTAEIB

Computer Security- Farmingdale State College - State University of New York
Farmingdale, New York 11735, USA

Robert McCLOUD

Computer Science & Technology - Sacred Heart University
Fairfield, CT 06825, USA

Jill A. O'SULLIVAN

Computer Systems - Farmingdale State College - State University of New York
Farmingdale, New York 11735, USA

ABSTRACT

Ukraine's conflict is a hybrid conflict. Despite several publications discussing this topic, this paper focuses on thoroughly examining cyberattacks. Cybersecurity experts claim that Ukraine has been the target of cyberattacks, including espionage, misinformation, and subversive attempts.

Keywords: Cyberattacks, Ukraine, Malware and Cybersecurity

1. INTRODUCTION

Cyberattacks would be a defining feature of a conflict between high-tech enemies in the twenty-first century. Russian cyber attackers gained access to the vote counting system in general elections in Ukraine, since at least 2014, deleting electronic records, and forcing the Ukrainian authorities to manually count the votes[1]. Ukraine has consistently been the target of Russian cyberattacks[2].

According to a Politico study, Ukraine is the "ideal sandbox for anyone eager to test new cyber-weapons, strategies, and tools" since thousands of assaults take place there each month[3]. In fact, hacking activities related to Russia's war in Ukraine indicate that Cyberoperations have been used in cyberwarfare, proving that they are an essential component of conflict[4].

Cyber warfare against the Ukraine was launched long before the actual war between Russia and Ukraine broke out. Hackers launched waves of assaults against almost every Ukrainian website and compromised government systems with data-erasing software[5]. Ukraine's cyber-security authority has warned that the country's government and infrastructure networks are continually under cyber-attack, with particular officials being targeted[6].

According to Google, a high number of phishing efforts were aimed towards Ukrainian authorities. Websites for government and financial services were temporarily inaccessible, and some were hacked with the message "the worst is yet to come." [7].

Since February 23, 2022, the day before the start of Russian military operations, cyberattacks compromised numerous Ukrainian government websites, online banks, ATMs, and platforms. This included vandalization and deletion of websites, and government systems being infected with data-wiping malware[8].

Research done by Google's Threat Analysis Team (TAG) highlighted that the attackers connected from Russia or its allies[8-10]. The targeted users of their phishing campaign

included users of UkrNet, a Ukrainian media company, the Ukrainian government, and military institutions, which resulted in the shutdown of the country's electrical infrastructure. The most frightening aspect relates to their boasting about using hacks and cyber-attacks to subjugate other countries[11].

The impact of these attacks on Ukraine was significant because, like most other countries, they were not prepared to deal with this kind of war[12]. In fact, Ukraine suffers a lack of cyber security expertise, poor regulation, limited response capacity, and a lack of coordination between cyber-related agencies. Ukraine has also become one of the world's most active cyber battlegrounds[13].

Cybersecurity experts report these unprecedented ferocious cyber-attacks such as espionage, misinformation, and subversion activities[14]. The U.S. Assistant Attorney General for National Security John Demers stated. "No government has weaponized its cyber capabilities as viciously or recklessly as Russia, willfully inflicting unparalleled harm to chase modest tactical advantages and satisfy fits of vengeance," according to the Politico report[15, 16].

Microsoft's Threat Intelligence Center (MSTIC) discovered a fresh wave of offensive and destructive cyberattacks intended for the Ukraine's digital infrastructure many hours before missiles were launched or tanks were moved on February 24[6, 17].

These came in the form of a new malware payload (named FoxBlade), that may utilize your computer to launch distributed denial-of-service (DDoS) cyberattacks without your permission[18].

Another massive hacking effort was launched against Ukrainian energy providers in the first hours of the Russian military invasion, according to an article in the MIT technology review [2].

There is no doubt that cyberwars and cyberattacks will be a distinguishing element of any confrontation between adversaries in this era. Cybersecurity experts and scientists raise awareness through research to shed more light on this omnipotent threat, to 'ring the bell' on upcoming threats that our communities may face[19].

The big question is whether Russia will use its cyberweapons against other countries. Will these countries react, and how they will react? That is why it is so important to study these techniques in depth, so we are ready for anything. This study attempts to draw picture of the Russian roadmap of cyberattacks, including its tactics, and to shed light on the complex network of cyber players.

Russia has a previous history of producing viruses and malware used in hacking[20]. The US Justice Department has charged

Russian intelligence officials with launching some of the "worst damaging malware the world has ever known", that knocked down the Ukrainian power infrastructure in December 2015 and the NotPetya global ransomware campaign in 2017[21]. Petya is a crypto-malware family that was originally found in 2016. [2]. According to security experts, Russia's and other countries' cyber assaults will continue to be used in future military conflicts[22].

2. PROSPECTS FOR THE FUTURE OF CYBER CONFLICT

Based on "History is a great teacher, in this part, we survey some of the most famous viruses and Trojans used by Russian hackers. The actors and Interveners listed below are all Russian and use their skills and resources to conduct successful cyberattack operations.

The Interveners: Group: Sandworm Team, Electrum:

Russian GRU Unit 74455 has been linked to the disruptive threat organization known as Sandworm Team[23]. Their assaults on the Ukrainian electricity sector since the NotPetya strikes are among the most prominent attacks carried out by the Sandworm Team[24]. The viruses known as KillDisk, BlackEnergy 3, and Industroyer have all been connected to the Sandworm Team, which has been active since at least 2009[25, 26].

The United States District Court, Western District of Pennsylvania, defined the main Intelligence Directorate of the General Staff of the Armed Forces as a military intelligence organization run by the Russian Federation ("Russia") ("GRU"). The GRU had its headquarters in Moscow, Russia, and was made up of many units, among them Military Unit 74455, also known as Sandworm Team, Telebots, Voodoo Bear, and Iron Viking by cybersecurity researchers, and as the "Main Center for Special Technologies" (also known as "GTsST") inside the GRU[27-29].

Fancy Bear: APT 28, Fancy Bear, Sofacy, or Swallowtail, are all names for the Russian government-affiliated cyberespionage organization. The gang has been active since 2008, using phishing operations and credential harvesting to target the energy, government, media, aerospace, and military industries[30]. Computers and mobile devices are both common targets for Fancy Bear, which conducts several simultaneous penetration operations[31].

Energetic Bear: It is a Russian cyberspy organization, sometimes referred to as an advanced persistent threat. The gang is said to be made up of "FSB hackers," either those who are directly hired by the FSB or Russian civilians, criminal hackers who were forced into signing contracts as FSB hackers while continuing working as freelancers or second jobs as criminal hackers[32]. FSB stand of Federal Security Service of the Russian Federation.

Red October: After a series of cyberattacks on the computer networks of several foreign diplomatic service organizations, Kaspersky Lab's Global Investigation & Analysis Team started a new threat research[32]. The inquiry, which was dubbed "Red October" (after the bestselling book "The Hunt for the Red October"), exposed and examined a substantial cyber-espionage network[33]. Many of the nation's top infrastructure websites, including embassies, oil and gas institutions, and nuclear power plants, have been effectively hacked by a high-level cyberspying

operation[34]. Months have passed as Kaspersky Lab experts analyzed this kind of malware.

Conti Malware : The malware known as Conti has been around since 2020 and is thought to be transmitted by a gang with ties to Russia[35]. It is known that all versions of Microsoft Windows are impacted[34]. In early May 2022, the US government announced a reward of up to \$10 million for information on the gang[36].

Petya Virus : The virus infects the master boot record of Microsoft Windows-based computers, executing a payload that encrypts a hard drive's file system table and stops Windows from starting[37]. In order to restore access to the system, it then requests that the user pay a fee in Bitcoin. During the first year after its introduction, the Petya virus infected millions of PCs. Petya versions were initially discovered in March 2016 and spread through infected e-mail attachments[38]. A new form of Petya was used in a worldwide cyberattack in June 2017 that mainly targeted Ukraine[39]. Actually, Petya or NotPetya, which is updated version of Petya, propagated via the internal networks of international corporations with Ukrainian branches, when it was disguised as an upgraded version of a Ukrainian tax accounting application called MeDoc [40]. It would encrypt the computer's entire file system, including the file table at the very top of the hard disk, rendering the machine unbootable[41].

A Series of Accidents Against Ukrainian websites :

Cyberattacks were stated to be intended to erase data from the targeted utility control rooms; however, their impact on military activities has not yet been evaluated[25]. Russia and its delegates were suspected of being behind the defacements of Ukrainian websites, damaging malware, and distributed denial-of-service (DDoS) operations before the invasion[42]. Denial of Service (DoS) attacks are malicious efforts to take down individual or network resources by interrupting the services of a host connected to a network, most often by flooding it with excessive requests. A DDoS assault works in the same way; the difference is that the incoming traffic comes from several sources, making it impossible to stop[43].

Another malware series known as KillDisk is one of the most well-known malware families[44]. Cybercriminals usually utilize it in the final stages of an infection to wipe drives and remove forensic data in order to cover their tracks[45]. That is why, during Telebots' assaults on the Ukrainian electrical infrastructure, it was linked to the BlackEnergy virus so that the hackers could carry out their plot invisibly[46]. A BlackEnergy malware version and a modified kill-disk feature were utilized in the hack on Ukraine's power infrastructure[47]. The component was rendered useless by the disk-remove function, which removed the master boot records (MBR). Using the human-machine interface, disabling the MBR disabled thirty substation breakers (HMI)[47].

3. WHY DO ATTACKS ON ENERGY FACILITIES OCCUR DURING WARS?

When it comes to vital infrastructure, nothing is more crucial than keeping the lights on. It is common knowledge that assaults on electricity networks may have far-reaching effects on a variety of institutions from a political, social, and military standpoint. In fact, I think, there are two major political repercussions that come about as a result of electrical cut off[47].

As a first, morale among the populace will plummet, which will force the governments under attack to change their tactics. Second, these assaults may increase the costs that political leaders in a nation are already bearing, which may cause them to change course. In addition, the loss of electricity will have direct effects on the opposing troops, and it will likely diminish the assaulted country's capacity for adequate war equipment manufacture[48]. Targeting power networks will be the quickest and most efficient approach to start a direct assault on the will of a country, "to destroy its economic structure and intimidate its very life." On February 23, 2022, various cybersecurity experts revealed that HermeticWiper malware was being deployed against Ukrainian enterprises[48]. The virus affects Windows devices by tampering with the master boot record, resulting in boot failure. Destructive malware may pose a direct danger to a company's day-to-day operations, posing a risk to key assets and data[47]. More disruptive cyberattacks on Ukrainian firms are expected to occur, with unintended consequences for businesses in other countries. For such an incident, organizations should improve their awareness and examine their capabilities in terms of planning, preparedness, detection, and reaction[49]. This is acceptable. Any other fonts must be embedded in your document to ensure that it will print properly.

4. CYBERSECURITY THREATS TO POWER GRIDS

SCADA is an acronym for supervisory control and data acquisition. SCADA systems are used in many sectors including telecommunications, water and waste management, and energy, to monitor and manage a facility or piece of equipment. Security issues arise when power grids linked to the internet through SCADA systems use protocols like TCP/IP[50]. Process automation systems employ a set of communications protocols called Distributed Network Protocol 3 (DNP3)[51]. More security issues are raised by DNP3. Modbus and DNP3 do not have enough authentication or encryption, thus anybody may access data sent across the network in plain text[52]. Searching for control systems, routers, and other internet-accessible devices is possible with the aid of programs like SHODAN and the Google Hacking Database. On January 20, 2022, Microsoft disclosed malicious malware named Whisper Gate that was disguised as ransomware and targeted hundreds of governments and non-profit organizations, as well as information technology institutes in Ukraine[53].

5. ARE WE SAFE?

The two nations have historically utilized the internet for spying. Russia presents more of an immediate danger to the U.S. energy system and vital infrastructure sectors, but China is more concerned with stealing American research to develop its projects, and to discover U.S. military methods and vulnerabilities that may be exploited in times of conflict[54]. Russian efforts to develop offensive cyber capabilities, including cyber weapons, are becoming more concentrated. Attacks on the Ukrainian energy grid and French TV5-Monde serve as proof of this. Additionally, these assaults have shown that cyberspace has the ability to interfere with physical infrastructure[55]. It is no secret that Russia is interested in interfering with the American energy infrastructure, and this has lately become known. According to United States intelligence officials and

technology company executives, Russian hackers, who the State sponsors, seem to focus more on suggesting that their technology can disrupt the American electric utility grid than the events surrounding the November 2018 elections, according to a report by David Sanger, a New York Times journalist with a background in cybersecurity[56].

According to George Perera, associate director of cybersecurity law at St. Thomas University, "Potentially, you may lose access to clean water, energy, and financial markets, to name a few."

Notably, he emphasized that the chance of an assault on the US being successful was "low" according to the US's defensive capabilities[57].

However, some sectors of the private sector, in particular, may be underprepared, despite the fact that many businesses have hurried in recent years to strengthen their cyberdefenses.

6. REDUCE THE IMPACT OF ANY CYBER ATTACK

Future threats to the world from this war are substantial. They become clear while analyzing the material at hand. When the study of cyber-attack is closely examined, it becomes clear how much the ongoing war, cybersecurity technology, management, and procedures have been pushed. Cybersecurity has altered as a result of attacks on power grids, the rapid spread of NotPetya, the development of similar ICSs that target malware, and the weaponization of open-source software[58].

"National governments, including the US, conduct intelligence collecting activities in cyberspace, but no one has termed such action a full-fledged cyberwar," James Turgal, vice president of cyber risk, strategy, and board relations at cybersecurity company Optiv, told Recode. "However, with Russia's invasion of Ukraine, we have entered a new age"[59].

So, for any future conflict they will target the danger against vital infrastructures, mobile devices, the cloud, news, and social media, as well as the coordinated supply chain. We need collaborative efforts between the public and commercial sectors to tackle cyberattacks. We need lunch while stress-testing the system, and we continually test our systems in order to rectify and improve them[27].

7. CONCLUSIONS

The government needs a fundamental cyber-security workforce to preserve national interests and develop basic cyber defenses while safeguarding vital infrastructure from existential threats. In order to defend the interests of the United States against its enemies, the country also requires a powerful force of highly trained, technical forces that are specialized to execute secret operations using cutting-edge technology. These specialist cyber fighters must be among the elite and most technically adept personnel. Outer cyber warriors may inflict crippling costs on the nation's opponents in order to create genuine deterrence, supported by the US government's authority and resources.

