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Effective organizational factors in adopting e-Learning in education: extracting determinants and frameworks

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Abstract

Organizational contextual factors, influencing the implementation of any new system, either in a business enterprise or an education institution, should be taken into consideration when comprehensive implementation of new system is considered. This scoping review was conducted with the aim of identifying the effective organizational factors in adopting e-learning. Data collection was carried out by searching the related keywords Web of sciences (WOS) and Scopus, with no limitation on date of publication. Different search strategies were applied to find the related articles. The content of the articles was analyzed by using a qualitative synthesis approach, and according to the inclusion and exclusion criteria. The search resulted in 21 articles eligible for analysis, which showed 20 effective organizational factors in adopting e-learning. These factors were classified in to four main themes: 1) institutional infrastructure and compatibility, 2) resources allocation, 3) organizational support and monitoring, and 4) motivation, innovation & change management. The results also showed that Unified Theory of Acceptance Model (UTAUT) was the most prevalent adoption theory in the studies, followed by Technology Acceptance Model (TAM). This study reviewed the literature pertaining to the organizational effective factors in adopting e-learning. The results acknowledged that organizational factors are the backbone of e-learning adoption in universities and institutions. This fact should be taken into consideration by mangers and policy makers, especially in developing countries.

KEYWORDS: E-Learning, Organizational Factors, Adoption, Acceptance, University, Institution.

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1. Introduction

Recently, the advances in technology have extended its border to education which is an appealing realm for reform and innovation. Thus, we have witnessed drastic changes in teaching and learning, namely E-learning which has removed the barriers to accessibility to education by learning anytime and anywhere. E-learning can be found among the innovative methods of teaching and learning, and are offered in the form of E-contents via content management platforms, mainly learning management systems (Lopez-Belmonte, Segura-Robles, Moreno-Guerrero, & Parra-Gonzalez, 2021). E-learning allows learners to deploy e-contents both synchronously and asynchronously (Campos Soto, Soler Costa, & Moreno Guerrero, 2018).

There are several advantages distinguishing e-learning, as a modern approach to teaching and learning, over other conventional methods. Availability of learning materials, anywhere anytime, flexibility of learning strategies, connectivity and interactivity are some of the advantages. E-learning allows learners to use their own individualized strategies of learning, and learn at their own pace. Moreover, the platforms used for e-learning

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facilitates the communication between learners and teachers through forums, chat box, message systems, online classes, etc. (Alqudah et al., 2020; Farhan, Razmak, Demers, & Laflamme, 2019; Ibrahim, Ibrahim, Zukri, Yusof, & Roslan, 2019; Kim, Hong, & Song, 2019; Tawafak, Romli, bin Abdullah Arshah, & Malik, 2020). Leaners could also manage their learning progress through self-assessment, progress reports, and feedbacks they receive. (Wu et al., 2020).

However, E-Learning has some challenges and limitations(Wu et al., 2020). Resistance to adopt e-learning by managers, instructors and students has often been reported as the main impediment for the development of e-learning especially in developing countries (Abbasi Kasani, Shams Mourkani, Seraji, Rezaeizadeh, & Abedi, 2020; Adams, Sumintono, Mohamed, & Noor, 2018; DeAlwis, 2020). Lack of training programs for e-teachers, lack of basic infrastructure, and support systems, lack of awareness of advantages of e-learning, and how to integrate e-learning in curriculum, resistance to change (Rakhyoot, 2017), and lack of assessment of organizational readiness for e-learning adoption (Alshaher, 2013) are the challenges in facing e-learning. Lopes (2007) remarks that the business, technology, content, culture, human and financial resources can influence the readiness for e-learning and consequently its adoption(Lopes, 2007). Al Ajmi et al. (2017) have mentioned cost reduction, information technology readiness, viability influenced by organizational factors, and decision makers supports as effective factors in adopting cloud computing in e-learning(Al Ajmi, Arshah, Kamaludin, Sadiq, & Al-Sharafi, 2017). Administrative, organizational, technological and human challenges, have also been reported as the main barriers to adoption of e-learning in many institutes(Faria Kanwal, Rehman, Bashir, & Qureshi, 2017).

Organizational contextual factors, influencing the implementation of any new system, either in a business enterprise or an education institution, should be taken into consideration when introducing a new system, approach, method, etc. E-learning is no exception to this principle, and there some studies reporting the significant effect of organizational contextual factors in adopting e-learning in institutions (Al-Sayyed & Abdalhaq, 2016; Mokhtar, Ali, Al-Sharafi, & Aborujilah, 2014; Tom, Virgiyanti, Rozaini, & Ieee, 2019).

