Lecture Notes in Networks and Systems 764

Marcelo Milrad · Nuno Otero · María Cruz Sánchez-Gómez · Juan José Mena · Dalila Durães · Filippo Sciarrone · Claudio Alvarez-Gómez · Manuel Rodrigues · Pierpaolo Vittorini · Rosella Gennari · Tania Di Mascio · Marco Temperini · Fernando De la Prieta *Editors*

Methodologies and Intelligent Systems for Technology Enhanced Learning, 13th International Conference

Springer

Lecture Notes in Networks and Systems 764

The series "Lecture Notes in Networks and Systems" publishes the latest developments in Networks and Systems—quickly, informally and with high quality. Original research reported in proceedings and post-proceedings represents the core of LNNS.

Volumes published in LNNS embrace all aspects and subfields of, as well as new challenges in, Networks and Systems.

The series contains proceedings and edited volumes in systems and networks, spanning the areas of Cyber-Physical Systems, Autonomous Systems, Sensor Networks, Control Systems, Energy Systems, Automotive Systems, Biological Systems, Vehicular Networking and Connected Vehicles, Aerospace Systems, Automation, Manufacturing, Smart Grids, Nonlinear Systems, Power Systems, Robotics, Social Systems, Economic Systems and other. Of particular value to both the contributors and the readership are the short publication timeframe and the world-wide distribution and exposure which enable both a wide and rapid dissemination of research output.

The series covers the theory, applications, and perspectives on the state of the art and future developments relevant to systems and networks, decision making, control, complex processes and related areas, as embedded in the fields of interdisciplinary and applied sciences, engineering, computer science, physics, economics, social, and life sciences, as well as the paradigms and methodologies behind them.

Indexed by SCOPUS, INSPEC, WTI Frankfurt eG, zbMATH, SCImago.

All books published in the series are submitted for consideration in Web of Science.

For proposals from Asia please contact Aninda Bose (aninda.bose@springer.com).

Marcelo Milrad · Nuno Otero ·
María Cruz Sánchez-Gómez · Juan José Mena ·
Dalila Durães · Filippo Sciarrone ·
Claudio Alvarez-Gómez · Manuel Rodrigues ·
Pierpaolo Vittorini · Rosella Gennari ·
Tania Di Mascio · Marco Temperini ·
Fernando De la Prieta
Editors

Methodologies and Intelligent Systems for Technology Enhanced Learning, 13th International Conference

Springer

Editors
Marcelo Milrad
Linnaeus University
Växjö, Sweden

María Cruz Sánchez-Gómez
Department of Didactics, Organization and Research Method
University of Salamanca
Salamanca, Spain

Dalila Durães
University of Minho
Braga, Portugal

Claudio Alvarez-Gómez
Facultad de Ingeniería y Ciencias Aplicadas
Universidad de los Andes
Santiago, Chile

Pierpaolo Vittorini
Department of Life, Health and Environmental Sciences
University of L'Aquila
L'Aquila, Italy

Tania Di Mascio
Department of Information Engineering, Computer Science and Mathematics
University of L'Aquila
L'Aquila, Italy

Fernando De la Prieta
Department of Computer Science and Automation Control
University of Salamanca
Salamanca, Spain

Nuno Otero
University of Greenwich
London, UK

Juan José Mena
Department of Didactics, Organization and Research Method
University of Salamanca
Salamanca, Spain

Filippo Sciarrone
Mercatorum University
Rome, Italy

Manuel Rodrigues
University of Minho
Braga, Portugal

Rosella Gennari
Faculty of Computer Science
Free University of Bozen-Bolzano
Bolzano, Italy

Marco Temperini
Dipartimento di Ingegneria Informatica
Sapienza Universita' di Roma
Rome, Italy

ISSN 2367-3370 ISSN 2367-3389 (electronic)
Lecture Notes in Networks and Systems
ISBN 978-3-031-41225-7 ISBN 978-3-031-41226-4 (eBook)
https://doi.org/10.1007/978-3-031-41226-4

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Education is the cornerstone of any society, and it serves as one of the foundations for many of its social values and characteristics. The state-of-the-art and novel methodologies and technologies allow researchers, designers, and domain experts to pursue Technology-Enhanced Learning (TEL) solutions targeting not only cognitive processes but also motivational, personality, or emotional factors. Nowadays, we can identify two main legs, providing necessary and complementary strengths to a TEL-oriented design process: appropriate technologies should be applied, and appropriate methods should guide such application. Technologies in TEL can deliver smart, personalized, tailored, and motivating learning solutions. Methods come from different fields, such as psychology, medicine, computer science, and from diverse communities, where collaboration and co-working is used, such as maker communities and participatory design communities. In addition, learning analytics can help manage (big) data to enhance learning opportunities for learners and educators alike, for instance, by supporting self-regulated learning or adaptation of the learning material.

As to these topics, the annual appointment of MIS4TEL established itself as a consolidated fertile forum where scholars and professionals from the international community, with a broad range of expertise in the TEL field, share results and compare experiences. The calls for papers of the 13th edition of the conference welcomed novel research in TEL and expands on the topics of the previous editions: it solicited work from new research fields (ranging from artificial intelligence and agent-based systems to robotics, virtual reality, Internet of Things, and wearable solutions, among others) concerning methods and technological opportunities, and how they serve to create novel approaches to TEL, innovative TEL solutions, and valuable TEL experiences.