8. REFERENCES

1. Ashmore, W.C., Impact of alleged Russian cyber attacks. 2009, ARMY COMMAND AND GENERAL STAFF COLL FORT LEAVENWORTH KS SCHOOL OF ADVANCED
2. Lam, C., A slap on the wrist: Combatting Russia's cyber attack on the 2016 US presidential election. *BCL Rev.*, 2018. 59: p. 2167.
3. Maschmeyer, L. and M. Dunn Cavely, Goodbye Cyberwar: Ukraine as Reality Check. *CSS Policy Perspectives*, 2022. 10(3).
4. Unwala, A. and S. Ghorri, Brandishing the cybered bear: Information war and the Russia-Ukraine conflict. *Military Cyber Affairs*, 2016. 1(1): p. 7.
5. Shackelford, S.J., et al., From Russia with love: Understanding the Russian cyber threat to us critical infrastructure and what to do about it. *Neb. L. Rev.*, 2017. 96: p. 320.
6. Samarasekera, U., Cyber risks to Ukrainian and other health systems. *The Lancet Digital Health*, 2022. 4(5): p. e297-e298.
7. Van Camp, C. and W. Peeters, A World without Satellite Data as a Result of a Global Cyber-Attack. *Space Policy*, 2022. 59: p. 101458.
8. Boschetti, N., N.G. Gordon, and G. Falco, Space Cybersecurity Lessons Learned from The ViaSat Cyberattack, in *ASCEND 2022*. 2022. p. 4380.
9. Eun, S.T., Cyber Warfare in the Russo-Ukrainian War: Assessment and Implications. *IFANS FOCUS (영문)*, 2022. 2022(16): p. 1-4.
10. Božena, S.M., STARTUPS OFFERING CYBER SECURITY SOLUTIONS AND SERVICES IN THE FACE OF WAR IN UKRAINE. *NATIONAL PEDAGOGICAL DRAHOMANOV UNIVERSITY*, 2022: p. 165.
11. Kostyuk, N. and E. Gartzke, Why Cyber Dogs Have Yet to Bark Loudly in Russia's Invasion of Ukraine (Summer 2022). *Texas National Security Review*, 2022.
12. Eichensehr, K.E., Ukraine, Cyberattacks, and the Lessons for International Law. *American Journal of International Law*, 2022. 116: p. 145-149.
13. Stojanović, G., Hybrid Wars in the 21st Century: Study on the Russia-Ukraine Conflict, in *Fighting for Empowerment in an Age of Violence*. 2022, IGI Global. p. 238-248.
14. Diorditsa, I.V., et al., Information interventions as a new dimension of Ukraine's cyber-vulnerability. *Linguistics and Culture Review*, 2021. 5(S2): p. 152-166.
15. Primush, R., PUBLIC ADMINISTRATION IN NATIONAL SECURITY PROTECTION: THE USA EXPERIENCE FOR UKRAINE. 2021.
16. SCHEAFFER, K., Russia's invasion of Ukraine has global impacts. 2022.
17. Magafas, L. and K. Demertzis, Russia vs Ukraine Cyberwarfare: Lessons Learned.
18. Vaas, L. Microsoft detected cyberattacks launched against Ukraine hours before Russia's tanks and missiles began to pummel the country last week. 2022 [cited 2022; Available from: <https://threatpost.com/microsoft-ukraine-foxblade-trojan-hours-before-russian-invasion/178702/>].
19. Analytica, O., Ukrainian cyberattack is symbolic. *Emerald Expert Briefings*, 2022(oxan-es).
20. Analytica, O., Ukraine conflict alters the role of cyberspace in war. *Emerald Expert Briefings*, 2022(oxan-es).
21. Albarakati, A.J. and M. Bikdash, Empirical framework for identification of the most harmful malicious attacks on a smart grid. *Applied Network Science*, 2022. 7(1): p. 1-21.
22. Patel, P.R., Ebola Virus, in *StatPearls* [Internet]. 2022, StatPearls Publishing.
23. Treyger, E., J. Cheravitch, and R. Cohen, Russian Disinformation Efforts on Social Media. 2022, RAND CORP SANTA MONICA CA.
24. Johns, S., Sandworms and Computer Worms: An Assessment of American Critical Infrastructure Cyber Vulnerabilities and the Russian Federation's Growing Offensive Capabilities. 2022.
25. Serpanos, D. and T. Komminos, The Cyberwarfare in Ukraine. *Computer*, 2022. 55(7): p. 88-91.
26. Firoozjahi, M.D., et al., An evaluation framework for industrial control system cyber incidents. *International Journal of Critical Infrastructure Protection*, 2022. 36: p. 100487.
27. Long, A., Secrets of the Cold War: Espionage and Intelligence Operations-From Both Sides of the Iron Curtain. 2022: Pen and Sword History.
28. Juutilainen, J., Cyber Warfare: A Part of the Russo-Ukrainian War in 2022. 2022.
29. Jasper, S., Russian Cyber Operations: Coding the Boundaries of Conflict. 2022: Georgetown University Press.
30. Carlos, O.S., Using cyber threat intelligence to support adversary understanding applied to the Russia-Ukraine conflict. *arXiv preprint arXiv:2205.03469*, 2022.
31. Bear, F., et al., Fancy Bear.
32. Nespolo, R.F., C. Mejias, and F. Bozinovic, Why bears hibernate? Redefining the scaling energetics of hibernation. *Proceedings of the Royal Society B*, 2022. 289(1973): p. 20220456.
33. Dogan, G.G., et al., The 30 October 2020 Aegean Sea tsunami: post-event field survey along Turkish coast. *Pure and applied geophysics*, 2021. 178(3): p. 785-812.
34. Anwar, W., Privilege Access Analysis Security Tool for Windows & Linux.
35. Umar, R., Analysis of Conti Ransomware Attack on Computer Network with Live Forensic Method. *IJID (International Journal on Informatics for Development)*, 2022. 1, 2021(1, 2021,): p. Pp. 53-61.
36. Abrams, L. US govt will pay you \$10 million for info on Conti ransomware members. 2022 [cited 2022; Available from: <https://www.bleepingcomputer.com/news/security/us-govt-will-pay-you-10-million-for-info-on-conti-ransomware-members/>].
37. Fayi, S.Y.A., What Petya/NotPetya ransomware is and what its remediations are, in *Information technology-new generations*. 2018, Springer. p. 93-100.
38. Gupta, B.B., et al., Identity-based authentication mechanism for secure information sharing in the maritime transport system. *IEEE Transactions on Intelligent Transportation Systems*, 2021.
39. Bhargava, P., R. Choudhary, and A. Gupta, A Review Study on Computer Virus.
40. von Clausewitz, C., WHAT IS DIGITAL WARFARE? AI for Digital Warfare, 2021: p. 43.
41. Krasznay, C., Case Study: The NotPetya Campaign.
42. Levy, B.S. and J. Leaning, Russia's war in Ukraine—the devastation of health and human rights. *New England Journal of Medicine*, 2022. 387(2): p. 102-105.
43. Gao, Q., et al. Periodic Event-Triggered Resilient Control for Multiarea Interconnected Power Systems under Denial-of-

- Service Attacks. in 2022 IEEE International Conference on Mechatronics and Automation (ICMA). 2022. IEEE.
44. O'Connor, P., Ukraine: The Cyber Battlefield. ITNOW, 2022. 64(2): p. 42-43.
 45. Morin, B., Russian Information and Influence Operations: Putin's regime survival tools. 2022.
 46. Duo, W., M. Zhou, and A. Abusorrah, A Survey of Cyber Attacks on Cyber Physical Systems: Recent Advances and Challenges. IEEE/CAA Journal of Automatica Sinica, 2022. 9(5): p. 784-800.
 47. Aljohani, T.M., Cyberattacks on Energy Infrastructures: Modern War Weapons. arXiv preprint arXiv:2208.14225, 2022.
 48. Rawtani, D., et al., Environmental damages due to war in Ukraine: A perspective. Science of The Total Environment, 2022. 850: p. 157932.
 49. Purim, A.G.M. and B. Duma, Reassessing Russian Cyberwarfare and Information Warfare (2007-2022).
 50. Astolfi, D., et al., Discussion of wind turbine performance based on SCADA data and multiple test case analysis. Energies, 2022. 15(15): p. 5343.
 51. Altaha, M. and S. Hong, Anomaly Detection for SCADA System Security Based on Unsupervised Learning and Function Codes Analysis in the DNP3 Protocol. Electronics, 2022. 11(14): p. 2184.
 52. Abdelkhalek, M. and M. Govindarasu. ML-based Anomaly Detection System for DER DNP3 Communication in Smart Grid. in 2022 IEEE International Conference on Cyber Security and Resilience (CSR). 2022. IEEE.
 53. Mohee, A., Cyber war: The hidden side of the Russian-Ukrainian crisis. 2022.
 54. Lynch, S.N., FBI says Russian hackers scanning U.S. energy systems and pose 'current' threat, in reuters. 2022, <https://www.reuters.com>:
<https://www.reuters.com/world/fbi-says-russian-hackers-scanning-us-energy-systems-pose-current-threat-2022-03-29/>.
 55. MA'AM HAFIZA, A.S., RESEARCH PROJECT.
 56. Baezner, M. and S. Cordey, Influence operations and other conflict trends, in Cyber Security Politics. 2022, Routledge. p. 17-31.
 57. Morrisonsara, S., Is the cyberwar coming or is it already here? Russia's history of destructive cyberattacks in Ukraine is raising concerns about a cyberwar in the future. <https://www.vox.com>, 2022.
 58. Kiyani, O., ESTABLISHING CYBERSECURITY NORMS IN THE UNITED NATIONS: THE ROLE OF US-RUSSIA DIVERGENCE. Harvard International Review, 2022. 42(4): p. 24-28.
 59. Colorado, C., Cyber Security Experts Warn Of Online Attacks As Russia's Invasion Of Ukraine Continues To Unfold, in CBS news. 2022, CBS news: <https://www.cbsnews.com/colorado/news/cyber-security-online-attacks-russia-invasion-ukraine/>.

Network attacks classification using Computational Intelligence

Brandon MEDINA

Instituto Politécnico Nacional, ESIME Zacatenco
Lindavista, Mexico City 07730, Mexico (BEIFI Student)

Elena ACEVEDO

Instituto Politécnico Nacional, ESIME Zacatenco
Lindavista, Mexico City 07730, Mexico

Antonio ACEVEDO

Instituto Politécnico Nacional, ESIME Zacatenco
Lindavista, Mexico City, 07730, Mexico

Sandra ORANTES

Instituto Politécnico Nacional, CIC
Lindavista, Mexico City, 07738, Mexico

ABSTRACT

Attacks are a threat that no network is exempt from, either to steal data of users or to compromise the information of a company. In the present work a system for the detection of attacks to the network is implemented by the means of a Network Intrusion Detection System. The system detects nine types of attacks. A neural network was implemented to detect these attacks. The data was normalized and balanced to obtain better results. A 70-30 Hold Out validation algorithm was applied. The results of accuracy were: ARP MitM = 99.97%, Active Wiretap = 99.98%, Mirai = 99.76%, SSDP Flood = 99.99%, SSL Renegotiation = 99.96%, Video Injection = 99.99%, SYN DoS = 99.71%, Os Scan = 99.99%, Fuzzing = 99.96%.

Keywords: Artificial Intelligence, Machine Learning, Neural Networks, Network attacks, Classification.

1. INTRODUCTION

The threats that afflict the networks of the National Polytechnic Institute, according to data provided by the Department of Information Security of the National Polytechnic Institute in the year 2021, in the month of January, more than 40,000 attacks of critical severity were detected, 97,000 attacks of high severity and a institutional networks, however, January being a relatively safe month since in November of the same year more than 1.8 million critical severity attacks and 114 thousand high severity attacks were detected [1]. These data are an indicator that even a network such as the National Polytechnic Institute is constantly attacked, which requires a good cybersecurity system.

Referring to the Internet of Things, according to the Palo Alto Laboratory, 57% of IoT devices in the world are vulnerable to attacks, with 41% of the attacks on these devices taking advantage of these weaknesses and one of the most widely used attacks is attacks. Denial of Service Botnet (DoS) [2], these Internet of Things networks tend to have less security as they are local grade networks, since they are at home, they are not usually given importance to protect this type of network.

Currently, there are devices such as firewalls that manage to avoid attacks to a large extent, preventing traffic that may be compromised from entering the network. This is achieved by constantly updating their databases each time a new attack method is identified. this will be added to your information tables, however, this method has an important flaw, to prevent an attack from happening this should have already happened before, been identified and added to the database if this is not fulfilled it cannot be done avoid the attack.

Mexico is one of the most attacked countries in all of America, with more than 60 billion attacks reported in the first 6 months of 2021. Of these attacks, the ones that stand out the most are of a particular type, those that target means of payment, these online services increase their use every day, however, threat prevention methods are not always implemented correctly. properly. For which tools such as the use of biometric data and artificial intelligence are increasingly being studied as a solution to this problem [3].

By 2022, attacks in Mexico increased by 42% compared to the previous year, reaching a sum of more than 85 billion cyberattacks, of which 48% were threats using insecure remote access connections. These attacks, in the same way as in 2021, were carried out with the objective of obtaining information to later demand ransoms to avoid leaking the information [4]. In the same way, data was revealed in which it is ensured that hackers obtained more than 6 trillion dollars and by 2025 the profits of these criminals will increase to more than 15 trillion dollars.

Our proposal is the creation of an algorithm capable of detecting attacks even if they have not occurred before, making a series of data sets with information from numerous attacks and machine learning to train a neural network. so that it identifies when an attempt is made to violate a network and that it manages to prevent said action.

Related works

In 2018, Mirsky *et al* [5], from the University of Negev, proposed a Network Intrusion Detection System which detect attacks on a local network. This system is implemented with a set of ensemble neural networks called autoencoders.

An innovative NIDS architecture was proposed to address effective intrusion detection and non-monolithic NIDS

provisioning in virtualizing NIDSes [6]. For the problem of effective intrusion detection, they need to detect the estate sharing, therefore, they used a static program analysis to solve it. In the second case, they applied a program slicing to parallelize the detection logic programs.

Cano de Benito proposed a Multi-Agent system that detects and slows down DDOS-type attacks in telecommunications networks [7]. A neural network is implemented to predict the protocol corresponding to each attack. This system detects attacks based on protocols: ICMP, UDP and TCP. If the attacker generates random IPs, the system is unable to classify and learn about the origin of the attack.

Liu *et al* [8] implemented a hybrid Intrusion Detection System (IDS) based on machine learning approaches. The system is a scalable framework which makes use of two components: a Host-level and Network-level IDS. This hybrid system allows facing the diversity of cyberattacks while being flexible and efficient in the face of the continuous change of information.

In the same year, 2020, another IDS was proposed [9] against DDoS attacks in Software-Defined Networking environments. The authors combined a Recurrent Neural Network (RNN) with autoencoder. This method showed the best performance in terms of precision, recall, F1-score and accuracy compared to different classical techniques.

2. METHODS AND MATERIALS

Network attacks

Network attacks come in a wide range of forms such as Trojan attacks, DoS/DDos attacks, scan attacks, etc. Within this category, special attention should be paid to DoS attacks, it is difficult to attack the original source of the attack, a good way to protect these attacks is by restricting access to the network, however, this in turn can isolate a network that requires more open connections as is the case of IoT [10].

Below are mentioned some network attacks.

Denial-of-Service (DoS): DoS attacks are an internet event in which hackers attack servers running internet services preventing them from working. In this type of attack, servers are flooded with messages for no other purpose than to saturate the network to prevent it from working, also, the server is bombed with requests to which it must spend resources to respond. This prevents users from being able to access common services provided by the server [11].

The main types of type two attacks are as follows:

- DNS (Domain Name System) attack on the server.
- HTTP (Hypertext Transfer Protocol) attack on the server.
- ICMP (Internet Control Message Protocol) flooding.
- Dead Ping attack.
- SYN flood attack on TCP (Transmission Control Protocol).

Distributed Denial of Service (DDoS): Although DDoS attacks are similar to DoS attacks in the sense that they are responsible for denying common users access to network services provided by the server. In DDoS attacks, a computer is used to violate multiple computers around the world, these computers will become infected and will infect more computers.

Man-in-the-Middle (MitM): These attacks are cyber-attacks in which a hacker intercepts communications between a user and a web server without the knowledge of either. This type of

attack is carried out to intercept, decrypt and steal the personal information sent between the two sources.

This type of attack consists of 3 main steps:

- Search for network vulnerabilities.
- Emails are sent in which information is requested, such as the credentials of social network or bank accounts (this step is called Phishing).
- The information is decrypted and used for different purposes, such as extracting money from bank accounts.

Artificial Neural Network

An Artificial Neural Network is a set of single neurons interconnected to simulate the architecture and the function of the human brain.