Al-Fraihat et al. (2017) in a study about the success factors of e-Learning in higher education noticed that planning, readiness, management, support, pedagogy, technology, faculty, institution, evaluation and ethics were the main dimensions of adoption in a successful e-learning program (Al-Fraihat, Joy, & Sinclair, 2017).

Satria's 2022 systematic review uncovered four categories of obstacles in e-learning: human factors, technological factors, financial factors, and organizational factors. Educational institutions need to modify their material delivery methods as one way to tackle this issue, potentially incorporating gamification. Furthermore, the organization's role is crucial in addressing these barriers, acting as both policymakers and supporters, providing financial aid and training (Satria, 2022).

However, there are few studies in which the effective organizational factors in adopting e-learning have been comprehensively investigated. This, scoping review was conducted to identify effective organizational factors, and the most prevalent model in adopting e-learning through a comprehensive literature review. The findings of this study could assist mangers and decision makers, especially in developing countries, when adoption of e-learning is in progress.

2. Materials and methods

This study was a scoping review conducted in January 2020. We included published papers in the Web of Science (WOS) and Scopus, addressing effective organizational factors in adopting e-learning, with no limitation on date of publication in these databases. Web of Science (WOS) and Scopus were selected as the databases for searching the articles since they are the most influential citation and information databases worldwide. Articles were included without limitation on publication date (from 1986 until January 2020) and type of article. Thus, all articles indexed in the Web of Science and Scopus, including original articles, reviews, and short articles addressing organizational factors in adopting e-learning were included for evaluation. Studies were retrieved by a Boolean search of the following keywords:

Search strategies on the Scopus:

1. ((TITLE (e-learning) AND TITLE (adoption) AND TITLE-ABS-KEY ("Organizational factors"))
2. ((TITLE (e-learning) AND TITLE (adoption) AND TITLE-ABS-KEY (management))
3. (TITLE (e-learning) AND TITLE (adoption) AND TITLE-ABS-KEY (administration))
4. (TITLE (e-learning) AND TITLE (adoption) AND TITLE-ABS-KEY (organization))
5. (TITLE (e-learning) AND TITLE (adoption) AND TITLE-ABS-KEY (institution))

Search strategies on the WOS:

1. ((TITLE (e-learning) AND TITLE (adoption) AND Topic ("Organizational factors"))
2. ((TITLE (e-learning) AND TITLE (adoption) AND Topic (management))
3. (TITLE (e-learning) AND TITLE (adoption) AND Topic (administration))
4. (TITLE (e-learning) AND TITLE (adoption) AND Topic (organization))
5. (TITLE (e-learning) AND TITLE (adoption) AND Topic (institution))

Upon the initial search, 209 articles were retrieved (76 articles form WOS and 133 articles from Scopus) and entered into EndNote software. After removing the duplicates (75 articles), the rest of the articles were evaluated on the basis of the titles, among which 40 articles were eliminated due to having irrelevant titles. In the next step, articles were evaluated on the basis of abstracts and subject relevance. Thereafter, two articles were eliminated because the abstract and full text were not accessible. The remaining 92 articles were reviewed by considering the content relevance. Ultimately, after reading the abstracts and full text of the studies, 21 related articles were selected to be closely reviewed. The selected articles (presented in Table 2) were analyses in terms of study objectives and results. The search process is depicted in Figure 1.

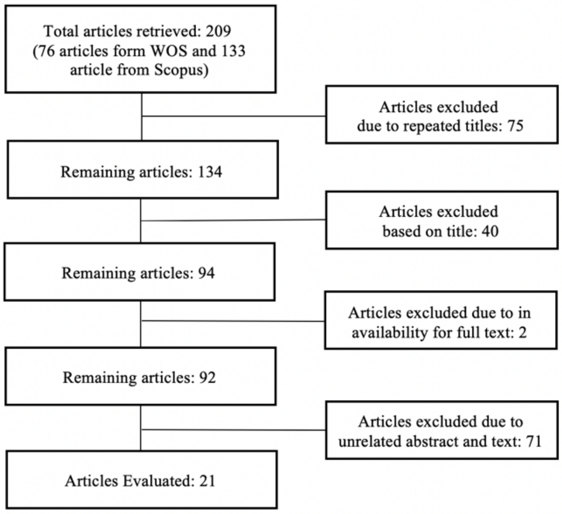

Figure 1 - Process of search, retrieval and inclusion of articles in the study.