The result of the call for papers is that both the main track of MIS4TEL 2023 and its four related workshops: *Integration of emerging technologies into education and training (ETELT), Interactive Environments and Emerging Technologies for eLearning (IEETeL), Technology Enhanced Learning in Nursing Education (NURSING), and Technology-Enhanced Learning for Future Citizens (TEL4FC)*, contribute to novel research in TEL and expand on the topics of the previous editions. This volume presents the papers that were accepted for the main track of MIS4TEL 2023.

All papers underwent a peer-review selection: each paper was assessed by four different reviewers, from an international panel composed of about 76 members from 30 countries. From a total of 40 articles, the program of MIS4TEL 2023 counts 26 contributions (13 full papers and 13 short papers) from diverse countries.

This conference is organized by the LASI and Centro Algoritmi of the University of Minho (Portugal). We would like to thank all the contributing authors, the members of the Program Committee, the reviewers, the sponsors, and the Organizing Committee for their hard and highly valuable work. Thanks for your help—MIS4TEL 2023 would not exist without your contribution.

Marcelo Milrad
Nuno Otero
María Cruz Sánchez-Gómez
Juan José Mena
Dalila Durães
Filippo Sciarrone
Claudio Alvarez-Gómez
Manuel Rodrigues
Pierpaolo Vittorini
Rosella Gennari
Tania Di Mascio
Marco Temperini
Fernando De la Prieta

Organization of MIS4TEL 2023

https://edition2023.mis4tel-conference.net/

General Chairs

Marcelo Milrad	Linnaeus University, Sweden
Nuno Otero	University of Greenwich, UK

Technical Program Chairs

María Cruz Sánchez-Gómez	University of Salamanca, Spain
Juan José Mena	University of Salamanca, Spain
Dalila Durães	University of Minho, Portugal
Filippo Sciarrone	Universitas Mercatorum, Italy

Paper Chairs

Claudio Álvarez Gómez	Universidad de los Andes, Chile
Manuel Rodrigues	University of Minho, Portugal

Workshop Chairs

Zuzana Kubincová	Comenius University in Bratislava, Slovakia
Federica Caruso	University of L'Aquila, Italy

Steering Committee

Pierpaolo Vittorini	University of L'aquila, Italy
Rosella Gennari	Free University of Bozen-Bolzano, Italy
Tania Di Mascio	University of L'aquila, Italy
Marco Temperini	Sapienza University of Rome, Italy
Fernando De la Prieta	University of Salamanca, Spain

Local Organizing Committee

Paulo Novais (Chair)	University of Minho, Portugal
José Manuel Machado (Co-chair)	University of Minho, Portugal
Hugo Peixoto	University of Minho, Portugal
Regina Sousa	University of Minho, Portugal
Pedro José Oliveira	University of Minho, Portugal
Francisco Marcondes	University of Minho, Portugal
Manuel Rodrigues	University of Minho, Portugal
Filipe Gonçalves	University of Minho, Portugal
Dalila Durães	University of Minho, Portugal
Sérgio Gonçalves	University of Minho, Portugal

Organizing Committee

Juan M. Corchado Rodríguez	University of Salamanca and AIR Institute, Spain
Fernando De la Prieta	University of Salamanca, Spain
Sara Rodríguez González	University of Salamanca, Spain
Javier Prieto Tejedor	University of Salamanca and AIR Institute, Spain
Ricardo S. Alonso Rincón	AIR Institute, Spain
Alfonso González Briones	University of Salamanca, Spain
Pablo Chamoso Santos	University of Salamanca, Spain
Javier Parra	University of Salamanca, Spain
Liliana Durón	University of Salamanca, Spain
Marta Plaza Hernández	University of Salamanca, Spain
Belén Pérez Lancho	University of Salamanca, Spain
Ana Belén Gil González	University of Salamanca, Spain
Ana De Luis Reboredo	University of Salamanca, Spain
Angélica González Arrieta	University of Salamanca, Spain
Angel Luis Sánchez Lázaro	University of Salamanca, Spain
Emilio S. Corchado Rodríguez	University of Salamanca, Spain
Raúl López	University of Salamanca, Spain
Beatriz Bellido	University of Salamanca, Spain
María Alonso	University of Salamanca, Spain
Yeray Mezquita Martín	AIR Institute, Spain
Sergio Márquez	AIR Institute, Spain
Andrea Gil	University of Salamanca, Spain
Albano Carrera González	AIR Institute, Spain

Program Committee

Marie-Helene Abel	HEUDIASYC - Université de Technologie de Compiègne, France
Agnese Addone	University of Salerno, Italy
Juan M. Alberola	Universitat Politècnica de València, Spain
M. Teresa Anguera	University of Barcelona, Spain
Blanca Berral Ortiz	University of Granada, Spain
Rosa Maria Bottino	ITD-CNR, Italy
Tharrenos Bratitsis	University of Western Macedonia, Greece
Juan Luis Cabanillas García	University of Salamanca, Spain
Natalia Campos Soto	University of Granada, Spain
Nicola Capuano	Università della Basilicata, Italy
Davide Carneiro	Polytechnic Institute of Porto, Portugal
Federica Caruso	University of L'Aquila, Italy
Maiga Chang	Athabasca University, Canada
Vincenza Cofini	University of L'Aquila, Italy
Cesar A. Collazos	University of Cauca, Colombia
Giovanni De Gasperis	Università degli Studi dell'Aquila, Italy
Juan Carlos De la Cruz Campos	University of Granada, Spain
Irene Del Brío Alonso	University of Salamanca, Spain
Sofía Díaz Hinarejo	University of Valencia, Spain
Damiano Distante	University of Rome Unitelma Sapienza, Italy
Benedict Du Boulay	University of Sussex, UK
Florentino Fdez-Riverola	University of Vigo, Spain
Baltasar Fernandez-Manjon	Universidad Complutense de Madrid, Spain
Margarida Figueiredo	Universidade de Évora, Portugal
Maria A. Flores	University of Minho, Portugal
Blanka Frydrychova Klimova	University of Hradec Kralove, Czechia
Denis Gillet	Swiss Federal Institute of Technology in Lausanne, EPFL, Switzerland
Jorge Gomez-Sanz	Universidad Complutense de Madrid, Spain
José González-Such	Universitat de València, Spain
Sabine Graf	Athabasca University, Canada
Eelco Herder	Utrecht University, the Netherlands
Christothea Herodotou	The Open University, UK
Mirjana Ivanovic	University of Novi Sad, Serbia
Vicente Julian	Universitat Politècnica de València, Spain
Manpreet Kaur	Partap College of Education Ludhiana, India
Dan Kohen-Vacs	Holon Institute of Technology, Israel
Milos Kravcik	DFKI GmbH, Germany
Rosa Lanzilotti	University of Bari, Italy