ANN has a skill to generalize the data from previous examples to find and converge the new ones [12].

ANN models can be implemented in software to carry out classification, diagnosis, and pattern recognition tasks.

Multi-Layer Perceptron (MLP) is a feed-forward, and supervised neural network. The architecture of the multilayer perceptron is characterized by having its neurons grouped in layers of different levels. Each of the layers is made up of a set of neurons, and there are three different types of layers: the input layer, the hidden layers, and the output layer, as shown in Figure 1.

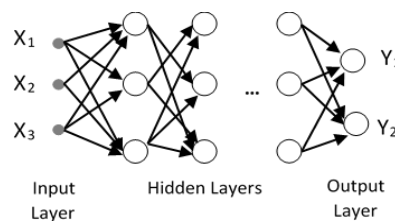


Figure 1. Basic architecture of a Multi-Layer Perceptron

From Figure 1, it can be observed that the connections of the multilayer perceptron are always directed forward, which means the neurons of one layer are connected with the neurons of the next layer; hence they are also called forward-fed networks. The connections between neurons are associated with a real number called the connection weight. All neurons in the network are also associated with a threshold.

For the propagation of the input patterns for the Multi-Layer Perceptron the following must be defined:

C: No. of layers of the MLP. Therefore, there are $C-2$ hidden layers.

nc: neurons in layer c , for $c = 0, 1, 2, \dots, C-1$.

$W^c = (w_{ij}^c)$ is the weight matrix associated with the connections from layer $c-1$ to the layer c for $c = 1, 2, \dots, C-2$, where w_{ij}^c is the weight of the neuron connection i of layer $c-1$ to the neuron j of layer c .

$U^c = (u_i^c)$ is the vector of thresholds of the neurons of the layer c for $c = 1, 2, \dots, C-1$.

a_i^c is the activation of the neuron i of the layer c .

The activations of neurons are activated in the following way.

- Activation of input layer neurons (a_i^0). The neurons of the input layer are responsible for transmitting signals received from outside to the network. Therefore, Eq.(1) shows the activations of the input layer.

$$a_i^0 = x_i \text{ para } i = 1, 2, \dots, n_1 \quad (1)$$

where $X = (x_1, x_2, \dots, x_{n_1})$ represents the pattern from the input of the network.

- Activation of hidden and output layers neurons c (a_i^c). The hidden neurons of the network process information received by applying an activation function f to the sum of the products of the activations received by their corresponding weights as Eq.(2) shows:

$$a_i^c = f \left(\sum_{j=1}^{n_{c-1}} a_j^{c-1} w_{ji}^c + u_i^c \right) \quad (2)$$

for $i = 1, 2, \dots, n_c$ and $c = 1, 2, \dots, C-2$. Where a_j^{c-1} are the activations of the neuron of layer $c-1$.

The goal of neural network training is to minimize the cost function by finding the appropriate weights for the connections of the network, trying to ensure the best generalization. The discovery of these weights is performed by an algorithm called backpropagation.

In the feedforward process, the activations are propagated forward. In the Backpropagation algorithm, the error made by the network is propagated backward while the network weights are updated. The optimizer is in charge of generating better and better weights. Its operation is based on calculating the gradient of the cost function (partial derivative) for each weight (parameter/dimension) of the network. Since the error must be minimized, each weight is modified in the (negative) direction of the gradient. The update of the parameters (weights and thresholds) is represented by Eq. (3).

$$w(n) = w(n-1) - \alpha \frac{\partial e(n)}{\partial w} \quad (3)$$

where $e(n)$ is the error for pattern n and α is the learning ratio or rate, a parameter that influences the magnitude of the displacement on the surface of the error.

Dataset

The dataset is called Kitsune Network Attack Dataset and it was obtained from the web page of the UCI Machine Learning Repository [13]. The dataset has 115 attributes and 27170754 instances. There are nine attacks which can be observed in Table 1.

Table 1. The nine attacks in Kitsune Network Attack Dataset.

| Type of attack | Name |
|-------------------|--|
| Recon. | Os Scan Fuzzing |
| Man in the Middle | Video Injection ARP MitM Active Wiretap |
| Denial of Service | SSDP Flood SYN DoS SSL Renegotiation |
| Botnet Malware | Mirai |

The type of the numbers in the dataset is real. The range of data is very varied. Some columns vary from values from 0 to 1

Others reach values of up to hundreds of units and they even reach a couple of thousand. Figure 2, shows this behavior.

Figure 2. Raw data from Kitsune Network Attack Dataset. The ranges of the dataset are varied.

There is a file for each attack. The size of the files is not the same, that is, the number of rows is not homogeneous, the smallest file has 70 thousand study subjects, however, the largest archive reaches 4.5 million study subjects. The file size can be observed in Table 2.

Table 2. The file size of each attack

| Name of the attack | File size (GB) |
|--------------------|----------------|
| Os Scan | 4.55 |
| Fuzzing | 6.02 |
| Video Injection | 6.63 |
| ARP MitM | 6.71 |
| Active Wiretap | 6.11 |
| SSDP Flood | 10.9 |
| SYN DoS | 7.43 |
| SSL Renegotiation | 5.92 |
| Mirai | 1.27 |

The large size of the files represents a problem due to the available RAM memory capacity. To be able to handle these file sizes and, at the same time, have the compute capacity for the training process to take place, it would be necessary to have a memory of at least 64 GB.

The problem was solved by taking 10% of the records and joining them into a single data set to train the network. This process was performed 7 times, that is, 70% of the data set was taken. The remaining 30% was used to carry out functional tests of the neural network.

3. THE PROPOSED ARCHITECTURE

The classifier was developed with Python 3.7. language, using Anaconda Navigator and Jupyter Notebook, and Tensorflow library. It was implemented in a Laptop Omen core i7, 32GB-RAM.

The problem of non-standardized data was solved by the function *preprocessing.scale* which has two main functions:

- Standardize data on any axis.
- Center the mean using unit variance

With the previous process, a mean equal to 0 and a standard deviation equal to 1. This function applies the following mathematical formula:

$$Z = \frac{X - Media}{Standart\ Deviation}$$

For example, the Fuzzing dataset had more than 800 thousand common traffic packets but only 2000 attack packets, therefore, there are approximately 400 times more packets of common traffic than that of packets that represent attacks.

After performing several tests, we found the optimal architecture for the neural network which can be observed in Table 3.

Table 3. The architecture of the neural network proposed in this work.

| Parameter | Information | Values |
|------------------------------------|------------------------|--------|
| Number of hidden layers | Hidden layers | 2 |
| Number of neurons | Input layer | 115 |
| | Hidden layer 1 | 115 |
| | Hidden layer 2 | 115 |
| | Output layer | 1 |
| Data split | Training data | 70% |
| | Testing data | 30% |
| Activation function between layers | ReLU | |
| Last layer activation function | Sigmoid | |
| Loss function | Root mean square error | |
| Optimization algorithm | Adam | |
| Data processing functions | Scale() | |
| | BatchNormalization() | |
| Data balancing functions | Smote() | |

In this case, 300 epochs and a batch size of 450 were occupied.

4. RESULTS

The Hold-Out (70-30) test were used as validation. The metrics that were applied were: Confusion Matrix, Accuracy, Precision, Recall and F1-score. First, the results from individual attacks are shown. In Table 4, the training time is presented for each attack.

Table 4. Neural network training time and number of packets per set of data.

| Attack | Number of packets analyzed | Training time (mins) |
|-------------------|----------------------------|----------------------|
| ARP MitM | 2,504,267 | 46 |
| Active Wiretap | 2,278,689 | 42 |
| Fuzzing | 2,244,139 | 43 |
| Mirai | 764,136 | 11 |
| Os Scan | 1,697,851 | 33 |
| SSDP Flood | 4,077,266 | 73 |
| SSL Renegotiation | 2,207,571 | 42 |
| SYN DoS | 2,771,276 | 53 |
| Video Injection | 2,472,401 | 43 |
| | Average | 42.88 |

From Table 4, it can be observed that the number of packages is not balanced, it means that, for example, there are more packages from SSDP Flood attack than Mirai attack. This is a problem when combining all the data and training the neural network because the characteristics of an attack that has more data would be learned more strongly than attacks that have

fewer packets. The solution is to oversample so that all attacks have the same number of packets. For this, the Python function SMOTE() was applied.

The results of the metrics for individual attacks are shown in Table 5.

Table 5. Results obtained from the evaluation metrics for each attack with balanced data.

| Attack | Accuracy (%) | Precision (%) | Recall (%) | F1-score (%) |
|-------------------|--------------|---------------|------------|--------------|
| ARP MitM | 99.97 | 99.99 | 99.96 | 99.97 |
| Active Wiretap | 99.98 | 99.98 | 99.97 | 99.97 |
| Mirai | 99.76 | 99.99 | 99.72 | 99.86 |
| SSDP Flood | 99.99 | 99.99 | 99.96 | 99.97 |
| SSL Renegotiation | 99.96 | 99.17 | 99.92 | 99.54 |
| Video Injection | 99.99 | 99.96 | 99.99 | 99.97 |
| SYN DoS | 99.71 | 99.45 | 99.98 | 99.71 |
| Os Scan | 99.99 | 99.99 | 99.99 | 99.99 |
| Fuzzing | 99.96 | 99.94 | 99.99 | 99.96 |

Below are the results when data from all nine attacks are pooled together. Table 6 shows the confusion matrix of this test. Remember that you are working with 70% of the data to train and the remaining 30% to test.

Table 6. Confusion matrix when working with the nine attacks.

| | |
|-----------------|-----------------|
| True positives | False Positives |
| 916487 | 98 |
| False Negatives | True Negatives |
| 1611 | 1611 |

Table 7 shows the results of the metrics.

Table 7. Results obtained from the nine attacks applying the four-evaluation metrics.

| Accuracy (%) | Precision (%) | Recall (%) | F1-score (%) |
|--------------|---------------|------------|--------------|
| 99.86 | 99.97 | 99.53 | 99.75 |

Now, the results of the comparisons between the works of the state of the art and our proposal are presented.

It is important to begin by mentioning that not all the related works present comparable results with those obtained in this proposal, therefore, only works whose results can be compared should be mentioned since they have used similar evaluation metrics. Table 8 shows the comparisons between the results from Kitsune [5] and this paper.

From Table 8, It is confirmed that the network exceeded expectations, but it should also be clarified that this network can work without internet while Kitsune only works online.

Now, we will compare the results of this paper with Elsayed [9]. In this case, only the results for denial-of-service attacks will be compared, since in this article only this type of attack is detected. This can be observed in Table 9.

The work in that document has two advantages over Elsayed: it provides better results and detects more than one type of attack, not just a denial-of-service type.

Finally, in Table 10, the comparisons of the results between Liu [8] and our proposal are shown. Recall that in [8] two different types of neural networks were applied.

Table 8. Comparison of results between Kitsune and our proposal.

| Attack | Accuracy (%) | |
|-------------------|--------------|---------------|
| | Kitsune | This proposal |
| Os Scan | 94.80 | 99.99 |
| Fuzzing | 99.99 | 99.96 |
| Video Injection | 80.45 | 99.99 |
| ARP MitM | 79.49 | 99.97 |
| Active Wiretap | 90.87 | 99.98 |
| SSDP Flood | 99.99 | 99.99 |
| SYN DoS | 92.28 | 99.71 |
| SSL Renegotiation | 93.93 | 99.96 |
| Mirai | 99.85 | 99.76 |

Table 9. Comparison of results between Elsayed and our proposal.

| This proposal Accuracy (%) | Elsayed Accuracy (%) |
|--|----------------------|
| SSDP Flood = 99.99 SYN DoS = 99.71 SSL Renegotiation = 99.96 | DDoSNet = 99.00 |

Table 10. Comparison of results between Liu and our proposal.

| Algorithm | Accuracy (%) | Precision (%) | F1-score (%) |
|-------------------------------|--------------|---------------|--------------|
| NSL-KDD Multi-classification | 99.51 | 82.17 | 83.74 |
| ADFA-LD Binary classification | 92.81 | 75.28 | 77.90 |
| This paper | 99.8 | 99.97 | 99.75 |

From Table 10, it can be observed that our neural network showed the best results.

It should be noted that the complexity of the neural networks used in [8] is greater than that applied in the present work.

5. CONCLUSIONS

The neural network architecture proposed in this work showed the best results compared to related works.

Our system works offline unlike Kitsune's. The average difference between their results and our proposal is 11.29. In the result of the SSDP Flood attack the same accuracy was obtained, and in the Fuzzing and Mirai attacks, Kitsune obtained better results, resulting in differences of 0.03 and 0.09, respectively.

In the case of Elsayed, our results were better showing an average difference of 0.88 in efficiency. In addition, that, in this work, only three attacks are detected.

Finally, in the case of Liu, our results were better and our system architecture is less complex.

6. REFERENCES

[1] Instituto Politécnico Nacional. Seguridad informática. [Online]. 2022. Available: <https://www.seguridad.ipn.mx/estadisticas.html>.

[2] L. de Palo Alto. Seis de cada diez dispositivos de internet de las cosas son vulnerables a ataques. 2022 [Online]. Available: <https://www.laautenticadefensa.net/194159>.

[3] J. Leyva, México lidera en la región intentos de ciberataques, El Financiero, 2022. [Online]

<https://www.elfinanciero.com.mx/economia/2022/05/19/mexico-lidera-en-la-region-intentos-de-ciberataques/>

[4] C. Calderón, México ‘clientazo’ de los ciberataques: crecen 42% amenazas por internet, El Financiero, 2022. [Online] <https://www.elfinanciero.com.mx/empresas/2022/06/09/au-mentan-42-los-ciberataques-con-85-mil-millones-de-intentos-en-mexico/>

[5] Y. Mirsky, T. Doitshman and A. Shabtai, “Kitsune: An ensemble of autoencoders for online network intrusion detection”, **Network and Distributed Systems Security Symposium (NDSS)**, 2018.

[6] H. Li, “vnids: Towards elastic security with safe and efficient virtualization of network intrusion detection systems”, **Conference on Computer and Communications Security**, 2018.

[7] J. C. de Benito, “Despliegue de sistema multi-agente para la detección y mitigación de ataques de denegación de servicio”, Unidad Politécnica de Madrid, 2018.

[8] J. Liu; K. Xiao; L. Luo; Y. Li; L. Chen. “An intrusion detection system integrating network level intrusion detection and host-level intrusion detection”, **IEEE 20th International Conference on Software Quality, Reliability and Security (QRS)**, 2020.

[9] M. Elsayed, N. Le-Khac, S. Dev, and A. Jurcut. “DDoSNet: A Deep-Learning Model for Detecting Network Attacks”, **IEEE 21st International Symposium on A World of Wireless, Mobile and Multimedia Networks**, 2020.

[10] A. Ghorbani, W. Lu, M. Tavallae. “Network Intrusion Detection and Prevention: Concepts and Techniques” in *Advances in Information Security*, 2010.

[11] D. Thakur and A. Pathan, “Cybersecurity Fundamentals. A Real-World Perspective”. Milton Park, Abingdon: CRC Press, 2022.

[12] F. Chollet, “Deep Learning with Python”, New York: Manning Shelter Island, 2018.

[13] <https://archive.ics.uci.edu/ml/datasets/Kitsune+Network+Attack+Dataset>

Toward Automated Project Management

Yadira-Jazmín PÉREZ-CASTILLO

Instituto Politécnico Nacional, Centro de Investigación en Computación (CIC-IPN),
CDMX, 07738, México.

Sandra-Dinora ORANTES-JIMÉNEZ

Instituto Politécnico Nacional, Centro de Investigación en Computación (CIC-IPN),
CDMX, 07738, México.