We gathered relevant data from sources to align with our research objectives. Then, we grouped this information into primary themes based on similarities or relationships. Within each theme, we identified and classified additional subtopics or subcategories present in the data. Continuously, we reviewed and refined the sub-themes to ensure they accurately represented the data and aligned with our research goals.

3. Results

As it is displayed in Figure 1, 21 articles related to the topic of "organizational factors in adopting e-learning" were closely evaluated. Table 1 shows the main themes and sub themes extracted after reviewing the articles. Four main themes, showing the effective organizational factors in adopting e-learning were identified: 1) Institutional Infrastructure and Compatibility, 2) Resources Allocation, 3) Organizational Supporting and Monitoring, and 4) Motivation, Innovation & Change Management.

Table 1 - Themes and sub-themes obtained from evaluating articles.

No.	Main theme	Sub-theme
1	Institutional Infrastructure and Compatibility	1. Accessibility 2. Facilitating Conditions (FC) 3. Organizational Compatibility 4. Service Quality 5. Security Concerns
2	Resources Allocation	1. Allocate Resources 2. Resources Management 3. Human Resource Readiness 4. Cost, Investment
3	Organizational Supporting and Monitoring	1. Government Support 2. Institutional Support from Management and Educators 3. Academics' Commitments 4. Leadership Support 5. Management Support 6. Organizational Support 7. Service Provider Support 8. Comprehension Monitoring Strategies
4	Motivation, Innovation & Change Management	1. Strategic Change Management Plans 2. Innovative Ideas 3. Incentives 4. Competitive Pressure

Table 2 shows the bibliographic information of the articles along with the aim of the study and the findings. In addition, the table depicts the adoption models applied in the studies and the effective organizational factors. As it is seen, the most prominent adoption theory was Unified Theory of Acceptance and Use of Technology (UTAUT), followed by Technology Acceptance Model (TAM).

4. Discussion

This study was carried out to pursue two main objectives: 1) identifying the main effective organizational factors in adopting e-learning in universities and educational institutions, 2) identifying the most prominent theory / model applied as reported in the literature. First, we found that organizational factors have determining effects on comprehensive adoption of e-learning. This finding has been confirmed by several previous studies. However, it seems that there are still hidden angles in this field and more detailed studies should be performed. In 2020, Porto discovered that hierarchical culture prevails in higher educational institutions. They found a strong correlation between teachers' acceptance of technology and the embrace of e-learning. Through linear regression, it was revealed that four out of six dimensions of organizational culture impact technology adoption, alongside all constructs of the Technology Acceptance Model (TAM). Furthermore, attitude and behavior were found to predict the actual adoption of e-learning technologies in an educational context.