Fernando Lara Lara	University of Granada, Spain
Luigi Laura	International Telematic University Uninettuno, Italy
Carla Limongelli	Universita' Roma Tre, Italy
Andreas Lingnau	Ruhr West University of Applied Sciences, Germany
Matteo Lombardi	Griffith University, Australia
Ángel Losada-Vázquez	Universidad Pontificia de Salamanca, Spain
Teresa Magal-Royo	Universitat Politècnica de València, Spain
George Magoulas	Birkbeck Knowledge Lab, Birkbeck College, University of London, UK
Ivana Marenzi	L3S Research Center, Germany
Marta Martín Del Pozo	University of Salamanca, Spain
María Victoria Martín-Cilleros	University of Salamanca, Spain
Anna Mavroudi	University of Oslo, Norway
Alessandra Melonio	Ca' Foscari University of Venice, Italy
Minoru Nakayama	Tokyo Institute of Technology, Japan
Alessandro Pagano	University of Bari, Italy
Kyparissia Papanikolaou	School of Pedagogical and Technological Education, Greece
António Pedro Costa	University of Aveiro, Portugal
Elvira Popescu	University of Craiova, Romania
Francesca Pozzi	Istituto Tecnologie Didattiche - CNR, Italy
Magdalena Ramos Navas-Parejo	Universidad de Granada, Spain
Kasper Rodil	Aalborg University, Denmark
Sara Rodríguez	University of Salamanca, Spain
Carmen Rodríguez Jiménez	University of Granada, Spain
Ivan Rodriguez-Conde	University of Arkansas at Little Rock, USA
Veronica Rossano	University of Bari, Italy
Purificación Sánchez Delgado	Universitat de València, Spain
Giuseppe Sansonetti	Roma Tre University, Italy
Juan M. Santos	University of Vigo, Spain
Olga C. Santos	aDeNu Research Group, UNED, Spain
María Jesús Santos Villalba	Univesity of Málaga, Spain
Vittorio Scarano	University of Salerno, Italy
Andrea Sterbini	Sapienza University of Rome, Italy
Davide Taibi	Italian National Research Council, Italy
Laura Tarantino	Università dell'Aquila, Italy
Olga Viberg	KTH Royal Institute of Technology, Sweden
Henrique Vicente	Universidade de Évora, Portugal
Juan José Victoria Maldonado	University of Granada, Spain

MIS4TEL'23 - Organizers and Sponsors

Contents

Statistical Analysis of the Influence of Teaching Experience on the Perception of Virtual Reality

Álvaro Antón-Sancho[1], Diego Vergara[1](✉), Pablo Fernández-Arias[1], and Sara Rodríguez-González[2]

[1] Catholic University of Avila, 05005 Avila, Spain
diego.vergara@ucavila.es
[2] University of Salamanca, 37008 Salamanca, Spain

Abstract. The use of virtual reality (VR) technologies applied to higher education is experiencing a vertiginous increase, mainly in scientific-technical areas. In this work, quantitative descriptive research is carried out on the perceptions of the didactic use of VR technologies by Latin American professors of engineering and health sciences. Specifically, a statistical analysis is carried out to identify significant gaps in the assessments carried out by the participating professors according to their area of knowledge and to study the influence exerted on these assessments by the teaching experience of the professors. For this purpose, a questionnaire designed for this purpose has been used, which has been answered by 432 professors of engineering and health sciences from different Latin American universities. The results reveal that engineering professors give better evaluations than health sciences professors of the didactic aspects of VR and that teaching experience positively influences engineering professors' evaluations but negatively those of health sciences professors. It is recommended to increase teacher training in the use of VR, considering the specificities identified in each area of knowledge.

Keywords: Virtual Reality · Didactic Resource · Teaching Experience

1 Introduction

In recent years, the use of Information and Communication Technologies (ICT) for didactic uses in higher education has been gradually increasing. This is mainly due to the increase in demand for online education [1], the digitalization process that universities around the world have carried out due to the COVID-19 pandemic [2, 3], the various potentialities presented by the higher education metaverse [4, 5], and the increasing progress in the development of technologies and algorithms [6, 7]. The specialized literature emphasizes that the use of ICTs has a significant positive influence, mainly in the motivation and involvement of students in the development of teaching-learning activities and in the acquisition of more significant and lasting learning [8, 9].