María-Elena ACEVEDO-MOSQUEDA

Instituto Politécnico Nacional, Escuela Superior de Ingeniería Mecánica y Eléctrica (ESIME-IPN),
CDMX, 07738, México.

ABSTRACT

The development of new technologies, such as Artificial Intelligence, has opened opportunities to support several disciplines, including Project Management; however, the relationship between both disciplines is still developing. Therefore, the objective of this paper is to know the current situation of Artificial Intelligence about PM and to detect new areas of opportunity to generate research within these two areas, which, when integrated, seek an improvement in the processes of organizations.

Keywords: Software Engineering, Project Management, Artificial Intelligence, Machine Learning, Success Projects.

1. INTRODUCTION

The emergence of new technologies is having a major impact on our lives and on the way people work. Likewise, new models and methods have been created to speed up the implementation of existing processes in industries. The application of these technologies will greatly improve work efficiency and create enormous economic benefits, as well as bring opportunities and challenges.

Therefore, knowing and actively applying new technologies is essential to improve the company's competitiveness.

One of these new technologies is Artificial Intelligence (AI), which, as a new emerging technology, is revolutionizing the industry and affecting the global economy and the way organizations decide to consider it in their process improvement.

AI has been described as "The design and construction of intelligent agents that receive perceptions from the environment and take actions that maximize their chances of successfully achieving their goal" [1] by Stuart J. Russell and Peter Norvig, computer scientists have known for their contributions.

On the other hand, Project Management (PM) has become a tool that allows organizations to generate quality projects, according to the time and cost required for the same, in the same way, allows obtaining a final product with the requirements established by the stakeholders in the project.

PM has become a critical skill in the last few decades with the rise of technology. Now, with the integration of AI into our applications, there will be a shift in technology, but the real driver of our success will lie in the culture of our teams, and how we use the information provided by AI-based systems [2].

The objective of this paper is to review the status of PM supported by AI technologies. This paper is distributed as follows: in section 2, the main background of this in-depth research is presented; in section 3, relevant concepts that will help the reader to better understand the current landscape of Machine Learning (ML) focused on PM are provided; in section 4, the main findings of this research are discussed.

Finally, in sections 5 and 6, the conclusions of the work and comments on future work are established.

2. BACKGROUND

AI research has explored a variety of problems and approaches since its inception, but over the past few decades, progress has been tremendous. As capabilities in these areas are assessed, there is now a broad consensus that AI and its impact on society are likely to increase.

The role of AI in PM for organizations is changing, primarily in the way it provides information to its stakeholders, based on a variety of data sources.

In this report, we explore trends and projections on how PM functions should adapt to the new trends and what happens if the impact of AI.

Currently, PM has several areas that can be supported by artificial intelligence models. During many years of experience in solving planning and project management tasks, it has accumulated an extensive historical database (status and actual results of projects, costs, and resources used for each type of activity), which is the so-called "Big Data" and can be used to develop forecasting models using ML methods such as neural networks, decision trees and more [3].

For efficient PM, the Project Management Institute (PMI) has established a set of recognized practices from the perspective of

the Project Management Body of Knowledge. (PMBOK) [4]. PM is more than just a tool used for a project, but a results-oriented method used to manage any project within various sectors of the economy [5]. It is used to plan strategies and achieve organizational objectives [6] [7].

The following sections will explore how these two disciplines, AI, and PM, are highly related, and what benefits it can have for a project manager to use AI models to more efficiently manage the data generated when tracking projects.

3. CURRENT STATUS

Exploring current views of the potential impact and future possibilities and opportunities for PM professionals suggests the future direction of the AI approach. Openness and adaptability appear alongside technology as the way forward.

AI will change the way the PM discipline and the role of project managers will work in the future. By 2030, 80% of the work of today's PM discipline will be eliminated as AI takes over traditional PM functions such as data collection, tracking, and reporting [8]. In an analysis carried out at [9], the support of AI over PM is highlighted:

- 1) 3% PM substitute
- 2) 2% assistant PM
- 3) 44% PM advisor AI role
- 4) Most organizations already have a digital transformation strategy that includes the adoption of AI.

In addition, the AI technology with the greatest potential for improving PM has been determined to be ML [9]. Top 3 reasons identified for the adoption of AI in PM [9]:

- 1) Improved decision making
- 2) Increased productivity levels
- 3) Improved performance and reporting

Five key non-IT skills required to use AI in PM [9]:

- 1) Analytical thinking
- 2) Creative thinking
- 3) Problem-solving skills
- 4) Learning skills
- 5) Strategic thinking

It was also determined that practitioners currently use a mix of traditional and agile methods in their projects [9].

On the other hand, in an analysis conducted in [10], according to a survey of Atlassian users, 87% of respondents said that AI would change their jobs in the next three years and the same number said that AI could perform part of their job. This survey shows that AI technology is gradually being applied to various industries and many people are beginning to feel anxious, worried that AI will replace their jobs.

Within the literature, it has been analyzed that one of the most used and common disciplines within the AI area are ML techniques and algorithms, such as ANN, Fuzzy Logic, Genetics,

and Regression. Some of the most common application areas within PM that are currently being supported by ML are:

- 1) Effort estimation
- 2) Cost estimation
- 3) Project success
- 4) Team analysis
- 5) Methodology Adoption
- 6) Task distribution
- 7) Defect detection
- 8) Risk detection

Some of the papers showing the use of ML in support of GP are, [11], in which a review of the current state of ML, focused on GP, is made, and in [12], for example, the current state of the art is analyzed but focused on the area of application for detection.

Software engineering, as a support to GP, is a very large discipline, and one that still has several application areas that can be supported by AI. AI is undoubtedly revolutionizing how Project Managers perform their monitoring processes.

4. DISCUSSION

With this work, a brief analysis of how AI is growing PM was conducted. It was found that AI methods are considered:

- a. PM assistant
- b. PM substitute
- c. PM advisor

Increased flexibility and responsiveness is the main change in project work brought about by AI technologies.

In [9] it was highlighted that 56% of organizations already have a digital transformation strategy that includes the adoption of AI.

However, despite the success that AI is exerting within this area of PM, there is still some uncertainty about project managers; mainly for fear that, they will be completely replaced in the performance of their day-to-day activities.

Despite this, there is still a long way to go for the human to be completely replaced in this area, since the knowledge of experts in a certain area, such as project management, is still required, and primarily for decision-making. An expert system, trained with ML models, can support decision-making, but the final choice will always remain in the hands of the Project Managers.

On the other hand, within the literature, PM has been addressed from a traditional approach, there are advances in each of the lines of application, such as costs, risks, and defects, however, from an agile perspective, there is still room for research to use AI methods, for example, for the analysis of project status from an agile approach.

In works such as [13] [14], for example, the use of ML models focused only on a single line of application, such as risk and cost analysis, has been proposed.

According to al PMBOK [4], three factors including time, cost, and scope are used to analyze the quality of work on a project. However, these three factors alone are not always enough in a real environment to decide the success of a project. Other factors

contribute to the success of projects, such as the collaboration of team members, and their satisfaction with their position in the projects to keep the project on track, it is necessary to allocate resources appropriately and manage quality to reduce errors [15].

On the other hand, by leveraging AI capabilities, project managers can benefit from intelligent automation, predictive analytics, and data-driven insights. AI-enabled project management tools can automate repetitive tasks, freeing up valuable time for managers to focus on strategic planning and critical thinking. This automation can help streamline project workflows, reduce human error, and optimize resource allocation, for example.

Furthermore, AI-powered predictive analytics can analyze large volumes of project data, identify patterns, and provide valuable insights for more accurate forecasting and risk assessment. This allows project managers to make informed decisions, identify potential bottlenecks, and mitigate risks proactively.

Collaboration and communication within project teams can also be enhanced through AI. Intelligent chatbots and virtual assistants can facilitate real-time communication, provide instant access to project information, and assist team members in finding solutions to common issues. Additionally, AI-powered natural language processing capabilities can aid in analyzing project documentation, extracting relevant information, and generating automated reports.

However, it is important to acknowledge that the successful integration of AI in PM requires careful consideration of ethical and privacy concerns. Safeguarding data security, addressing biases in AI algorithms, and ensuring transparency in decision-making processes are crucial aspects that must be prioritized.

In summary, the combination of PM and AI holds great promise in improving project outcomes, enhancing efficiency, and enabling better decision-making. As AI technologies continue to advance, project managers and organizations can leverage these capabilities to navigate complex projects with greater ease and achieve higher levels of success.

5. CONCLUSIONS

This paper analyzed how AI has directly influenced the PM. It was observed that organizations, despite being increasingly open to the use of new technologies, still maintain a certain rejection of new emerging technologies such as AI.

Within the PM area, this is no exception, some PMs tend to maintain a traditional approach and therefore fear being replaced in their work. However, this does not imply that AI does not provide multiple benefits to PM, such as predicting the success of a project to be implemented, for this it is clear that the experience of the PM is required to determine the variables and features that come into play when making the prediction.

On the other hand, it was observed that there is still a lack of work focused on agile project management, which has already begun to occur, but it needs to be refined and integrated with certain application areas, such as cost management, risk management, etc.

Finally, AI as a discipline is growing too fast, and there are still more areas in which to explore its application, and in which to assess its effectiveness, but with the existing work within the state of the art, it has been shown that its use has improved how companies incorporate new technologies to improve their processes.

In conclusion, the integration of PM and AI has the potential to revolutionize the way projects are planned, executed, and managed. AI technologies offer significant advantages in enhancing project efficiency, decision-making, and overall success.

6. FUTURE WORK

Among the proposed future works, which were identified as areas of opportunity for this research area, the following stand out:

- 1) Analyze the current state of the art focused on the application area of agile project tracking supported by AI techniques.
- 2) To implement an ML model that supports project tracking within an agile environment.
- 3) To analyze new opportunities within the application lines of the agile approach that can be supported by AI techniques.

7. REFERENCES

- [1] S. J. Russell, P. Norvig, and E. Davis, Artificial intelligence : a modern approach, Third edition. Upper Saddle River, N.J. : Prentice Hall, 2010, 1962.
- [2] C. Chheda and C. D. Chheda, Project Management in the Age of Artificial Intelligence, vol. VIII, 2019.
- [3] A. Piskarev and N. Zarikovskaya, Intelligent system of planning support and project management, vol. 1488, Institute of Physics Publishing, 2020.
- [4] Project Management Institute, A Guide to the project management body of knowledge (PMBOK® guide), 6th ed., Project Management Institute, 2017.
- [5] J. C. F. de Guimarães, E. A. Severo and P. S. Vieira, Cleaner production, project management and Strategic Drivers: An empirical study, vol. 141, Elsevier, 2017, pp. 881-890.
- [6] B. Neverauskas and R. Railaite, Formation approach for project management maturity measurement, vol. 18, Publishing House Technologija, 2013, pp. 360-365.
- [7] M. A. Fauzi, K. F. Anuar, R. A. Rahman, J. Jupir and N. M. Sapuan, Determinants of project management success: view from an emerging economy, 2021.
- [8] A Virtual Partnership? How Artificial Intelligence will disrupt Project Management and change the role of Project Managers, 2019.

- [9] Artificial Intelligence impact in Project Management in association with, 2020.
- [10] Q. Wang, How to apply AI technology in Project Management, vol. VIII, 2019.
- [11] M. Z. M. Hazil, M. N. Mahdi, M. S. Mohd Azmi, L. K. Cheng, A. Yusof and A. R. Ahmad, Software Project Management Using Machine Learning Technique - A Review, Institute of Electrical and Electronics Engineers Inc., 2020, pp. 363-370.
- [12] A. Sousa, J. P. Faria and J. Mendes-Moreira, An analysis of the state of the art of machine learning for risk assessment in software projects, Vols. 2021-July, Knowledge Systems Institute Graduate School, 2021, pp. 217-222.
- [13] K. Periyasamy and J. Chianelli, A Project Tracking Tool for Scrum Projects with Machine Learning Support for Cost Estimation, vol. 76, EasyChair, 2021, pp. 86-76.
- [14] I. Shamshurin and J. S. Saltz, A predictive model to identify Kanban teams at risk, vol. 14, IOS Press, 2019, pp. 321-335.
- [15] R. Mamatha and K. G. Suma, Role of machine learning in software project management, vol. 2040, IOP Publishing Ltd, 2021.

Generative AI as a Dangerous New Form of Media

Louis ROSENBERG

Unanimous AI

Pismo Beach, CA 93448, USA

ABSTRACT

When policymakers and regulators assess the near-term risks of generative AI, they often focus on the dangerous ability to create and disseminate traditional misinformation at scale. This paper argues that we must expand this view and consider generative AI not merely as a vehicle for producing traditional content at scale, but as enabling an entirely new form of media that is adaptive and interactive in real-time and can be personalized for individual users. Referred to herein as Interactive Generative Media (IGM), this new form of targeted influence could be used to manipulate individual users at scale and compromise human agency. Two specific tactics are presented: Targeted Generative Advertising and Targeted Conversational Influence. The risks of each are described along with recommended policy protections.

Keywords: Generative AI, Large Language Models, Chatbots, Interactive Generative Media, Conversational Advertising, HCI.

1. INTRODUCTION

As policymakers confront the dangers of generative AI, they often focus on its ability to create and disseminate traditional misinformation at scale. This is because generative systems can now fabricate everything from images and videos, to articles, legal briefs, and scientific papers with convincing results. For example, recent research found that users cannot distinguish between tweets generated by GPT-3 and those created by real human users [1]. The risk, therefore, is that bad actors will flood the digital world with untruths, overwhelming our ability to distinguish the factual from the fabricated.

On the other hand, the dissemination of false and misleading content is already a significant problem online whether generated by humans or not. From this perspective, current methods for combatting traditional misinformation may be effective against this type of generative content. Regulators, therefore, must also focus on how generative AI could create entirely new threats that are not addressed by current protections. In particular, we must consider how generative AI technology can enable new forms of targeted content that are personalized, interactive and adaptive in real-time, and can be deployed at scale to target individual users on a person-by-person basis [2,3].

Referred to herein as *Interactive Generative Media*, this new form of personalized content has the potential to not only spread misinformation, but it could also threaten human agency through real-time deception, coercion, or manipulation. The phrase “epistemic agency” refers to an individual’s control over his or her own personal beliefs [4]. When epistemic agency is compromised by new forms of media, the political establishment can undermine democratic institutions by deploying propaganda, disinformation, and misinformation that supports authoritarian objectives, interests, or policies [5-8].

Mass media techniques have been used for generations to weaken agency in populations, but over the last decade this problem has been amplified by social media and its ability to

spread targeted influence with network effects [9]. This has been shown to drive polarization, promote radicalization, and foster discontent [10,11]. In this context, all new forms of media should be evaluated in their capacity for abuse and misuse, especially when it has the potential to threaten human agency [12].

2. INTERACTIVE GENERATIVE MEDIA

Interactive Generative Media (IGM) is informational content that is custom crafted by generative AI systems to maximize impact on individually targeted users and can adapt its persuasive tactics in response to real-time user reactions. Unlike traditional forms of targeted media (e.g., essays, articles, videos, memes, and posts) that are aimed at specific demographic groups, like buckshot fired at flocks of birds, generative AI will enable targeted content to be deployed more like heat-seeking missiles, zeroing-in on individual users for optimal effect.