Table 2 - Summary of information on articles included in the study

Art. Code	Title	Authors	Year	Adoption models	Effective Organizational Factors
1	E-Learning during COVID-19 Outbreak: Cloud Computing Adoption in Indian Public Universities	Bhardwaj, A.K. Garg, L. Garg, A. Gajpal, Y.	2021	Technology Acceptance Model (TAM) Technology-Organization Environment (TOE) Diffusion of Innovation (DOI)	senior leadership support, security concerns, government support
2	Identifying key factors affecting college students' adoption of the e-learning system in mandatory blended learning environments	Zhang, Z. Cao, T. Shu, J. Liu, H.	2020	Unified Technology Acceptance and System Success (UTASS)	facilitating conditions (FC)
3	E-learning benchmarking adoption: A case study of sur university college	Zoubi, S.I.A. Alzoubi, A.I.	2019	McLean & DeLone Information System Success (IS Success) and Diffusion of Innovation (DOI)	service quality
4	Factors affecting the adoption of e-learning technologies among higher education students in Nigeria: A structural equation modelling approach	Yakubu, M.N. Dasuki, S.I.	2019	Unified theory of acceptance and use of technology (UTAUT)	facilitating conditions
5	Empirical investigation of E-learning adoption of university teachers: A PLS-SEM approach	Xian, X.	2019	UTAUT 2	facilitating conditions
6	Understanding the Determinants of Infrastructure-as-a Service-Based E-Learning Adoption Using an Integrated TOE-DOI Model: A Nigerian Perspective	Tom, A.M. Virgiyanti, W. Rozaini, W.	2019	Diffusion of Innovation; Technological, Organizational, Environmental theory	cost savings, competitive pressure, service provider support
7	E-Learning Adoption in the UAE: A Case Study of the Higher College of Technology	Alblooshi, S. Hamid, Naba	2019	unified theory of acceptance and use of technology (UTAUT)	facilitating conditions
8	E-learning adoption in rural-based higher education institutions in South Africa	Patel, N.M. Kadyamatimba,A. Madzvamuse, S.	2018	UTAUT (Unified Theory of Acceptance Model)	institutional support from management and educators
9	Analysis of the Factors for the Successful E-Learning Services Adoption from Education Providers' and Students' Perspectives: A case study of Private Universities in Northern Iraq	Abdullah, M.S. Toycan, M.	2018	technology acceptance model (TAM)	human resource readiness factor
10	A comparative evaluation of e-learning adoption in private and public higher education institutions: A Tanzania survey	Mwamahusi, M.P. Tossy, T.	2016	None	initial investment, strategic change management plans, innovative ideas
11	Challenges affecting adoption of e-learning in public universities in Kenya	Mutisya, D.N. Makokha, G.L.	2016	None	investment
12	Determinants of E-Learning Adoption in Universities: Evidence from a Developing Country	Ansong, E. Boateng, S.L. Boateng, R. Effah, J.	2016	technological, organizational and environmental (TOE)	organizational compatibility
13	Interventional factors affecting instructors adoption of e-learning system: A case study of Palestine	Al-Sayyed, F. Abdalhaq, B.	2016	Technology Acceptance Model (TAM)	management support, organizational support,
14	Exploring factors that influence adoption of e-learning within higher education	King, E. Boyatt, R.	2015	None	institutional infrastructure
15	E-learning adoption model: A case study of Pakistan	Kanwal, F. Rehman, M.	2014	Technology Acceptance Model (TAM)	Accessibility
16	Trust as an Organizing Principle of e-Learning Adoption: Reconciling Agency and Structure	Martins, J.T. Nunes, M.B.	2013	None	academics' commitments
17	Barriers to E-learning adoption in China's traditional higher education institutions: An exploratory study at the institutional level	Fan, W. Yi, S.	2012	None	incentives
18	Measuring the acceptance and adoption of e-learning by academic staff	Al-Alak, B.A. Alnawas, I.A.M.	2011	None	management support
19	An investigation on predictors of E-learning adoption among Malaysian E-learners	Haron, H. Suriyani, Sahar	2010	None	comprehension monitoring strategies, resources management strategies
20	e-learning adoption inside jordanian organizations from change management perspective	Harfoushi, O.K. Obiedat, R.F. Khasawneh, S.S.	2010	None	leadership
21	Factors affecting e-Learning adoption by faculties	Plaisent, M. Diallo, A. Bernard, P.	2007	None	Allocate resources

The results indicate that empowering and involving faculty actively is crucial for technology adoption in an educational setting. This underscores the dual role of teachers as both creators of the learning environment and shapers of organizational culture (Porto, 2020). Satria's (2022) systematic review findings revealed four barrier categories in e-learning: human factors, technological factors, financial factors, and organizational factors. To address this challenge, educational institutions must alter their material delivery methods, with gamification being one potential approach. Additionally, the organization plays a crucial role in addressing these barriers, serving as policymakers and supporters, both financially and as training providers (Satria, 2022).

In our study, the results indicate that "institutional infrastructure and compatibility", have significant effect on e-learning adoption in universities and educational institutions. Accessibility, facilitating conditions, organizational compatibility, service quality, and security concerns are the main determinants addressed in the literature (Alblooshi & Hamid, 2019; Ansong, Boateng, Boateng, & Effah, 2016; Bhardwaj, Garg, Garg, & Gajpal, 2021; F. Kanwal & Rehman, 2014; Xian, 2019; Yakubu & Dasuki, 2019; Zhang, Cao, Shu, & Liu, 2020). Likewise, Kanwal et al. (2017), found that organizational infrastructure, and accessibility of hardware and internet; are the critical factors of e-learning adoption(Faria Kanwal et al., 2017). Al-Fraihat et al (2017) remarked that administrative affairs, academic affairs, student services, student advice and consultation, leadership commitment to effective learning, appropriateness of the processes to the e-learning environment, strategy, financial sustainability and feasibility, institution and service quality, leadership strategy, change in the study habits, and making people understand how to learn; are the main institutional factors influencing e-learning adoption (Al-Fraihat et al., 2017). Thus, the issue of "institutional infrastructure and compatibility" should be taken into consideration when successful implementation on e-learning is considered.