Virtual Reality (VR) technologies have grown faster in recent years because of the diversity of their applications in many technical fields in which geometric and spatial visualization is relevant [10]. Specifically, VR technologies are among the technologies

M. Milrad et al. (Eds.): MIS4TEL 2023, LNNS 764, pp. 1–10, 2023.
https://doi.org/10.1007/978-3-031-41226-4_1

of the training metaverse that are of most interest to researchers [11, 12]. They are computational technologies that can recreate certain environments in a realistic and interactive way, so that the user can experience and interact with those environments [13]. Although the didactic use of VR technologies can be extended to a wide range of knowledge areas, the literature shows that the areas of engineering and health sciences are particularly prolific in terms of the applicability of VR in lectures and in terms of the publication of research papers on the didactic use of VR in higher education, whose trend is increasing in the last 25 years [14].

The main utility of VR is that it allows illustrating complex concepts in a more realistic and interactive way than traditional methodologies can, both in the technological [15] and health areas [16]. Specifically, VR is applied to engineering education in the design of virtual laboratories [17] or 3D visualization environments [18, 19], manufacturing [20], or interior design [21]. In health education, VR is applied to the three-dimensional recreation of anatomical models [22] or the simulation of realistic situations, for example in the field of nursing or surgery [23].

A fruitful line of research on the didactic use of VR consists of analyzing the assessments that university professors make of these technologies [24]. The expression professor will be used throughout the article to designate lecturers, assistant professors, associate professors, and full professors. The literature has shown that both engineering and health sciences professors give good assessments of VR, in the sense that they consider these technologies as tools that effectively help in the acquisition of knowledge and increase academic performance [14, 25]. However, the same works identify the main disadvantages for its implementation as the costs involved and, above all, the lack of specific training for professors in its use [14, 25]. Engineering professors identify as the main didactic benefits of VR the motivation it arouses in students and the increase that the use of these technologies causes in the interest shown by students in the subject of study [26]. In this sense, the literature identifies notable differences between the perceptions of professors and those of engineering students. Indeed, although students recognize that they feel more motivated to study when using VR technologies [27], they especially value the ease of use and the realism of virtual designs [28]. In the area of health sciences, professors also highlight the motivation aroused in students by VR, in addition to the increase in their academic performance it causes [29]. Engineering professors emphasize the technical advantages of VR, such as 3D design [30], interactivity [31], realism [32], or immersiveness [33], more strongly than health sciences professors, who emphasize the didactic benefits of VR to a greater extent [14, 34].

The literature has identified factors that influence the perceptions given by professors about VR. In particular, the private or public ownership of the professors' university influences their perceptions, with professors from private universities giving higher ratings to both VR and the digital competencies for its use [15]. Among professors at private universities there is greater homogeneity between male and female ratings than among professors at public universities [14]. Sociodemographic factors have also been identified, such as the level of digitization of the professors' country of origin, which condition their opinions on VR [35]. Specifically, it has been found that in the Latin American and Caribbean region, which is precisely where the present study is framed, a higher level of digitization of the countries leads to a correction of the age gaps, but a widening of the gender gaps in the assessments of VR [35].

The main research objective is to quantitatively analyze the existence of significant differences between the assessments of VR technologies given by Latin American engineering professors and health science professors, as well as to study the influence of teaching experience on these assessments in both areas of knowledge. Specifically, this work analyzes the influence of the professors' teaching experience on their assessment of VR comparing, in addition, the assessments of professors of engineering vs. professors of health sciences and the behavior of the teaching experience in the two areas of knowledge analyzed. This objective is intended to help show the need for faculty training in the development of techno-pedagogical skills and to provide opportunities for the use of VR technologies. It also aims to analyze the convenience of adapting this training and experience to the specificities of each area of knowledge, carrying out a study focused on the two areas –engineering and health sciences– in which the use of VR is more frequent. In this way, it is intended to contribute to provide keys to promote the use of VR technologies in relation to learning activities in higher education.

2 Materials and Methods

2.1 Participants

The criteria for inclusion in the study were the following: (i) to be an active professor at a university in the Latin American region; (ii) to be a specialist in one of the fields within the areas of Engineering or Health Sciences; and (iii) to teach in degrees assigned to the areas of Engineering or Health Sciences. The areas of knowledge were defined in terms of the integrated classification standardized by UNESCO [36]. A total of 432 professors participated in the study (36% Health Sciences professors and 64% Engineering professors) and all responses were validated as complete. The most frequent range of teaching experience is, in the two areas of knowledge analyzed, from 6 to 10 years (Fig. 1), although there is an approximately homogeneous distribution of participants by range of teaching experience, without significant differences by area of knowledge being identified in these distributions ($\chi^2 = 2.32$, p-value = 0.80).

2.2 Variables

The main explanatory variable is the area of knowledge, which is nominal dichotomous (health sciences or engineering). The secondary explanatory variable is the teaching experience, which is a polytomous nominal variable with six possible values ($\leq$5 years, 6 to 10 years, 11 to 15 years, 16 to 20 years, 21 to 25 years, and $>$25 years). Likewise, the following explained variables have been defined: (i) assessment of technical aspects of VR; (ii) assessment of didactic aspects of VR; (iii) level of disadvantages of the use of VR in higher education; and (iv) future projection perceived for the use of VR in higher education. All the explained variables are quantitative ordinal and are valued in a 1 to 5 Likert scale, where 1 is very low, 2 is low, 3 is intermediate, 4 is high, and 5 is very high.