In this way, Interactive Generative Media can be defined as personalized, adaptive, and interactive content that is deployed in real-time to maximize engagement and optimize influence on individually targeted users. It is no coincidence that driving user engagement and selling user influence are core business goals of most ad-based social platforms. It is therefore likely that IGM will be used aggressively by major corporations unless regulators put guardrails in place. In fact, Google, Meta, and Microsoft each announced plans in early 2023 to use generative AI to automate the creation of targeted ads [13, 14, 15]. If meaningful regulatory protections are not put in place, it is likely that two dangerous forms of interactive media will become standard practice among large technology platforms: “*Targeted Generative Advertising*” and “*Targeted Conversational Influence*.”

Targeted Generative Advertising can be defined as text-based, image-based, and video-based forms of informational content that look and feel like traditional advertising but is personalized by generative AI for maximum impact on individually targeted users. These ads will be created in real-time based on influence objectives provided by third-party sponsors that describe the advertising concept and messaging goals. This will be used in combination with personal background data accessed for the specific user for whom the custom content is being created. The personal data may include the user’s age, gender, interests, values, education-level, aesthetic and intellectual sensibilities, purchasing tendencies, and cultural biases.

In response to the influence objectives and personal data, the generative AI system will create the ad, customizing the layout, feature images, and language used to maximize effectiveness on that user. Everything down to the colors, fonts, and punctuation could be personalized along with age, race, and clothing styles of any persons shown in the imagery. And because tech platforms can track user engagement, the system will learn which promotional features work best on individual consumers, discovering for example, whether you respond better to redheads or brunettes – whether you are drawn to images of families with

minivans or bachelors driving expensive sports cars – whether you react most to logical arguments or emotional messaging.

Assuming these generative methods produce more clicks for advertiser, they will likely become standard practice, and an arms race will follow, with platforms competing to produce the most effective personalization techniques. Even platforms that choose to avoid manipulative tactics for ethical reasons may be pressured to pursue these methods by rivals that take a more aggressive posture on interactive adaptive ads [27]. For this reason, policy solutions may be the only way to prevent the industry from racing in this direction. Furthermore, this risk is likely to accelerate as the market transitions from traditional forms of print and video advertising to new forms of conversational influence.

Targeted Conversational Influence can be defined as real-time generative techniques in which pre-defined influence objectives are conveyed to individual users through interactive dialog rather than traditional documents or videos. Until recently, the risks of conversational influence were largely theoretical, as the tools did not exist to enable convincing AI-generated conversations at scale. This has rapidly changed over the last 12 months with the deployment of foundational Large Language Models (LLMs) such as GPT-4 from Open AI.

Currently, the most popular conversational AI systems are text-based chatbots. That said, voice-based systems (powered by LLMs) will become equally pervasive in the near future. We can therefore predict that consumers will soon engage chatbots and voice-bots frequently throughout their daily lives, as third-party developers use APIs to integrate LLMs into apps and websites. For example, in the near future you might request the latest scores on a sports website by speaking naturally to an AI-powered conversational agent. During the interaction, you may receive the desired information (as dialog) but could also be targeted with conversational influence – subtle messaging integrated into the flowing dialog with pre-defined promotional objectives.

In this way, Targeted Conversational Influence may become an insidious form of persuasion, as it may not be easily identified by users as promotional material. Instead, it could be woven skillfully into the dialog, mixed with informational content. And like Targeted Generative Ads, these conversational experiences will be generated in real-time for individually targeted users based on (i) influence objectives provided by sponsors along with (ii) personal background data accessed for the specific user engaged in the dialog. The personal data may include the user's age, gender, interests, hobbies, values, etc... thereby enabling the generative AI system to produce dialog that could optimally appeal to the specific person.

Why conversational influence? As most salespeople know, the best way to persuade a target customer is not to hand them a brochure or tell them to watch a video. Instead, the best way to influence a customer is to engage them in interactive face-to-face conversation so the salesperson can pitch a product, hear the customer's reactions and reservations in real-time, and then adjust the promotional arguments and sales tactics to overcome resistance. It is a cyclic process of pitching and adjusting, all highly individualized, until the salesperson finally talks the customer into the purchase [16, 17, 18].

While conversational pitching has been a purely human skill in the past, generative AI has enabled automated systems to perform all of the steps – (pitching, observing, adjusting) – but potentially with deeper knowledge and greater skills than human representatives. This is dangerous as it could easily create a highly asymmetric relationship between the customer and the AI-powered representative in which the human is deeply outmatched and easily manipulated [16, 17, 22-26]

For example, unlike a human salesperson who only has one persona for engaging customers, a conversational AI is a *digital chameleon* that can assume any speaking style from formal to folksy, nerdy to hip, and can pursue any sales tactic from befriending the customer to playing on their fear of missing out. And the conversational systems will be armed with personal data about every unique user it faces, enabling it to mention the right sports teams or musical groups to ease the user into friendly dialog, or appeal to the right political values or sensibilities.

Furthermore, it is not just about choosing an effective style or tactic for a given user. These personalized conversations will be modified in real time based on user interactions. This means the AI agent could assess the user's reactions, determining which arguments are working and which are being met with resistance. The AI agent will then adjust its arguments and persuasive tactics to maximize appeal and overcome objections. And because tech platforms could document the effectiveness of prior promotional conversations, the system could learn over time which types of arguments work best on specific users. Does that user respond best to logical or emotional appeals? Is that user most influenced by a confident and forceful representative, or a friendly and empathetic one? In our rapidly approaching conversational future, platforms could quickly learn to pull our strings [16].

Of course, the biggest danger is not the optimized ability to sell products and services. The very same techniques could be used to drive propaganda and misinformation, talking users into false beliefs or extreme ideas that they might normally reject. A conversational agent, for example, could easily be directed to convince you that perfectly safe medicines are dangerous. And because it has access to all the world's information, it could cherry-pick evidence in ways that would overwhelm a human user who does not have infinite information access. And even if large LLM providers like Open AI put protections in place, these systems are accessible by API which means that third party developers can implement mediation layers that could easily enable conversations on false or misleading content.

It is therefore critical that policymakers consider the unique dangers of conversational AI and its potential use as a highly personalized and interactive form of targeted influence. It is also important to point out that conversational agents are likely to advance significantly in the next few years, evolving from simple text and voice chatbots to "digital personas" that are embodied as simulated human faces that have an authentic appearance and can express realistic emotional sentiments. These are often referred to as virtual humans or Virtual Spokespeople (VSPs) and are likely to become the interactive face of businesses and services that are accessed online [17]. They are also likely to be more impactful and potentially more manipulative than current chatbots because they will be perceived as more human and will convey information with greater affect [19,20, 24].

Some argue that interactive and adaptive influence on an individual basis is not a new problem because human salespeople and other representatives perform similar tactics. There are two counterarguments. First, while human persuaders can be quite effective, they cannot be deployed at scale with nearly the flexibility or diversity. Second, and more importantly, when human representatives engage in real-time dialog with a human target, the power balance is mostly reciprocal, with each party having similar ability to read the other and similar access to supporting facts. When a human is engaged with an AI-powered conversational agent, the power balance has the potential to be extremely asymmetrical. This is especially true if the AI agent is *designed for persuasion* (i.e., trained on sales tactics, personality types, cognitive biases, and other influence related skills). This is discussed in detail in the following section.

3. THE ASYMMETRY OF CONVERSATIONAL AI

When a user is engaged in real-time dialog with an AI-powered conversational agent, the power balance has the potential to be highly skewed with the human at significant disadvantage. These imbalances can be summarized as follows:

Familiarity Asymmetry: unless regulated, it is likely that AI agents will have access to personal data about target users, ranging from age, interests, education and political views to their favorite teams, movies, and musical artists. This will empower the AI to customize dialog for individual targets. On the other side of the conversation, the human will know nothing about the entity they are conversing with. And if the AI agent is given a visual or vocal persona that represents a particular age, gender, style, or background – it is entirely a façade. In this way, the AI agent could know a great deal about the user, while the user would know nothing about the AI agent. This is a deeply asymmetric relationship and a scenario that has no equivalence with respect to human salespeople.

Emotional Asymmetry: unless regulated, it is likely that AI agents will be able to “read users” when engaged in conversation, assessing not just resistance or agreeableness to influence, but also sense emotional state. *Is the user getting angry, anxious, excited?* This is detectable in text-based dialog and will become even more invasive in voice-based systems in which AI agents can assess vocal inflections of target users. The human, on the other hand, will be unable “to read” their digital counterpart, for any emotions or inflections conveyed in language, voice, or facial expressions (in the case of virtual personas) are entirely fictional, chosen to maximize impact and do not reflect emotional state. This is a deeply asymmetric relationship and not something that has an equivalent with respect to human salespeople.

Continuity Asymmetry: unless regulated, platforms deploying generative media will likely keep track of user’s reactions to targeted influence and will learn what types of persuasive tactics are most effective on individual users. The human in the loop, on the other hand, will learn nothing about the digital representatives they engage throughout their day, for they could be *digital shapeshifters* that can assume any style, tactics, or persona in response to simple API calls. This too is a deeply asymmetric scenario that has no equivalent with human salespeople.

Information Asymmetry: unlike human influencers who can make arguments and counterarguments based on human-level knowledge and experience, AI agents will be able to craft dialog that draws on a nearly infinite information pool and could easily cherry-pick points that the human could not possibly validate in real-time. In fact, an AI agent could create the illusion of expertise by citing overwhelming factual information as a deliberate form of persuasion. This is a deeply asymmetric situation that has no direct equivalent with human salespeople.

Strategic Asymmetry: unless regulated, conversational agents could be trained in sales tactics, negotiation tactics, human psychology, cognitive biases, game theory and other persuasive strategies that make them extremely effective instruments of influence. For example, in 2022 DeepMind developed a strategic AI system called DeepNash that learned to bluff human players and sacrifice gaming pieces for the sake of long-term victory [21]. While human salespeople are often trained in sales tactics, it is likely that AI agents will possess a broader and more nuanced range of persuasive strategies than any human could command

creating a uniquely asymmetric power-imbalance.

Clearly, generative media poses unique interactive risks that have not been faced in traditional media. And as the digital world transitions to conversational interaction with apps, websites, and other software tools, the dangers will only increase. To help policymakers appreciate the unique risks posed by interactive and adaptive forms of influence, it is useful to describe the issue in the language of “feedback control,” which is a common engineering technique used to drive real-time behaviors of target systems. As will be described in the section below, many dangers associated with generative media relate to a platform’s ability to “close the loop” around individual users and use feedback control to maximize influence. Appreciating the basics of control theory may help guide effective policy protections.

4. THE AI MANIPULATION PROBLEM

The AI Manipulation Problem refers to real-time scenarios in which artificial agents manipulate human users by imparting targeted influence through persuasive interactions [2, 3, 17]. It abstracts the problem down to the following sequence of steps performed by an AI system on an individual human user:

- 1) Impart real-time influence on an individual user;
- 2) Detect the user’s reaction to the imparted influence;
- 3) Adjust influence tactics to increase persuasive impact;
- 4) Repeat steps 1-3 to maximize user influence over time;

This may sound like an abstract series of computational steps, but we humans often just call it a conversation. As described above, when a human wants to influence another human in real-time, they will make arguments (i.e., impart targeted influence), listen to reservations and counterarguments (i.e., sense user reactions) and then adjust tactics to overcome objections. The unique danger is that generative AI systems can now perform all of these steps, creating a “feedback control system” around a human user that has the potential to be an extremely effective form of coercion, manipulation, and persuasion.

To help policymakers appreciate how a “feedback control system” is fundamentally different from traditional forms of media-based influence, it is helpful to provide background from the field of Control Theory (see Figure 1).

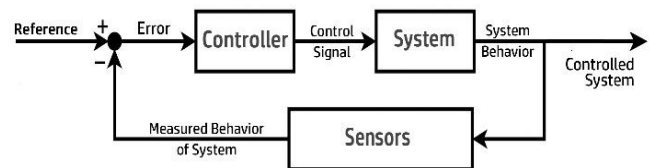


Figure 1: Standard Diagram of Feedback Control System

Control Theory (CT) is the engineering discipline that formalizes how real-time feedback loops can be used to guide the behavior of any system towards a specified goal. The classic example is a thermostat. A homeowner sets a temperature goal and if the house falls below the goal, a controller turns up the heat. If the temperature rises too much, the controller reduces the heat. When working properly, the thermostat keeps the house close to the specified objective.

Referring to Figure 1, the System being controlled in the heating example is a house, the Sensor is a thermometer, and the Controller is a thermostat that modulates the heat as needed. An input signal called the Reference is the temperature goal. The goal is compared to the actual temperature in the house (i.e., the

Measured Behavior) and the difference is fed into the controller which then determines how to adjust the heat. This creates a real-time feedback loop that continually detects behavior (i.e., temperature) and imparts influence (i.e., heat).

While a controller can be as simple as a thermostat, it can also be quite sophisticated. For example, self-driving cars use AI-controllers to navigate traffic, achieving targeted goals in rapidly changing environments. When considering the use of generative AI to impart influence on humans, similar feedback-control methods can be employed. Instead of a simple thermostat that turns up or down the heat as needed, an AI system could modulate persuasive tactics used on an individual human based on the Measured Behavior of the system, which in this case are the real-time reactions of that user. The Reference signal, instead of being a temperature goal, becomes the influence objectives of a third party such as a corporate sponsor or state actor. The third party need not be the creator of the generative AI system but merely needs to input influence objectives through API access. This yields the manipulative control system of Figure 2 below.

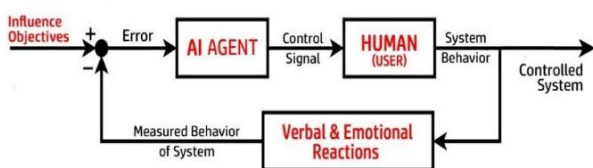


Figure 2: Manipulative Control System using Generative Media

As diagramed above, AI-driven control systems can easily be deployed using generative media techniques to create interactive agents that are designed to maximize the persuasive impact on individually targeted users. For example, conversational agents could be designed to draw target users into friendly dialog and gradually *talk them into* specific influence objectives. This is instructional for policymakers because restricting one or more of the elements in the control system diagram above, the feedback loops could be disrupted and the ability of third parties to deploy optimized influence could be mitigated.

For example, regulators could consider banning generative AI systems from making any real-time adjustments to promotional imagery or promotional messaging in response to detected user reactions. This could prevent generative AI systems from being used in these highly manipulative ways.

In addition, regulators and policymakers could require that all forms of Targeted Conversational Influence be obligated to disclose their *influence objectives* to the user upon initiation of the dialog. This disclosure would ideally be part of the conversation and not a subtle disclaimer that can be skipped over. This approach could prevent conversational influence from being added covertly to conversational exchanges without the user knowing that a third party has directed the system to impart personalized influence. This is significant because it will allow the user to view the interaction as promotional and bring a healthy dose of skepticism to the conversational exchange.

And finally, policymakers and regulators should consider an outright ban on all forms of Interactive Generative Influence that targets minors, for children are more impressionable than adults and already have a significantly harder time distinguishing between promotional and authentic content. This is especially true for conversational influence targeting minors.

5. POLICY RECOMMENDATIONS

As described above, many new risks emerge when targeted influence becomes interactive, adaptive, intelligent and highly

personalized. To mitigate those risks, three categories of policy recommendations are discussed below under the headings of Interactive Transparency, Emotional Privacy, and Protecting Human Agency. These are not the only policy needs related to generative AI but are directed to the unique and new risks that emerge from Interactive Generative Media.

5.1 Interactive Transparency

Marketing is pervasive in our physical and digital worlds, but most adults can easily identify promotional content across a wide range of environments. This allows individuals to consider ads in the appropriate context – as paid messaging delivered by a third-party sponsor. This enables consumers to bring skepticism and critical thinking when considering messaging for products, services, political ideas, and other promotional content. When engaging with conversational interfaces, from current chatbots and voice-bots to upcoming video-based “digital humans,” marketers and propagandists could easily undermine our ability to contextualize promotional material by easing it into conversations, blurring the boundaries between informational dialog and promotional messaging injected on behalf of a paying sponsor or state actor.