Other findings indicate that resources allocation, resources management, human resource readiness, cost, and investment are other effective organizational factors affecting e-learning adoption (Abdullah & Toycan, 2018; Haron & Suriyani, 2010; Mutisya & Makokha, 2016; Plaisent, Diallo, & Bernard, 2007; Tom et al., 2019). We categorized these factors in "resources allocation". In line with our results, Knawal et al. (2017), and AlAjmi et al. (2017) have discussed that economic concerns is a significant factor in e-learning adoption(Al Ajmi et al., 2017; Faria Kanwal et al., 2017). Thus, universities and educational institutes must be prepared in terms of resources allocation to adopt e-learning.

Also, the findings reveal that "organizational supporting and monitoring" have significant effect on e-learning adoption. Government support, institutional support from management and educators, academics commitments, leadership support, management support, organizational support, service provider support, and comprehensive monitoring strategies are the main factors reported in the literature (Bhardwaj et al., 2021; Haron & Suriyani, 2010; Martins & Nunes, 2013; Patel, Kadyamatimba, & Madzvamuse, 2018; Tom et al., 2019). Other studies also show that administrative and organizational support is a crucial factor in comprehensive adoption of e-learning(Al Ajmi et al., 2017; Faria Kanwal et al., 2017). Harrison (2018) noticed that top management support, organizational culture-E-learning strategy and policies, institutional leadership and strategy are effective organizational factors in the successful adoption of e-learning (Harrison, 2018). Thus, e-learning adoption needs the support of organization's leadership more than any other factors. In 2020, Ahmed Al Mulhem discovered an unprecedented strong correlation between organizational elements (specifically top management support and change management) and the quality of e-learning systems. Furthermore, the findings indicated a noteworthy and positive impact of quality factors (including course content quality, system quality, and service quality) on students' satisfaction with e-learning system quality. Consequently, educational institutions aiming to maximize the advantages of e-learning systems should prioritize both quality and organizational factors during the design and implementation phases, recognizing their critical role in enhancing e-learning system quality and service(Al Mulhem, 2020).

"Motivation, innovation & change management"; is the last theme identified as effective factors of e-learning adoption in this study. We classified strategic change management plans, innovative ideas, incentives, and competitive pressure as the sub-themes of this theme. (Fan & Yi, 2012; Mwamahusi & Tossy, 2016; Tom et al., 2019). Nayanajith et al (2019) have reported that there is a positive relationship between innovation and adoption of e-learning (Nayanajith, Damunupola, & Ventayen, 2019). In line with our findings, El-Masri et al (2017) reported that hedonic motivation is a significant factor in the adoption of e-learning and inferred that "users achieve an acceptable level of intrinsic motivation while using web-based learning systems" (El-Masri & Tarhini, 2017). Almaiah et al (2020) mentioned change management as one of the challenging issues, since it touches government policies and legislation, students, and instructors (Almaiah, Al-Khasawneh, & Althunibat, 2020).

5. Conclusion

This study has reviewed the literature pertaining to the organizational effective factors in the adoption of e-learning. The results indicate that organizational factors are the backbone of comprehensive e-learning adoption in universities and institutions. The findings also show that Unified Theory of Acceptance Model (UTAUT) is the most prevalent adoption theory, followed by Technology Acceptance Model (TAM).

This study clearly identified 20 effective organizational factors in the adoption of e-learning, which were classified into four themes: 1) institutional infrastructure and compatibility, 2) resources allocation, 3) organizational supporting and monitoring, and 4) motivation, innovation & change management. However, more studies are required to demonstrate a full scenario of successful adoption of e-learning. The results of this study help mangers and policy makers in successful implementation of e-learning, especially in developing countries.

Authors' contributions

Mohmmadhiwa Abdekhoda, contributed to the current study by acting as the corresponding author, supervisor and final reviewer of the manuscript.

Afsaneh Dehnad, as the counsellor of the research, gave technical advice during the research process.

Declarations

Ethics approval and consent to participate: different ethical aspects of the present research were approved by the Ethics Council of Tabriz University of Medical Sciences (IR.TBZMED.REC.XXX. XXXX).

Competing interests

The authors declare that there is no conflict of interest.