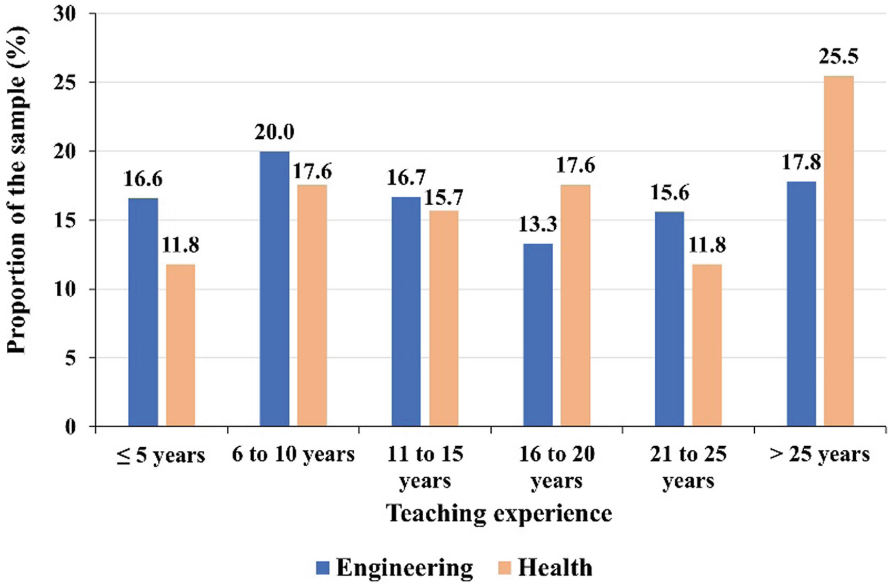

Fig. 1. Distribution of participants (%) by years of teaching experience.

3 Methodological Approach

3.1 Instrument

A questionnaire of 18 questions has been used, distributed in four families of questions corresponding to the four explained variables that have been defined (Table 1). Therefore, the survey is divided into four families of questions: (i) on technical aspects about the use of VR, which include assessments of the graphical characteristics of the 3D design of VR applications, the user experience, the ease of use and usability for the objectives pursued, the degree of immersion in the designed virtual environments, the realism of the recreated environments, and the employability of VR technologies in engineering or health sciences lectures; (ii) on the didactic usefulness of VR in engineering or health sciences education, including assessments of the expected user experience for students, the impact of VR use on academic outcomes, increased motivation for learning, and the benefits of using VR in lecture delivery; (iii) on the disadvantages attributed to the implementation of VR in engineering or health sciences education, including economic costs, space, human resources and equipment requirements, the limitations in terms of specific teacher training in VR, and the obsolescence of equipment and the need to update it; and (iv) on the participants' perspective on the future projection of the implementation of VR technologies, both immersive and non-immersive, in engineering or health sciences education. Cronbach's alpha parameters (all of them greater than 0.70) indicate that the instrument has a good level of internal consistency (Table 1).

Table 1. Questions of the questionnaire.

Variable	Cronbach's alpha	Question
Technical aspects of VR	0.86	3D design
		User experience
		Usability
		Immersion
		Interaction
		Realism
		Employability in lectures
Didactic aspects of VR	0.70	Expected experience of students
		Increase of academic performance
		Motivation of students
		Lecture development
Disadvantages	0.74	Costs
		Space required
		Technical and human resources required
		Lack of teacher training
		Technical obsolescence of equipment
Future projection	0.83	Immersive VR
		Non-immersive IVR

3.2 Methodology

Quantitative descriptive research of the assessment of the didactic use of VR in health science education and engineering education has been carried out. The following phases have been followed in the research process: (i) definition of objectives and variables and design of the research instrument; (ii) delivery of initial training on VR, selection of participants, and data collection; (ii) statistical analysis of the data obtained; and (iv) drawing conclusions. For the statistical analysis, the descriptive statistics of the responses have been obtained and parametric hypothesis contrast tests have been applied (specifically, the t-test and the multifactor analysis of variance –MANOVA–) to identify significant differences in the mean responses of the different families of answers according to the area of knowledge of the participants and their teaching experience. All tests have been performed with a significance level of 0.05.

4 Results

The participants of the two areas of knowledge analyzed give high evaluations to VR, both in its technical and didactic dimensions, and attribute a high future projection to its use in higher education (Table 2). However, in both areas the assessment of the technical aspects is higher than that of the didactic (14.9% in health sciences and 19.0% in Engineering). Despite this, the level of perceived disadvantages is also high (Table 2). The results of the mean comparison t-test allow to assume that there is a statistically significant difference in the assessment of the technical aspects of VR (Table 2), which is greater among engineering professors. However, no significant differences were identified in the mean responses of the rest of the variables analyzed.

Table 2. Mean responses of the different families of questions.

Variable	Engineering	Health Sciences	*t*-statistic	*p*-value
Technical aspects	4.25	4.09	7.24	0.01*
Didactic aspects	3.57	3.56	0.01	0.92
Disadvantages	3.56	3.58	0.04	0.84
Future projection	3.95	3.92	0.13	0.72

* $p < 0.05$

The way in which teaching experience influences the ratings of engineering professors and health science professors is different in the technical, didactic, and disadvantage dimensions of VR, according to the MANOVA test statistics. Regarding the technical and didactic aspects of VR (Tables 3 and 4), engineering professors with more experience are those who give lower ratings, while in health sciences the ratings given by professors to the technical and didactic aspects show a significant increase in the higher levels of teaching experience ($F = 5.45$, $p = 0.0001$ for technical aspects; $F = 3.40$, $p = 0.0047$ for didactic aspects). Regarding the identification of disadvantages for the use of VR, the engineering professors maintain an approximately homogeneous assessment as teaching experience increases, but in health sciences, the perception of the level of difficulties increases with teaching experience in the last stages of teaching experience ($F = 2.84$, $p = 0.0150$).

Table 3. Mean responses of engineering professors, differentiating by teaching experience.