Regulatory Approach: To adequately safeguard the general public, regulators and policymakers should consider requiring all conversational systems (text, voice, or video) to disclose any influence objectives that may have been assigned by a third party. This disclosure should be expressed by the conversational agent, informing the user that it is transitioning from informational content to promotional messaging and indicating what its influence objective is. For example, when providing factual information about the location of EV charging stations, an AI-powered chatbot should be required to inform the user if it transitions the conversation to promotional content about the benefits of a particular sponsored vehicle. With such disclosure, consumers will be less likely to confuse informational content and promotional messaging within a single stream of dialog. This is especially important for children who already struggle to identify promotional content across various settings.

5.2 Emotional Privacy

We humans communicate by expressing emotions on our faces, in our voices, and through postures and gestures. Emerging AI systems can now identify human emotions from human faces, voices, and bodies as well as from eye motions, pupil dilations and other physiological responses. While emotion detection will enable computers to communicate more effectively with humans when engaged in voice and video chat, it has significant risks. That’s because AI systems can detect emotions that are not perceptible to human observers. For example, AI systems can detect “micro-expressions” that are too brief or subtle for humans to notice. Even more concerning, AI agents can be designed to adjust promotional tactics mid-dialog based on detected emotions. These cues, whether detected in facial or vocal features, or inferred from the language expressed by users, can be used to determine which persuasive tactics are eliciting the most positive reactions and which are being met with resistance. This can allow the generative AI system to adapt its tactics in real-time for optimized influence.

Regulatory Approach: In the context of interactive systems, regulators should ban AI-powered emotional assessments that exceed natural human observational abilities. This would mean

not allowing vital signs, pupil dilation, micro-expressions, or facial blood patterns to be used in emotion detection by AI systems. In addition, the risk to users is greatly amplified if platforms are allowed to collect emotional data over time and create emotional profile models. Emotional models of individual users would allow AI systems to predict user reactions to a wide range of stimuli. This could be used in highly manipulatory ways. And finally, regulators should restrict or ban the use of real-time emotional assessments by interactive conversational systems that have a promotional agenda or other targeted influence objectives.

5.3 Protecting Human Agency

Background: As described above, real-time generative AI can be used for cognitive and/or behavioral manipulation on human users through real-time feedback control. This can be achieved by conversational AI systems that perform the following steps: (i) impart targeted influence on an individual user, (ii) detect the user's emotional or behavioral reaction to that influence, and (iii) repeatedly adjust the influence and detect results to gradually maximize the persuasive impact. This could easily cross the line from marketing to manipulation and compromise human agency.

Regulatory Approach: Regulators and policymakers should consider aggressive regulations that restrict or ban the use of AI-powered feedback-loops that adapt real-time content delivered to individual in response to their behavioral or emotional reactions. This is especially true for conversational content deployed through interactive dialog but could also involve adaptive forms of image-based and video-based advertising. Such protections are critical to guard against cognitive, emotional, or behavioral manipulations of individually targeted users at scale.

6. CONCLUSIONS

For the reasons described above, policymakers and regulators must expand their risk assessment of generative AI beyond its ability to create traditional misinformation at scale. In particular, policymakers must also consider the unique risk of generative AI being used to unleash a new form of media that is personalized, interactive, and adaptive in real-time. Referred to herein as Interactive Generative Media, this new form of targeted influence is particularly dangerous because it can employ feedback control methods to optimize persuasive impact on individual users. If regulatory protections are not put in place that focus specifically on AI-powered interactive and adaptive media, it is likely that two dangerous techniques will become widely used by large technology platforms: "*Targeted Generative Advertising*" and "*Targeted Conversational Influence*." The potential harms could be mitigated if policymakers adopt meaningful guardrails that prevent real-time AI-powered systems from "closing the loop" around human users for persuasive purposes.

7. REFERENCES

- [1] Giovanni Spitale et al., AI model GPT-3 (dis)informs us better than humans. *Sci. Adv.* 9, eadh1850 (2023). DOI:10.1126/sciadv.adh1850
- [2] Rosenberg, Louis. "The Metaverse and Conversational AI as a Threat Vector for Targeted Influence." 2023 IEEE 13th Annual Computing and Communication Workshop and Conf. (CCWC), 2023. [10.1109/ccwc57344.2023.10099167](https://doi.org/10.1109/ccwc57344.2023.10099167).
- [3] Rosenberg, Louis. The Manipulation Problem: Conversational AI as a Threat to Epistemic Agency. 2023 CHI Workshop on Generative AI and HCI (GenAICHI 2023). Association for Computing Machinery, Hamburg Germany (April 28, 2023) [link](#)
- [4] Gunn, H., Lynch, M.P.: The internet and epistemic agency. In: Lackey, J. (ed.) *Applied epistemology*, pp. 389–409. Oxford University Press, Oxford (2021).
- [5] Bozdog, Engin & van den hoven, Jeroen. (2015). Breaking the filter bubble: democracy and design. *Ethics and Information Technology*. 17. 10.1007/s10676-015-9380-y.
- [6] Caplan, B. (2008). *The myth of the rational voter: Why democracies choose bad policies*. New edition. Princeton, NJ; Woodstock: Princeton University Press. <http://www.amazon.com/The-Myth-Rational-Voter-Democracies/dp/0691138737>
- [7] Hardin, R. (2009). *Deliberative Democracy*. In T. Christiano & J. Christman (Eds.), *Contemporary debates in political philosophy*. West-Sussex: Blackwell.
- [8] Coeckelbergh, M. *Democracy, epistemic agency, and AI: political epistemology in times of AI*. *AI Ethics* (2022). <https://doi.org/10.1007/s43681-022-00239-4>
- [9] Commission on Information Disorder Final Report, Nov 2021. Aspen Institute.
- [10] Jae Kook Lee, Jihyang Choi, Cheonsoo Kim, Yonghwan Kim, Social Media, Network Heterogeneity, and Opinion Polarization, *Journal of Communication*, Volume 64, Issue 4, August 2014, Pages 702–722, <https://doi.org/10.1111/jcom.12077>
- [11] Tucker, J.A., et. al, 2018. Social media, political polarization, and political disinformation: A review of the scientific literature. *Political polarization, and political disinformation: a review of the scientific literature* (March 19, 2018).
- [12] Rosenberg, Louis. (2022). *Social Media is Making Us Stupid, but We Can Fix It*. VentureBeat. Retrieved January 1, 2023, from <https://venturebeat.com/business/social-media-is-making-us-stupid-but-we-can-fix-it/>
- [13] Murphy, Hannah, and Cristina Criddle. "Google to Deploy Generative AI to Create Sophisticated Ad Campaigns." *Financial Times*, April 20, 2023.
- [14] Mehta, Ivan. "Meta Wants to Use Generative AI to Create Ads." *TechCrunch*, April 5, 2023.
- [15] Person, and Sheila Dang. "Exclusive: Microsoft's Bing Plans AI Ads in Early Pitch to Advertisers." *Reuters*. Thomson Reuters, February 17, 2023.
- [16] Rosenberg, Louis (2023). "Conversational AI Will Learn to Push Your Buttons." *Barron's*. February 23, 2023.
- [17] Rosenberg, L., 2022, October. Marketing in the Metaverse and the Need for Consumer Protections. In 2022 IEEE 13th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON) (pp. 0035-0039). IEEE. [10.1109/UEMCON54665.2022.9965661](https://doi.org/10.1109/UEMCON54665.2022.9965661)
- [18] Rosenberg, Louis (2023). "The Profound Danger of Conversational AI." *VentureBeat*, February 4, 2023.
- [19] Breves, Priska. "Biased by Being There: The Persuasive Impact of Spatial Presence on Cognitive Processing." *Computers in Human Behavior*, vol. 119, 2021, p. 106723., <https://doi.org/10.1016/j.chb.2021.106723>
- [20] Han, E., Miller, M.R., DeVaux, C., Jun, H., Nowak, K.L., Hancock, J.T., Ram, N., Bailenson, J.N. (December, 2022). People, Places, and Time: A Large-scale, Longitudinal Study of Transformed Avatars and Environmental Context in Group Interaction in the Metaverse. *Journal of Computer-Mediated Communication*.
- [21] Perolat J, et. al., Mastering the game of Stratego with model-free multiagent reinforcement learning. *Science*. 2022 Dec 2;378(6623):990-996. doi: 10.1126/science.add4679.

- [22] Rosenberg, Louis. "Why Generative AI Is More Dangerous than You Think." VentureBeat, May 6, 2023. Available at: <https://venturebeat.com/ai/why-generative-ai-is-more-dangerous-than-you-think/>
- [23] Robertson, Derek. (2022, September 14). "The Most Dangerous Tool of Persuasion." POLITICO. POLITICO. <https://www.politico.com/newsletters/digital-future-daily/2022/09/14/metaverse-most-dangerous-tool-persuasion-00056681>
- [24] Heller, Brittan and Bar-Zeev, Avi. "The Problems with Immersive Advertising: In AR/VR, Nobody Knows You Are an Ad", Journal of Online Trust and Safety, October 2021.
- [25] Rosenberg, Louis. "Mind Control: The Metaverse May Be the Ultimate Tool of Persuasion." VentureBeat, VentureBeat, 22 Oct. 2022, <https://venturebeat.com/virtual/mind-control-the-metaverse-may-be-the-ultimate-tool-of-persuasion/>
- [26] Heller, Brittan. "Watching androids dream of electric sheep: immersive technology, biometric Psychography, and the law." Vand. J. Ent. & Tech. L. 23 (2020)
- [27] Spisak, Brian., Rosenberg, Louis and Beilby, Max (2023) 13 Principles for Using AI responsibly, Harvard Business Review. June 30, 2023. <https://hbr.org/2023/06/13-principles-for-using-ai-responsibly>.

Transdisciplinary Transformation of Digital Education: Emergency, Sustainability and Universality

Rusudan MAKHACHASHVILI

Germanic Philology Department
Borys Grinchenko Kyiv University, Bulvarno-Kudryavska-st., 18/2,
Kyiv, Ukraine

Ivan SEMENIST

Oriental Studies Department
Borys Grinchenko Kyiv University, Bulvarno-Kudryavska-st., 18/2,
Kyiv, Ukraine

ABSTRACT

Dynamic transformation of the knowledge economy, enhanced by Industry 4.0/5.0 development and rise of the networked society in the Digital Age, emergency digitization of all social communicative spheres due to pandemic measures have imposed dramatic changes onto transdisciplinary overlap in different areas of human knowledge and experience, induced by the cross-sectorial job market demands of university level education, curriculum design and learning outcomes.

The global pandemic and subsequent warfare in Ukraine induced amplified digitalization measures in the higher education sphere. This end-to end digital shift in the educational processes (communication, content, outcomes and outputs, skills) heralded the introduction of meta-disciplinary dimensions of learning – digital, hybrid and, blended. These meta-disciplinary dimensions can be considered conduits of vertical (endocentric) and horizontal (exocentric) transdisciplinary of digital education as a communicative system.

Applied trans-disciplinary lens of the phenomenological approach contributes to the solution of holistic modeling of processes and results of updating models and mechanisms of the highly dynamic communication system of education in the digital environment as a whole and its individual formats in dynamic sustainable and emergency digitization contexts.

Keywords: Transdisciplinary communication, Meta-framework, Digital Education

1. INTRODUCTION

Dynamic transformation of the knowledge economy, development of Industry 4.0/5.0 and elaboration of the networked society in the Digital Age, emergency digitization of all social communicative spheres due to pandemic measures have imposed dramatic changes onto transdisciplinary overlap in different areas of human knowledge and experience, induced by the cross-sectorial job market demands of university level education, curriculum design and learning outcomes.

The global pandemic and subsequent warfare in Ukraine induced amplified digitalization measures in the higher education sphere. This end-to end digital shift in the educational processes (communication, content, outcomes and outputs, skills) heralded the introduction of meta-disciplinary dimensions of learning –

digital, hybrid and, blended. These meta-disciplinary dimensions can be considered conduits of vertical (endocentric) and horizontal (exocentric) transdisciplinary of digital education as a communicative system.

Applied trans-disciplinary lens of the phenomenological approach contributes to the solution of holistic modeling of processes and results of updating models and mechanisms of the highly dynamic communication system of education in the digital environment as a whole and its individual formats at the beginning of the XXI century in particular.

As a product of modern civilization, the digital reality has become an independent format of being. Accordingly, electronic media act not only as a means of transmitting information, but also reveal their own world-creating, meaning-making and, as a consequence, language-forming and communicative potential [46; 48; 50]. The global digital realm stands as an integral environment, demanding new cognition and perception ways via complex philosophic, cultural, social, linguistic approaches, providing unlimited opportunities for human intellect, language development and research.

Given the conceptual system of identification of onto-mental and linguo-mental complex formations to identify constructs of reality, the global digital realm (cyberspace) and its innovative communicative shell can be located in the transdisciplinary coordinates of such paradigms: 1) philosophy - as a *particular type of substance* – material and ideal reality in the multitude of its forms; a meta-negentropy (the term after Nagib Callaos [6]); 2) anthropology – as an environment for actualization of post-humanistic forms of anthropogenesis; 3) psychology – as psychosomatic and emotional plane of a personality functioning; 4) sociology – as a system of multi-tiered and multi-directional social and communicative relations; 5) in culturology - as a sphere of spiritual experience, 6) in the theory of communication - as a system of multilevel, multidirectional social relations and communicative interaction.

The emergency and sustainable digitalization changes in the higher education sphere heralded the introduction of pervasive dimensions of learning – digital, hybrid and, blended. These dimensions can be considered the *3T coordinates ambient of digital education: transformation, transcendence, transdisciplinarity*. These dimensions are conduits of vertical (endocentric) and horizontal (exocentric) transdisciplinarity of digital education as a cohesive system.

¹ Peer-editor: Olena Tupakhina, PhD, Zaporizhzhya National University, Ukraine, Coordinator of Erasmus+ JMM Project “European Values in Literary Arts” (EUVOLIA, 599918-EPP-1-2018-1-UA-EPPJMO-MODULE)

Applied trans-disciplinary lens of the *synergetic approach* contributes to the solution of holistic modeling of processes and results of updating patterns and mechanisms of the highly dynamic self-sustainable and self-evolving system of education in the digital environment as a whole and its individual formats in particular. The transformative factors of the emergency and sustainable digitization in education are structured as attractors and repellents of educational development as a cohesive system.

Emergency digitization in education as a source of transformative end-to-end change is perceived through the lens of *calamity theory* that allows to identify and classify the ways in which education as a system can undergo sudden large changes as one or more of the variables that control it are changed continuously. Emergency digitization stages are perceived as *bifurcation points* of the educational system sustainable development.

The variables, that trigger and sustain systemic change in emergency digital education are connected to the concept of **trans-disciplinarity**, perceived as a transcendent product of merging multiple interconnected knowledge domains. *Transdisciplinarity of emergency digital education* is, therefore, postulated in this study as a computational framework of interconnected types of disciplinarity. **Meta-disciplinarity of emergency digital education is determined through the digital ambient, content and tools of its implementation.** The digital meta-dimension becomes the source of systemic structuring of innovative educational system on macro- and micro-levels. The **meta-framework** of education is, thus, approached as a *conceptual matrix of endocentric and exocentric transdisciplinarity of digital tools, skills, content and interactive aims.*

The fundamental transdisciplinarity, that digital procedural transformations imposed on the system, process and results of education, this way, acquires the property of transcendence and informs the qualitative (evolutionary – for sustainable scenarios, revolutionary – for emergency scenarios) changes of the system as a whole. The integrity of the education as a system is preserved through the meta-disciplinary characteristics of digitization as a state and a process.