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Digital gender divide and adoption of open educational resources

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Abstract

This study aimed to understand the differences in the perception of male and female students in adopting Open Educational Resources based on the Technology Acceptance Model. A quantitative survey method was adopted to collect data from 322 students enrolled in a private university in Karnataka, India. Except for registering and enrolling on OER sites, the study did not find any digital gender differences in terms of usefulness, ease of use, and behavioral intention in adopting OERs among students.

KEYWORDS: Online Educational Resources; Digital Gender Divide, Technology Acceptance Model; Usefulness, Ease of Use, Behavioral Intention.

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1. Introduction

The world has changed since the COVID-19 pandemic spread its tentacles in 2020. Like all other industries, the education sector was also impacted; however, it managed to stay afloat by transitioning to the online platform to conduct classes. This transition necessitated the preparation of online learning materials. To overcome the time, effort and expertise needed to prepare these materials, educational institutions are increasingly adopting Open Educational Resources (OERs) that are readily available on national and international repositories (Huang et al., 2020). Besides being cost-effective and open-licensed, OERs offer additional benefits in the accuracy of the information, time efficiency and ease of use (Hilton, 2016). The COVID-19 pandemic accelerated online media adoption prompting a 500 per cent increase in telehealth consultations, with e-retail reaching 95 per cent of Indian districts and digital payments surpassing 100 million daily transactions. Interestingly, it also triggered another phenomenon: the emergence of digital differences between males and females (USAID, 2020). This necessitates researching how different genders respond to such a digital gap while accessing and adopting OERs in higher education. Identifying such factors would shed light on the enhancers and barriers to adopting online modes of teaching and learning. Such findings would be of use to academia and practitioners, enabling them to effectively leverage both the offline and the online teaching methods to their advantage and provide students with an enhanced learning experience. Accordingly, this study examines the possible digital gender divide that exists in the adoption of OERs taking into consideration a sample of students from one of the private higher educational institutes in Karnataka, India. For the operational purpose, this study defines the digital gender divide as "gender biases coded into technology products, technology sector, and digital skills education" (West et al., 2019).

Meanwhile, a report by OECD (2018) stresses the need to close the gender digital gap in the Asia-Pacific Economic Cooperation (APEC) context. The report finds that women use technology less often than men in many APEC economies. Other factors contributing to the digital gender gap are affordability, negative

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experiences, and lack of skills. There is evidence in the literature to support the existence of digital inequalities, which are probably growing with the evolution of digital media (OECD, 2018). Thus, more research is required in order to fully comprehend digital inequalities in specific contexts (Hilton, 2016). Additionally, it is found that women/girls tend to have lower levels of literacy and computer abilities than their male counterparts. To achieve greater gender inclusion, it is necessary to improve digital literacy and confidence (OECD, 2018). Within the Asia-Pacific region, India has had the largest gender difference in internet usage in recent years with a 40.4 percent gender imbalance, with only 15 percent of women being able to access the internet compared to 25 percent of men. Thus, based on this background, this study intends to answer the following questions:

1. Does digital gender divide exist with regards to the usefulness of OERs?
2. Does digital gender divide exist with regards to the ease of use of OERs?
3. Does digital gender divide exist with regards to the behavioral intention towards adopting OERs?

The term Open Educational Resources (OER) was first used at UNESCOs' forum on "the impact of open courseware for higher education in developing countries" in 2002. According to UNESCO, "OERs are teaching, learning or research materials that are in the public domain or released with intellectual property licenses that facilitate the free use, adaptation and distribution of resources" (UNESCO, 2021). OERs include learning and teaching content, software, videos, tutorial, programs, etc. They offer several advantages. For example, they increase the opportunities for interaction between instructors and learners; facilitate personalized form of learning; ensure openness and accessibility of education to all; allow the dissemination of academic and educational content free of cost; improve the quality of educational content; and reduce the significant time for both learners and educators (Sharov et al., 2021).

One of the initial studies on OER in the Indian context dates back to 2009 in which Manisha and Bandyopadhyay (Manisha and Bandyopadhyay, 2009) emphasized that the availability of OER to a larger and broader audience could play a pivotal role in transforming the education system. This view has been consistently supported by several researchers (Das, 2011; Kumar and Singh, 2019; Midha and Kumar, 2021). However, it is also stressed that OER adoption in India could be a success only when the challenges and the barriers to adoption are addressed. Similarly, Upneja (2020) in their study have highlighted the various benefits of adopting OERs and also the challenges that could hinder their widespread use and effectiveness.