Variable	<5 years	6–10 years	11–15 years	16–20 years	21–25 years	>25 years
Technical aspects	4.18	4.36	4.18	4.35	4.32	4.14
Didactic aspects	3.63	3.42	3.71	3.83	3.54	3.38
Disadvantages	3.51	3.83	3.49	3.32	3.63	3.49
Future projection	3.87	3.83	3.97	3.98	4.10	3.98

*$p < 0.05$

Table 4. Mean responses of health science professors, differentiating by teaching experience.

Variable	<5 years	6–10 years	11–15 years	16–20 years	21–25 years	>25 years
Technical aspects	4.10	3.73	3.84	4.00	4.43	4.39
Didactic aspects	3.68	3.44	3.97	3.11	3.67	3.60
Disadvantages	3.33	3.47	3.00	3.69	3.93	3.89
Future projection	3.70	3.49	4.20	3.93	4.03	4.09

*$p < 0.05$

5 Discussion

Throughout this research it has been shown that the ratings made by Latin American professors about VR are very high, being the engineering professors those who better value the technical aspects, but there are no significant differences in the valuation of the didactic aspects between engineering and health sciences professors (Table 2). The high ratings obtained are in line with the results of previous studies focused on populations of university professors in general [34], engineering professors [15], or health sciences professors [25]. However, the results obtained show that there is greater homogeneity between the responses of engineering professors and health sciences professors than those described in previous studies [14].

The main novelty of the present study consists in the identification of teaching experience as an explanatory variable of the perceptions of the participating professors on VR. In general, as teaching competence increases, engineering professors give worse evaluations of the didactic and technical aspects of VR (Table 3), while health sciences professors increase their evaluations in this regard (Table 4).

The main implication of this study is that the training received by Latin American professors in the two areas of knowledge analyzed should be increased and improved. Universities should also consider the influence of the professors' teaching experience in the training sessions they design. They should be especially sensitive to the digital integration of engineering professors with a higher level of teaching experience, who are the ones who give lower evaluations of VR.

The main limitations and lines of future research of this investigation are the following: (i) it would be convenient to carry out an analogous analysis with a sample of professors homogeneously distributed by areas of knowledge, in order to corroborate the results obtained here; (ii) it would be interesting to complement the results obtained here through a qualitative analysis that addresses the reasons that explain the gaps identified; (iii) carrying out an analogous analysis with a sample of professors from all areas of knowledge or from different geographic regions would also allow for a deeper identification of gaps by areas of knowledge and the identification of explanatory socioeconomic and geographic factors; and (iv) analyzing the influence that other variables not analyzed here, such as experience with the use of a particular VR application, may have on professors' assessments.

6 Conclusions

Latin American professors of engineering and health sciences give very high ratings to VR, although they also identify strong limitations for its implementation, mainly in terms of their own lack of specific training to use it. In this sense, engineering professors report ratings of the technical aspects of VR almost 4% higher than those of health sciences professors. The teaching experience of Latin American professors in the areas analyzed influences their perceptions of VR, but in different ways. Specifically, the more the teaching experience of engineering professors increases, the more the ratings of the technical and didactic aspects of VR decreases. On the other hand, the more the teaching experience of health science professors increases, the more the rating of VR grows.

These results imply that the training of university professors, as well as providing equipment and opportunities for its application in the classroom, are crucial to grow in the process of integrating VR in higher education. However, this training must have a sensitive approach to the specificities of each area of knowledge. In particular, the training of more experienced engineering professors should be reinforced, while, among health sciences professors, the training of younger professors should be strengthened.

Acknowledgements. This research has been supported by the project "COordinated intelligent Services for Adaptive Smart areaS (COSASS), Reference: PID2021-123673OB-C33, financed by MCIN /AEI /https://doi.org/10.13039/501100011033 / FEDER, UE.

References

1. Alyoussef, I.Y.: Acceptance of e-learning in higher education: the role of task-technology fit with the information systems success model. Heliyon **9**, e13751 (2023)
2. Antón-Sancho, A., Sánchez-Calvo, M.: Influence of knowledge area on the use of digital tools during the covid-19 pandemic among Latin American professors. Educ. Sci. **12**(9), 635 (2022)
3. Antón-Sancho, A., Fernández-Arias, P., Vergara-Rodríguez, D.: Impact of the covid-19 pandemic on the use of ICT tools in science and technology education. J. Technol. Sci. Educ. **13**(1), 130–158 (2023)
4. López-Belmonte, J., Pozo-Sánchez, S., Moreno-Guerrero, A.-J., Lampropoulos, G.: Metaverse in education: a systematic review. RED. Revista de Educación a Distancia **73**(23), 2 (2023)
5. Corchado, J.M., Ossowski, S., Rodríguez-González, S., De-la-Prieta, F.: Advances in explainable artificial intelligence and edge computing applications. Electronics **11**, 3111 (2022)
6. Extremera, J., Vergara, D., Rodríguez, S., Dávila, L.P.: Reality-virtuality technologies in the field of materials science and engineering. Appl. Sci. **12**, 4968 (2022)