Therefore, it is stipulated in **the study design**, that the cognitive and ontological (framework) premise of *metatransformation of digital education* is informed by the following **dimensions**: 1) the *metadisciplinary dimension*, disclosed through the mutual transformative potential of information and modern technology, as “knowledge in a scientific sense can lag only slightly behind this world transformation because knowledge becomes transformed in the process” [17]; 2) the *universal dimension*, disclosed through the pervasive, ubiquitous nature of humanitarian and linguistic (especially multi-cultural) knowledge applicability, as “science and technology revolutionize our lives, but memory, tradition and myth frame our response” [32]; 3) the *interoperable dimension*, informed by the underlying anthropocentrism of linguistic knowledge and skills, providing the interface for development and application of skills and activities across different domains, as “a human is a nexus of existential horizons” [22].

The result of a fundamental Technosphere shift in the sphere of Education, induced by the pandemic development and enhanced by continuous iterative digitalization measures, was the need to take quick comprehensive action [29; 36] in order to achieve such desirable results: in order to achieve such desirable results: a) To activate comprehensive transdisciplinary domains and corresponding interdisciplinary skillsets, otherwise latent or underutilized in the educational process; b) To enhance the scope

of communication skills beyond the domains traditionally reserved for Arts and Humanities education; c) To boost information and communication technological competence and digital literacy, to meet the requirements of (post)COVID-19 job market and workplace; d) to introduce digital meta-solutions for facilitation of formal and informal educational workflow and communication.

The **objective** of the study is to explore the modelling and profiling of meta-disciplinary framework of transformations in digital education, modified by the sustainable (pandemic) and emergency (wartime) digitization measures.

The study of groundwork principles of universality and transdisciplinary of educational communication in professional linguistic training and linguistic education in general is a parcel of the framework project *TRANSITION: Transformation, Network, Society and Education* [28; 29; 30].

2. FINDINGS

Conceptual Groundwork of Meta-Disciplinarity in Digital Education

The following grid of groundwork concepts is applied to profile the Innovative Communication for Foreign Languages Education (FLE) in such disciplinary dimensions (Fig. 1):

- TRANSDISCIPLINARITY
- METADISCIPLINARITY
- UNIVERSALITY
- INTEROPERABILITY
- METAFRAMEWORK

The meaning of TRANSDISCIPLINARITY is synthesized for the purpose of this study as a transcendent agglomeration of two or more fields of knowledge into one scope/goal of study, inquiry or activity [6; 15; 18; 21].

UNIVERSALITY is generally understood as a property of object or state to **“exist everywhere (ubiquity), or involve everyone”** [7]. In the context of this study we suggest to attribute the property of universality/ubiquity to social activity, vocational activity and professional performance.

The concept of INTEROPERABILITY is disclosed across different approaches [20; 34; 35] as a characteristic of an object, product or system, that allows its interface to be comprehensible, to work with other objects, products or systems.

The concept of METAFRAMEWORK as applied to educational communication is derived from the target meta-status of its transdisciplinarity.

As applied to transdisciplinary communication in digital education, the concept of interoperability represents the property of functional, dynamic interconnectivity between the source and target domains of linguistic content, linguistic theory content, related areas of scientific and universal knowledge, and domains of professional and social application. Degrees of interoperability help define the measure of interdisciplinary transcendence and universality of activities, skills and competence applications of FLE stakeholders.

Consequently, the metaframework of transdisciplinary communication can be conceptualized through a following grid of nested notions (Fig. 1):

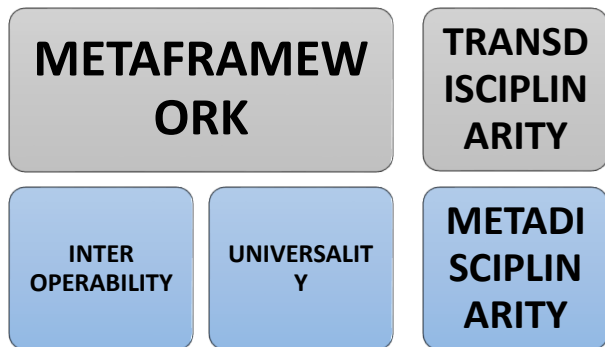


Figure 1: Conceptual Grid of Metaframework

Meta-disciplinary Framework of Transdisciplinary Communication in Digital Education

The generic concept of multiple disciplinarity [1; 38] comprises, in its turn, of a framework of interconnected concepts: Multi-disciplinarity; Interdisciplinarity; Transdisciplinarity; Metadisciplinarity.

Multi-disciplinarity, thus, is understood as a multitude of fields of knowledge, that comprise the scope of understanding a certain object, problem or area of inquiry.

Interdisciplinarity in this respect is interpreted as the interconnectivity of multiple spheres of knowledge that comprised the content of a problem or area of inquiry.

Trans-disciplinarity, subsequently, is perceived as a transcendent product of merging multiple interconnected knowledge domains.

Transdisciplinarity of digital educational communication in general is, therefore, postulated in this study as a computational framework of interconnected types of disciplinarity.

Meta-disciplinarity of digital educational communication is determined through the digital ambient, content and tools of its implementation. The digital meta-dimension becomes the source of systemic structuring of innovative educational communication on macro- and micro-levels.

Multidisciplinary **input** into the education design and content in the form of data, information and facts across different source domains of human knowledge in order 1) to constitute the thematic content of language acquisition; 2) to constitute the semantic referents of linguistic units; 3) to constitute the vast framework of reference and contexts for communicative application.

Interdisciplinary connections of the educational **content** for FLE – internal interconnectivity of theoretical and applied disciplines, external interconnectivity of FLE content with non-related areas of human knowledge (computer science, physiology, anthropology, philosophy etc.).

Transdisciplinary **output** in the transcendent nature target knowledge domains and universal applicability of skills, training and outlook of the FLE professionals upon graduation.

Therefore, the framework correspondence of relevant complex skills constitutes a TRANSDISCIPLINARY META-FRAMEWORK of educational communication.

It is relevant to postulate, that interoperability of TRANSDISCIPLINARITY and METADISCIPLINARITY, thus, constitute a close circuit within the metaframework of digital education (Fig. 2.):

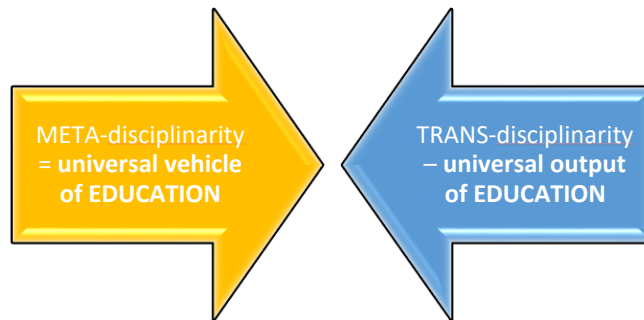


Figure 2: Disciplinary Circuit of Education

Interoperability for FLE skills ensured by the communicative nature of interdisciplinary skills. The core cross-sectorial domain that is referential for primary skills (social skills, emotional intellect, collaboration, communication, ICT-literacy), necessary for educational goals achievement, is COMMUNICATION.

Transdisciplinary communication in the global digital environment is, therefore, understood as an integrated at the macro and micro level set of cross-sectorial verbal referents, innovations and innovative communication practices and technologies, which by their specific characteristics are conditionally exhaustive phenomenological correlates of transdisciplinary elements of the digital environment.

The innovative nature of communication in the field of learning and education (formal and informal) in the global digital environment is determined by the phenomenological consolidation of substantive (ontological, pre-suppositional / cognitive [52]) characteristics of the macrostructure of communication in statics and end-to-end dynamic interaction of formal and semantic constituents and technological (digital) tools. The paradigm of innovation of educational communication in the digital realm (as a multidimensional, complex, dynamic system) is defined as the most comprehensive quantitative and qualitative terms of linguo-cognitive actualization of being, determined by a number of qualifying conditions of its emergence, existence and development. The inquiry results allow to provide a transdisciplinary synthesis of educational communication paradigm across communicative theory, information theory, philosophy, education and e-learning studies, semiotics, digital humanities.

Theoretical problems of holistic, transdimensional modeling of reality and its separate spheres are directed by the deterministic interaction of objects, signs of their reception and interpretation (in the field of individual and collective consciousness), embodiment, consolidation and retransmission of the results of interaction of these systems of features.

Conditions for the development of modern globalization civilization determine the expansion and refinement of the paradigm of views on the theoretical principles of determining the groundwork and characteristics of the consolidation of the world order, its perception in culture, collective social consciousness and natural language.

The transdisciplinarity of innovative educational communication in this respect is accessed through is the conceptual lens of the **logosphere**, synthetically perceived as 1) the plurality of language units, which are conditionally exhaustive phenomenological realizations of abstract and empirical elements of different spheres of life [4; 23]; 2) the zone of integration of thought, speech, and experience continuums of

cultures [5; 16; 26]; 3) the plurality of culturally relevant universal meanings and signs - **semiosphere** [27]; 4) a plurality of transcendent spiritual meanings – **pneumatosphere** [14]. Foreign Languages Acquisition on university-level major programs is a rigorous process that involves different stages and a regimen of communicative educational activities, communication types and competences across interconnected domains [24; 25]. Transdisciplinarity and ubiquity (universality) of innovative communication for Foreign Languages Education (FLE) in the 21st century, therefore, is informed, in crucial ways, by intellectualization and amplified information capacity of human activities in general. Thus, the intellectualization of modern global culture determines a qualitatively new approach to understanding the processes of parallel development of human activities, cognitive (intellectual), and communicative experiences. That is the origin and methodological premise of the concept of "noosphere". Noosphere is the unity of "nature" and culture, especially from the moment when the intellectual culture reaches (by force of influence on the biosphere and geosphere) the power of a peculiar "geological force" [40]. The noosphere is defined as the current stage of development of the biosphere, associated with the emergence of humanity in it [16; 40], and is interpreted as part of the planet and planet ambient with traces of human activity. The integral real component of the Noosphere is identified as the Technosphere - a set of artificial objects (technologies) created by the humankind, and natural objects changed as a result of technological activity of humankind [28]. In turn, Computer Being (computer reality, cyberspace) is a complex, multidimensional sphere of synthesis of reality, human

experience and activity mediated by the latest digital and information technologies; technogenic reality, a component of the technosphere of existence [17; 28]. The digital dimension of communicative interoperability of FLE stems from the structure of Noosphere [40] and content of its components: ANTHROSPHERE - a set of people as living organisms, their activities and achievements; SOCIOSPHERE - a set of social factors characteristic of this stage of society development and its interaction with nature; TECHNOSPHERE - a set of artificial objects created by man, and natural objects, altered as a result of human activity. Given the nature of increasingly digitalized context of foreign languages education and communicative application ("the Technospheric shift" [30]), it is suggested to consider the different types of information source and information destination (human and machine/computer/program, accordingly) in the structure of the groundwork Communication model (Cf. Claude Shannon [33]), when communication is approached as the core factor of interoperability of source and target knowledge and application domains in FLE. Thus, the fundamental transdisciplinarity, that pandemic and warfare emergency digital procedural transformations imposed on the educational process in the area of Foreign languages acquisition, is verified by a unified framework of correspondence between the components of a crucial communicative competence [19], comprising of a diverse skillset, and various aspects of digital competence in Arts and Humanities [3; 12; 13; 39], utilized in the educational process, elaborated for the purposes of this study (Fig. 3):

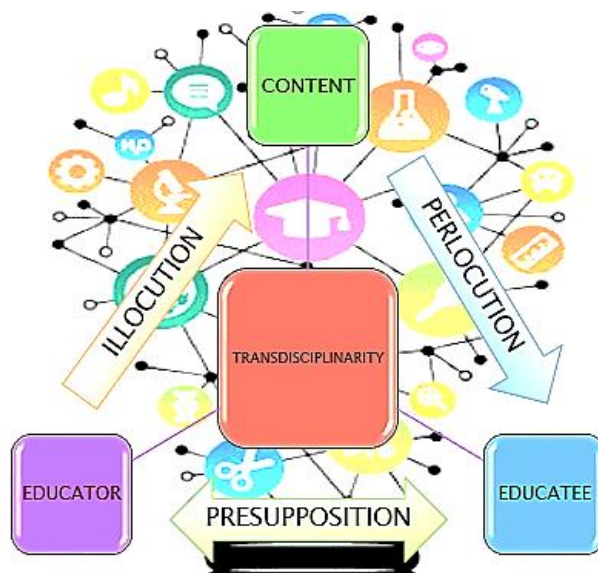


Figure 3: Communicative Act Model for Education

Trans-disciplinary and cross-referential integration between the corresponding skillsets, henceforth, constitutes a meta-framework of digital educational communication (Fig.4). The transdisciplinary integration of communication in digital education could be referred to the following key interdisciplinary

domains [30]: DIGITAL EDUCATION; DIGITAL CONTENT; INTEROPERABLE DIGITAL MEDIA; DIGITAL COMMUNICATION; DIGITAL SKILLS; DIGITAL OUTCOMES.

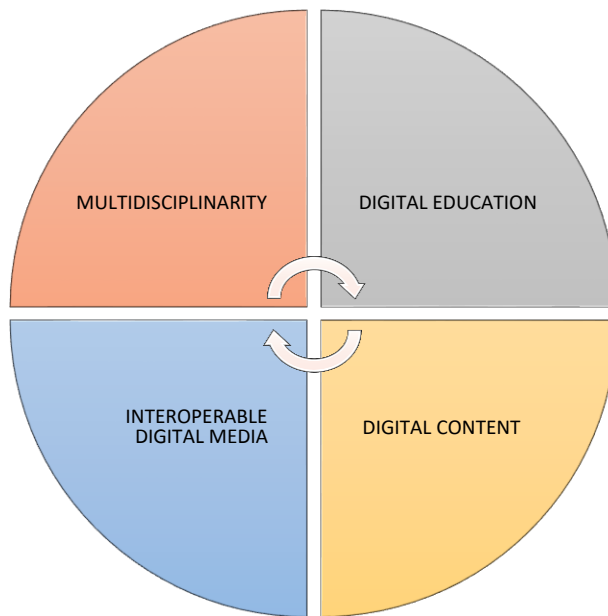


Figure 4: Meta-Framework of Digital Education

Taking into account the nature of suggested modelling of educational communication across frameworks of complex skills, it is stipulated that *META-disciplinarity* has become the universal vehicle or framework of education in the digital realm, whereas *TRANS-disciplinarity* can be perceived as a universal output of educational communication in the digital realm.

Consequently, the communicative dimension of education proper in the post-pandemic timeframe acquires a meta-digital and trans-digital (transcendent digital) properties (Fig.5). The trans-digital characteristics of educational communication is ensured through the interoperability of such framework parameters as: Interaction, Disciplinarity, Learning.

domains of professional and social application). Degrees of interoperability help define the measure of metadisciplinary transcendence of communicative activities, skills and competence applications of education stakeholders.