Research interest in OERs has gained momentum since the worldwide COVID 19 outburst in 2020. Though, literature is rich on the adoption, effectiveness, and efficiency of the online education model, it is argued that at institute levels, there is a lack of guidelines on the design and development of the OERs, which could possibly hinder their quality and minimize the benefits they are intended to provide (Upneja, 2020). This view is supported by other researchers (Maharaj, Upadhyay & Trivadi, 2021; Midha & Kumar, 2021) who expressed their concerns regarding the lack of awareness of their access and applicability. Users also found difficulty in customizing OERs (Singh & Ram, 2022). Thus, it is necessary for the educational institutes to advocate the use of OERs through their library website and maximize their outreach, especially when there is a switch between offline and online modes of education due to the prevailing COVID 19 scenario.

Researchers at Delhi University studied the influence of OERs on students and found that they were all familiar with the OERs and found them simple to locate on the university website (Manju & Bhatt, 2021). Additional advantages of OERs were highlighted as user-friendliness, the availability of resources in diverse formats, and supplements to course content and their utility. In addition, those who took part in this survey said that OERs improved their ability to learn on their own and discover new areas of study. Extensive studies have been conducted on the subject, for example, the long-term benefits of OERs in education (Das, 2011), their opportunities and challenges (Dutta, 2016), the decentralized and distributed framework for OERs, OER initiatives (Tang, Lin & Qian, 2021), teachers' attitudes toward sharing and distributing OERs, and the effect of OERs on educational practice (Manju & Bhatt, 2021).

Meantime, the COVID-19 pandemic has stimulated research on OERs. A study on the acceptance of OERs among K-12 teachers using a mixed-method approach (Tang, Lin & Qian, 2020) revealed that open educational practices increased teachers' perceived ease of use and self-efficacy towards the adoption of OERs. Open educational practice is a "broad descriptor of practices that include the creation, use, and reuse of open educational resources (OER) and open pedagogies and open sharing of teaching practices" (Banzato, 2012). A study conducted in Hong Kong to investigate the perceived usefulness of OERs after the rapid switch over to emergency found that students' perceived usefulness of OER increased significantly with regards to open online courses, online tutorials, and e-books (Cheung, 2021). While studies on OERs focus on the impact and effectiveness, utilization, awareness, and barriers to adoption (Midha & Kumar, 2022), no studies have been conducted on the possible gender digital gap that affected the adoption of OERs during the COVID 19 pandemic.

The role of gender in the context of computer-related attitude has been studied (Sieverding & Koch, 2009), and it is found that male students are more confident about their abilities to access them than females (Vekiri

& Chronaki, 2008). A similar pattern is found across different age groups and cultures (Colley & Comber, 2003; Imhof, Vollmeyer & Beierlein, 2007). However, the research on gender and its impact on technology acceptance is inconclusive in its findings. While a few studies suggest that gender does not affect computer ability (Houle, 1996), few other studies found that men and women differ in terms of their attitude towards computer ability (Jennings & Onwuegbuzie, 2001). Additionally, some recent research indicates that the gender divide is shrinking in the field of information technology, particularly in terms of basic connectivity or access to the internet (Hargittai & Shafer, 2006). To account for the contradictory findings in this area, the current study examines the probable digital gender gap in the use of OERs. To achieve this objective, the current study adopts the technology acceptance model as a theoretical framework.

Technology acceptance model

The technology acceptance model (TAM) is an information systems theory that models the adoption of technology by the users. The main focus of this model is on the user's behavioral intention in adopting any technology (Davis, 1989). According to this model, when users are presented with a new technology, several factors influence their behavioral intention to adopt, notably perceived usefulness and ease of use.

Perceived usefulness (PU)

Perceived usefulness, defined as asubjective perception of users where they believe that using certain technologies can improve their work performance (Davis, 1989), is one of the fundamental constructs of the TAM. Researchers in the past have investigated the users' perception of the usefulness of OERs for learning purposes (Cheung, 2018; 2019). The findings of these studies revealed that OERs were perceived as useful by teachers and students. However, considering the different abilities of male and female students, none of these studies have explored the possible difference in the perception between the male and female students. Therefore, considering this gap, this study investigates the difference between the perceptions of the male and female students with regards to the usefulness of OER. Thus, the following hypotheses are framed for the different dimensions of PU.