7. Ospina-Bohórquez, A., Rodríguez-González, S., Vergara-Rodríguez, D.: A review on multi-agent systems and virtual reality. In: Matsui, K., Omatu, S., Yigitcanlar, T., González, S.R. (eds.) Distributed Computing and Artificial Intelligence, 18th International Conference. DCAI 2021, vol. 1, pp. 32–42. Lecture Notes in Networks and Systems, Springer, Cham (2022)
8. Lee, Y., Lee, J., Hwang, Y.: Relating motivation to information and communication technology acceptance: self-determination theory perspective. Comput. Hum. Behav. **51**, 418–428 (2015)
9. Naveenkumar, M., Domnic, S.: Learning representations from spatio-temporal distance maps for 3D action recognition with convolutional neural networks. ADCAIJ: Adv. Distrib. Comput. Artif. Intell. J. **8**(2), 5–18 (2019)
10. Veloz, J., Extremera, J., Vergara, D., Alcívar, A., Rodríguez, S.: 3D virtual application as a guidance and facility management tool applied to university buildings. In: Methodologies and Intelligent Systems for Technology Enhanced Learning, 11th International Conference MIS4TEL 2021. Lecture Notes in Networks and Systems, vol. 326, pp. 3–11. Springer, Cham (2022)
11. Vergara, D., Fernández-Arias, P., Santos-Iglesia, C., Antón-Sancho, A.: The virtual reality: a sustainable technology. Dyna **97**, 556–560 (2022)
12. Rodríguez-Marín, P.A., Duque, N., Ovalle, D.: Multi-agent system for knowledge-based recommendation of learning objects. ADCAIJ: Adv. Distrib. Comput. Artif. Intell. J. **4**(1), 80–89 (2015)
13. Kamari, A., Paari, A., Torvund, H.Ø.: BIM-enabled virtual reality (VR) for sustainability life cycle and cost assessment. Sustainability **13**, 249 (2021)
14. Fernández-Arias, P., Antón-Sancho, A., Sánchez-Jiménez, M., Vergara, D.: Statistical analysis of professors' assessment regarding the didactic use of virtual reality: engineering vs. health. . Electronics **12**, 1366 (2023)
15. Vergara, D., Antón-Sancho, A., Dávila, L.P., Fernández-Arias, P.: Virtual reality as a didactic resource from the perspective of engineering teachers. Comput. Appl. Eng. Educ. **30**, 1086–1101 (2022)
16. Riva, G.: Virtual reality for health care: the status of research. Cyberpsychol. Behav. Soc. Netw. **5**, 219–225 (2002)
17. Vergara, D., Extremera, J., Rubio, M.P., Dávila, L.P.: The proliferation of virtual laboratories in educational fields. ADCAIJ: Adv. Distrib. Comput. Artif. Intell. J. **9**, 85–97 (2020)
18. Getuli, V., Capone, P., Bruttini, A., Isaac, S.: BIM-based immersive virtual reality for construction workspace planning: a safety-oriented approach. Autom. Constr. **114**, 103160 (2020)
19. Vergara, D., Rubio, M.P., Lorenzo, M., Rodríguez, S.: On the importance of the design of virtual reality learning environments. In: Methodologies and Intelligent Systems for Technology Enhanced Learning, 9th International Conference MIS4TEL 2019. Lecture Notes in Networks and Systems, vol. 1007, pp. 146–152. Springer, Cham (2020)
20. Mujber, T.S., Szecsi, T., Hashmi, M.S.: Virtual reality applications in manufacturing process simulation. J. Mater. Process. Technol. **155**, 1834–1838 (2004)
21. Kaleja, P., Kozlovská, M.: Virtual reality as innovative approach to the interior designing. SSP J. Civ. Eng. **12**, 109–116 (2017)
22. Nakai, K., Terada, S., Takahara, A., Hage, D., Tubbs, R.S., Iwanaga, J.: Anatomy education for medical students in a virtual reality workspace: a pilot study. Clin. Anat. **35**, 40–44 (2022)
23. Alam, F., Matava, C.: A new virtual world? The future of immersive environments in anesthesiology. Anesth. Analg. **135**, 230–238 (2022)
24. Vergara, D., Antón-Sancho, A., Extremera, J., Fernández-Arias, P.: Assessment of virtual reality as a didactic resource in higher education. Sustainability **13**, 12730 (2021)
25. Antón-Sancho, A., Fernández-Arias, P., Vergara, D.: Virtual reality in health science education: professors' perceptions. Multimodal Technol. Interact. **6**, 110 (2022)

26. Yıldırım, B., Sahin-Topalcengiz, E., Arıkan, G., Timur, S.: Using virtual reality in the classroom: reflections of STEM teachers on the use of teaching and learning tools. J. Educ. Sci., Environ. Health **6**, 231–245 (2020)
27. McDonough, D.J., Pope, Z.C., Zeng, N., Liu, W., Gao, Z.: Comparison of college students' blood pressure, perceived exertion, and psychosocial outcomes during virtual reality, exergaming, and traditional exercise: an exploratory study. Games Health J. **9**, 290–296 (2020)
28. Sulbaran, T., Baker, N.C.: Enhancing engineering education through distributed virtual reality. In: 30th Annual Frontiers in Education Conference. Building on A Century of Progress in Engineering Education, pp. S1D/13-S1D/18. IEEE, Kansas City, MO, USA (2000)
29. Mäkinen, H., Haavisto, E., Havola, S., Koivisto, J.-M.: User experiences of virtual reality technologies for healthcare in learning: an integrative review. Behav. Inf. Technol. **41**, 1–17 (2022)
30. Vergara, D., Rubio, M.P., Lorenzo, M.: New virtual application for improving the students' understanding of ternary phase diagrams. Key Eng. Mater. **572**, 578–581 (2014)
31. Vergara, D., Lorenzo, M., Rubio, M.P.: Virtual environments in materials science and engineering: the students' opinion. In: Lim, H.L. (ed.) Handbook of Research on Recent Developments in Materials Science and Corrosion Engineering Education, pp. 148–165. IGI Global (2015)
32. Vergara, D., Rubio, M.P., Lorenzo, M.: Interactive virtual platform for simulating a concrete compression test. Key Eng. Mater. **572**, 582–585 (2014)
33. Rubio, M.P., Vergara, D., Rodríguez, S.: Immersive virtual reality in technical drawing of engineering degrees. In: Methodologies and Intelligent System for Technology Enhanced Learning, 9th International Conference MIS4TEL 2019. Lecture Notes in Networks and Systems, vol. 1007, pp. 71–79. Springer, Cham (2020)
34. Antón-Sancho, A., Fernández-Arias, P., Vergara, D.: Perception of the use of virtual reality didactic tools among faculty in Mexico. Future Internet **15**, 72 (2023)
35. Antón-Sancho, A., Vergara, D., Fernández-Arias, P.: Impact of the digitalization level on the assessment of virtual reality in higher education. Int. J. Online Pedagogy Course Des. (IJOPCD) **13**(1), 1–19 (2023)
36. UNESCO Institute for Statistics: International Standard Classification of Education ISCED 2011. UNESCO-UIS: Montreal, QC, Canada Available online: http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf (2012). Accessed 20 Mar 2023