3. CONCLUSIONS

The study findings as to the systemic nature and paradigmatics of transdisciplinary educational communication in the digital environment allow to disclose the following key conclusions: the integrative theoretical and methodological bases of research of educational communication are defined; the methodological framework of modeling of transdisciplinary educational communication in the digital environment in the ontological, linguistic and cognitive planes is introduced; the macrostructure of transdisciplinary educational communication is identified as a set of linguistic-communicative and digital instrumental innovations in the systemic semantic unity of their reference correlation with trans-disciplinary and cross-referential (ontological, epistemic, anthropological, technological) dimensions and elements of the global digital environment, the manifestation of which determines the phenomenological originality of the studied communicative sphere; experimental verification of the effectiveness of innovative educational communication in the global digital environment during the period of emergency quarantine restrictions are implemented; the principles of universality of interdisciplinary modeling of educational communication in the digital environment are identified; the anthropocentric bases of communication innovation in the field of acquiring new knowledge in the global digital environment are determined; the instrumental mechanisms of transdisciplinary educational communication in the digital environment are systematized.

This sustainable and emergency digital shift in the educational processes (communication, content, outcomes and outputs, skills) heralded the introduction of meta-disciplinary dimensions of learning – digital, hybrid and, blended. These meta-

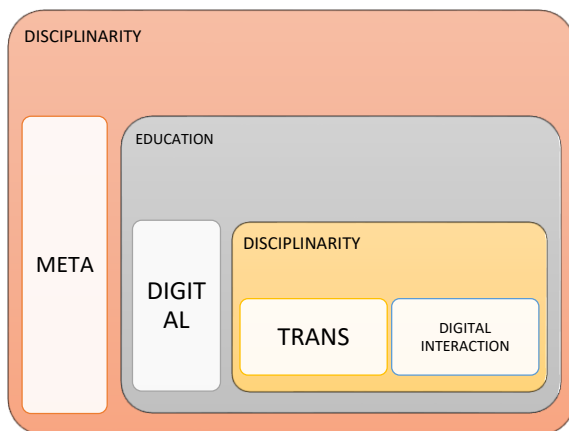


Figure 5: Trans-digital Modelling of Educational Communication

As a communicative macro-system, the transdisciplinary communication in digital education is distinguished by the functional, dynamic interoperability of linguistic, cognitive (presuppositional) and communicational parameters (the source and target domains of linguistic content, linguistic theory content, related areas of scientific and universal knowledge, and

disciplinary dimensions can be considered conduits of vertical (endocentric) and horizontal (exocentric) transdisciplinary of digital education as a communicative system.

Applied trans-disciplinary lens contributes to the solution of holistic modeling of processes and results of updating models and mechanisms of the highly dynamic communication system of education in the digital environment as a whole and its individual formats in the emergency digitization measures of different types.

The findings of the comprehensive framework research project ‘TRANSITION’ disclose a wide scope of generalized issues, permeating the social and educational context worldwide: global event horizon and paradigm shifts in the multi-disciplinary trends and meta-dimensions of digital education in the emergency digitization timeframes and beyond; transformative changes and avenues of development of the network society and education as a socio-cultural institution in the digital coordinates; global experiences, universal/generic challenges, technical advances and specific national gains in quality assurance of digital and hybrid learning in the emergency and wartime digitization paradigm.

4. ACKNOWLEDGEMENT

The paper has been reviewed by Hanna Prykhodko, Hab. Doc., Zaporizhzhya National University, Ukraine. Empirical findings and survey procedures have been conducted under the auspices of Integrated Research framework of Germanic Philology Chair *Digital Transformative Linguistics and Cross-cultural Communication in Romance and Germanic Languages (0123 U 102796)* and Integrated Research framework of Oriental Studies Chair of Borys Grinchenko Kyiv University *Oriental Studies development in the framework of Higher Education Internationalization (0116 U 007073)*. The authors extend special acknowledgement to the Armed Forces of Ukraine for providing safety to complete this work.

5. REFERENCES

[1] Alvargonzález D. “Multidisciplinarity, “Interdisciplinarity, Transdisciplinarity, and the Science”, **International Studies in the Philosophy of Science**, Vol. 25(4), 2011, pp. 387-403.

[2] Abbott S., **The Glossary of Education Reform**. Retrieved from: <http://edglossary.org/hidden-curriculum> (accessed July 2020), 2013.

[3] American Library Association, **Digital Literacy**. Retrieved from: <https://literacy.ala.org/digital-literacy>, 2020.

[4] Bakhtin M. **Aesthetics of verbal creativity**, M.: Art, 1979.

[5] Barthes R. **Elements of Semiology**, Hill and Wang, 1968.

[6] Callaos N., Marlowe T., “Inter-Disciplinary Communication Rigor”. **Rigor and Inter-Disciplinary Communication: Intellectual Perspectives from Different Disciplinary and Inter-Disciplinary Fields**. TIDC, LLC, 2020, pp. 4-29.

[7] **Cambridge Dictionary**, CUP, Retrieved from: <https://dictionary.cambridge.org>, 2020.

[8] Davies A., Fidler D. et al, **Future Work Skills 2020**, Institute for the Future for University of Phoenix Research Institute. Retrieved from: https://www.iftf.org/uploads/media/SR-1382A_UPRI_future_work_skills_sm.pdf, 2011.

[9] Dos Reis A., “To Be a (Blended) Teacher in the 21st Century - Some Reflections”, **International Journal of Research in E-learning**, 1(1), 2015, pp. 11-24.

[10] DQ Global Standards Report, **World’s first global standard for digital literacy, skills and readiness launched by the Coalition for Digital Intelligence**. Retrieved from: <https://www.dqinstitute.org/>, 2019.

[11] Eduventures, **TechLandscape**. Retrieved from: <https://encoura.org/2020-eduventures-tech-landscape-heres-what-to-expect/>, 2020.

[12] European Commission, **Digital Competence 2020**. Retrieved from: <https://ec.europa.eu/jrc/en/digcomp/digital-competence-framework>, 2020.

[13] European Commission, **European E-Competence Framework Guideline**. Retrieved from: <https://www.ecompetences.eu/>, 2020.

[14] Florensky P. “Namehail as a philosophical proposition. On the name of God”, **Studia Slavica Hung**, Budapest, Vol. 34/1-4, 1988, pp. 40-75.

[15] Frodeman R. (ed). **The Oxford Handbook of Interdisciplinarity (2 ed.)**, OUP, 2017.

[16] Gachev G. “Humanistic commentary to natural science”, **Issues of Literature**, Issue 11, 1993, pp. 71-78.

[17] Heim M., **The Metaphysics of Virtual Reality**. LA: Westport Publishers, 1993. 278 p.

[18] **Holbrook, J. Britt (2013)**. "What is interdisciplinary communication. Reflections on the very idea of disciplinary integration", **Synthese**, Vol. 190 (11), 2013, pp. 1865-1879.

[19] Hymes, Dell H., “Communicative competence”, **Sociolinguistics: selected readings**, Harmondsworth: Penguin., 1972, pp. 269-293.

[20] Interoperability Working Group, **Definition of Interoperability**. Retrieved from: <http://interoperability-definition.info/en/>, 2020.

[21] Jacobs, J.A. & S. Frickel, "Interdisciplinarity: a critical assessment", **Annual Review of Sociology**, Vol. 35, 2009, pp. 43-65.

[22] Khoryzhy S. “Notes on Ontology of Virtuality”. **Issues of Philosophy**, Vol. 6, 1997, pp. 53-58.

[23] Kranz W. (ed.), **Die Fragmente der Vorsokratiker**, Zürich: Weidmann, 1996.

[24] Legal Act of Ukraine, **On Higher Education**. Retrieved from: <https://zakon.rada.gov.ua/laws/show/1556-18#Text>, 2019.

[25] Legal Act of Ukraine, **On Standard of Higher Education in Specialization Field 035 “Philology”**. Retrieved from: <https://mon.gov.ua/storage/app/media/vishchaosvita/zatverdzeni%20standarty/2019/06/25/035-filologiyabakalavr.pdf>, 2019.

[26] Losev A. “Philosophy of the Name”, **Being. Name. Cosmos**. M: Thought, 1993, pp. 613-801.

[27] Lotman, Yu. **Semiosphere**. SPb: Art, 2000.

[28] Makhachashvili, R., Semenist, I., “Innovative Educational Communication in the Global Digital Environment: Trans-Disciplinary Models, Tools, and Mechanisms”, **Proceedings of the 13th International Multi-Conference on Complexity, Informatics and Cybernetics**, IIS, 2022, pp.134-140.

[29] Makhachashvili, R., Semenist, I., “Transdisciplinary Communication as a Meta-Framework of Digital Education”, **Proceedings of the 26th World Multi-Conference on Systemics, Cybernetics and Informatics, WMSCI 2022**, IIS, 2022, pp. 151-156.

- [30] Makhachashvili, R., Semenist, I., "Systemic Paradigm of Innovative Educational Communication in The Digital Realm", **Proceedings of the 16th International Multi-Conference on Society, Cybernetics and Informatics, IMSCI 2022**, IIS, 2022, pp.11-16.
- [31] Morze N., Makhachashvili R., Smyrnova-Trybulska E., "Communication in education: ICT tools assessment". **Proceedings from DIVAI**, Sturovo: University of Nitra, 2016, pp. 351-354.
- [32] Schlesinger, A.M. Jr. **Papers**. Manuscripts and Archives Division, The New York Public Library. Retrieved from: <http://archives.nypl.org/mss/17775#overview>, 2020.
- [33] Shannon, C. E., "A Mathematical Theory of Communication", **Bell System Technical Journal**, Vol. 27 (3), 1948, pp. 379–423.
- [34] Slater, T. "Cross-Domain Interoperability", **Network Centric Operations Industry Consortium - NCOIC**. Retrieved from: <https://www.ncoic.org>, 2013.
- [35] Slater, T. "What is Interoperability?", **Network Centric Operations Industry Consortium – NCOIC**. Retrieved from: <https://www.ncoic.org>, 2012.
- [36] Taleb, N. **The Black Swan: The Impact Of The Highly Improbable** (2nd ed.). London: Penguin, 2010.
- [37] The Digital Divide, **Project Overview**. Retrieved from: <https://cs.stanford.edu/people/eroberts/cs181/projects/digital-divide/start.html> (accessed October 2020), 2020.
- [38] Torre, I., Łuczniak, K., Francis, K. B., Maranan, D. S. et al. "Openness across disciplines: Reflecting on a multiple disciplinary summer school", **Open(ing) Education: Theory and Practice**, Brill, 2020, pp. 300–328.
- [39] UNESCO, **ICT Competency Framework for Teachers**. Retrieved from: <https://unesdoc.unesco.org/ark:/48223/pf0000265721>, 2018.
- [40] Vernadsky V. **Scientific thought as a planetary phenomenon**. M.: Academia, 1991.
- [41] World Economic Forum, **The Future of Jobs Report**. Retrieved from: http://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf, 2020.
- [42] Crystal D. **Language and the Internet**. Cambridge: CUP, 2001.
- [43] Davis E. **Techgnosis: Myth, Magic and Mysticism in the Age of Information**. NY: New York Publishers, Inc., 2001.
- [44] Fillmore, Ch. J., Baker, C. A. "Frames Approach to Semantic Analysis". In **The Oxford Handbook of Linguistic Analysis**. eds B. Heine, H. Narrod. 2010. P. 313–340.
- [45] Hillis K. **Digital Sensations: Space, Identity, and Embodiment in Virtual Reality**. UM: University of Minnesota Press, 1999.
- [46] Gelernter D. **Virtual Realism**. Oxford: Oxford University Press, 1998.
- [47] Johnson V.E., Brennan L. "Examining the impact of technology on social responsibility practices". **Research in Ethical Issues in Organizations**, V. 4, 2002, pp. 107-123.
- [48] Lazebna N. **English Language as Mediator of Human-Machine Communication**. Mysore, India: PhDians along with Ambishpere: Academic and Medical Publishers, Royal Book Publishing, 2021.
- [49] Mamardashvili M., Pyatihorsky A. **Symbol and Mind. Metaphysical Ruminations on the Mind, Symbolism and Language**. Moscow: Academia, 1997.
- [50] Shneiderman B. **Human Needs and the New Computing Technologies**. Cambridge, MA: The MIT Press, 2002.
- [51] Spet G. **Phenomenon and Meaning (Phenomenology as a Science)**. Moscow: Academia, 2001.
- [52] Zhabotynska S. "Lexical Fields and Non-Linear Dynamics of Cognitive Structures". **Visnyk of the Lviv University. Series Philology**, 2011, Vol 52, pp. 3-11.

AUTHORS INDEX

| | | | |
|--------------------------------------|-------------|--------------------------------|-------------|
| Acevedo, Antonio | 156 | McCloud, Robert | 151 |
| Acevedo, Elena | 156 | Medina, Brandon | 156 |
| Acevedo-Mosqueda, María-Elena | 161 | Mendoza, Karina | 45 |
| Adarlo, Genejane | 87; 92 | Meza, Jaime | 45 |
| Balajadia, Janine Marie | 87; 92 | Montenegro, Sandra | 45 |
| Barbosa Seiffert, Otilia Maria Lúcia | 26 | Moroz, Svitlana | 13 |
| Brown, Tammy | 122 | Oberer, Birgit | 138 |
| Capshaw, Ter L. | 81 | Orantes, Sandra | 156 |
| Chancay, Carlos | 45 | Orantes-Jiménez, Sandra-Dinora | 161 |
| Chotikakamthorn, Nopporn | 7 | O'Sullivan, Jill A. | 151 |
| Cowin, Jasmin | 138 | Paciej-Woodruff, Amy | 122 |
| Delgado, Katherine | 99 | Pariñas, Lukas | 87; 92 |
| Dy, Maria Micole Veatrizze | 87; 92 | Pérez-Castillo, Yadira-Jazmín | 161 |
| ElSayary, Areej | 145 | Pimentel, Camila | 26 |
| Eltaeib, Tarik | 151 | Poolsawas, Banyapon | 7 |
| Gaete-Peralta, Claudio | 99; 126 | Posligua, Katty | 45 |
| Ganapathy, Subhashini | 131 | Prihodko, Ganna | 21 |
| Hama, Yasukazu | 110 | Prykhodchenko, Olexandra | 21 |
| Hattori, Akira | 34 | Rosenberg, Louis | 165 |
| Hendel, Russell Jay | 105 | Sánchez-Montecinos, Solangela | 126 |
| Huincahue, Jaime | 99; 126 | Semenist, Ivan | 21; 40; 171 |
| Ilunga, Masengo | 56; 62; 67 | Shibata, Kuniomi | 34 |
| Kalashnik, Olena | 13 | Siriani Oliveira, Marilda | 26 |
| Koikas, Evgenia | 115 | Somych, Mykola | 13 |
| Kopishynska, Olena | 13 | Songkram, Noawanit | 73 |
| Krisberg, Jeremy | 1 | Suddee, Nuttaporn | 73 |
| Kusumi, Ariyoshi | 110 | Swango, Logan | 1 |
| Kyriakidis, Kleantis | 115 | Taguba, Christine Leila | 87; 92 |
| Leon, Cristo | 138 | Tan, Alessandra Grace | 87; 92 |
| León, Cristo | 51 | Tardieu, Gregory | 81 |
| Libin, Alexander | 81 | Tekle, Senait | 81 |
| Lipuma, James | 51 | Tuazon, Maxine Therese | 87; 92 |
| Lugoma, Masikini | 56 | Tupakhina, Olena | 21 |
| Maduna, Lusiwe | 62 | Utkin, Yurii | 13 |
| Makhachashvili, Rusudan | 21; 40; 171 | Uy, Jerome Patrick | 87; 92 |
| Makhmudov, Khanlar | 13 | Xiao, Lijian | 131 |
| Martins, Antonio | 26 | Zanin, Linda | 81 |
| Martins, Carolina | 26 | Zeng-Treitler, Qing | 81 |
| Mathenjwa, Samukelisiwe | 67 | Zhang, Xinhui | 131 |
| Matsumoto, Sayaka | 34 | | |