Multiple-Choice Questions Difficulty Prediction with Neural Networks

Diego Reyes[1(✉)], Abelino Jimenez[1], Pablo Dartnell[1,2], Séverin Lions[1,3], and Sebastián Ríos[4]

[1] Center for Advanced Research in Education (CIAE), University of Chile, Santiago, Chile
diego.reyes.t@ug.uchile.cl,
{abelino.jimenez,dartnell,severin.lions}@ciae.uchile.cl
[2] Department of Mathematical Engineering (DIM), University of Chile, Santiago, Chile
[3] Department of Educational Assessment, Measurement, and Registry (DEMRE), University of Chile, Santiago, Chile
[4] Business Intelligence Research Center (CEINE), Department of Industrial Engineering, University of Chile, Santiago, Chile
srios@dii.uchile.cl

Abstract. Designing a high-quality multiple-choice test is a challenging task. Typically, to validate a test, this must be administered to a sample of the target population, allowing one to estimate the difficulty of each question and its consistency. In several scenarios, this administration is costly and time-consuming, so predicting the difficulty of multiple-choice questions before field testing could reduce costs and time during the test validation process. In this article, we propose three deep-learning approaches which aim to reduce the resources required to estimate the difficulty of multiple-choice questions during test development of high-stakes tests. These data-driven approaches use Neural Network architectures such as Recurrent Neural Networks (RNN), Bidirectional Long Short-term Memory (BiLSTM), and Bidirectional Encoder Representations for Transformers (BERT). The models are trained on a data source built with a sample of the standardized high-stakes exams for university admissions in Chile. Our approaches consider different configurations specific to each architecture and a set of features that represent the readability level and the similarities between the response options. The results show that BiLSTM performs best and is the most suitable model for the task, even though it could be considered outdated by the appearance of contemporary architectures. Finally, we elaborate on how this data-driven approach might be improved.

Keywords: Multiple-choice Questions · Difficulty · Deep Learning · IRT · Bidirectional LSTM · BERT

M. Milrad et al. (Eds.): MIS4TEL 2023, LNNS 764, pp. 11–22, 2023.
https://doi.org/10.1007/978-3-031-41226-4_2

1 Introduction

Multiple-choice questions (MCQs) are widely used in educational assessment. In several countries, high-stakes tests such as university admission exams are constituted mainly by MCQs. Therefore, a high-quality design for this type of question becomes critical. One relevant MCQ feature is item difficulty: MCQs should be neither too difficult nor too easy; tests should include a balance of easy, medium, and difficult questions; and when different test forms are administered to different examinees, these forms should be equivalent in terms of difficulty [1].

Consequently, high-stakes test developers are deeply interested in obtaining the best difficulty estimate possible for the MCQs they plan to include in their final tests. In this scenario, the most common method to obtain item difficulty estimates is pretesting, i.e., administering MCQs to a sample of examinees whose response accuracy is analyzed before the final test assembly. Pretesting is time-consuming and associated with an item exposure issue but enables the acquisition of valid and reliable measures of difficulty [2].

Still, items of all over the difficulty range should be pretested, and test developers must thus estimate item difficulty even before pretesting. This task is classically performed by domain experts, who are asked to estimate, categorize or rank item difficulty. However, this approach requires significant time and human resources, and experts' prediction accuracy can be disappointing [3]. For instance, experts might struggle to provide reasonable estimates for difficult items [1]. Predictions of item writers and reviewers can be combined to get more accurate estimates [4], and accuracy can be improved through training [5], but this makes this approach even less cost-effective. Moreover, experts' intuitive judgments of item difficulty can be acceptable when items have to be ranked or categorized, but it is usually a lot harder for humans to provide an accurate difficulty score [3]. As a result, alternative methods, such as predicting item difficulty with machine learning algorithms, potentially offer a new and efficient approach to overcome the limitations of traditional methods [2].

2 Related Work

In the last decade, several studies presented strategies to predict item difficulty automatically. Most studies have obtained question difficulty estimation from text, by analyzing the textual content of MCQs with Natural Language Processing (NLP) techniques, focused on designing computational algorithms and representations for processing natural human language [2]. Using Neural Networks (which is a set of Machine Learning algorithms composed of interconnected nodes, called neurons, organized in layers) has recently proven to be a promising approach for predicting item difficulty [6]. Recurrent Neural Networks (RNNs) can perform much better than traditional machine learning models for several tasks when working with short natural text. An RNN allows for retaining the information provided in sequence across the multiple layers of the network. However, when the sequence of words given to a simple RNN is too large, the