Hypothesis 1a: Perceptions of male and female students differ regarding the usefulness of OER on their academic productivity

Hypothesis 1b: Perceptions of male and female students differ on the usefulness of OER in reducing the cost of education

Hypothesis 1c: Perceptions of male and female students differ on the usefulness of OER in improving their learning outcomes

Hypothesis 1d: Perceptions of male and female students differ on the useful of OER as additional educational materials

Perceived ease of use (PEOU)

Perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort" (Ortinau et al., 1989). Perceived ease refers to how easy it is to access a technology system. The challenges with regards to technology adoption can be overcome if the technology is user-friendly. While extant research has investigated the effect of PEOU as a single dimension (Nazari & Abdekhoda, 2021), no study has investigated the different dimensions of PEOU and their impact across gender. Therefore, the current study investigates the impact of the five dimensions of PEOU across gender. These dimensions are registration, enrolling, language, availability, and usage.

Thus, based on these assumptions, the following hypotheses are proposed.

Hypothesis 2a: There is a difference in the perception of male and female students with regard to the ease of registration

Hypothesis 2b: There is a difference in the perception of male and female students with regard to the ease of enrolling on OER sites

Hypothesis 2c: There is a difference in the perception of male and female students with regard to the ease of understanding the language in which the content is presented.

Hypothesis 2d: There is a difference between the perception of male and female students with regard to the availability of the OER relevant to their studies.

Hypothesis 2e: There is a difference in the perception of male and female students with regard to the ease of using OER sites.

Behavioral intention (BI)

Behavioral intention refers to the motivational factors that influence a given behavior (Ajzen, 1987). If users have stronger intentions, it is more likely the behavior will be performed. It is also believed that gender plays a crucial role in affecting an individual's BI (Fakhrudin, Karyanto & Ramli, 2018). The disparity in the mindset and beliefs of men and women result in disparities in the values underlying BI. These distinctions are the product of cultural trends and biological variables. Thus, it is safe to assume that the gender effect on behavioral attention may have a strong correlation with an individual's BI.

Thus, the following hypotheses are postulated.

Hypothesis 3a: There is a difference in the perception of male and female students regarding the intention to use OERs in the future.

Hypothesis 3b: There is a difference in the perception of male and female students about the intention to continue to use OER

Hypothesis 3c: There is a difference in the perception of male and female students about the intention to use more OERs related to their learning

Hypothesis 3d: There is a difference in the perception of male and female students regarding the intention to recommend OER to their peers.

2. Materials and Methods

2.1 Background

This study adopts a descriptive survey research design because it is ideal to gain an in-depth understanding of the subject under discussion. Additionally, this method is less expensive and easy to conduct. The context of the study is a private university in Karnataka, India namely, Manipal Academy of Higher Education (MAHE). MAHE is a globally engaged institution with active partnership with more than 220 leading universities around the globe. It offers more than 350 programs across 30 disciplines and ranks 7th among Indian universities.

2.2 Measuring instrument

To capture and measure the constructs of OERs, this study used a structured questionnaire comprising of two parts. The first part had 14 statements on three dimensions of TAM. Perceived usefulness (PU) was measured using five items. The second dimension, perceived ease of use, was measured using five items. The third dimension, behavioral intention, was measured using four items – all these fourteen items were measured using a 5-point Likert scale. These items were adopted from previous studies (Mallya & Lakshminarayanan, 2017; Mallya, Lakshminarayanan & Payini, 2019). The respondents were asked to rate their agreement or disagreement on a 5-point Likert scale with 1 being strongly disagree and 5 strongly agree. The second part of the questionnaire had questions on the respondents' demographic details. The questionnaire was designed in Microsoft Form and emailed to students. Before emailing the questionnaire, the respondents were briefed about the objectives of the study. A total of 322 responses were received. The data collected using Microsoft Form was then imported to SPSS for further analysis.

2.3 Data collection

The data for this study was collected using Microsoft Forms. Before collecting the data, one of the authors explained the objectives of the study to the students and briefed them about the different types of OERs. They were asked to rate the ease of use and usefulness of the OERs. Some of the examples of OERs included: Swayam, Coursera, National digital library of India, NPTEL, PubMed, etc. After the briefing, the respondents were emailed the online form. The respondents belonged to the main three streams of disciplines: Health sciences, technical, and management. The health science respondents were students from the master's degree of Dietetics and Applied Nutrition. The technical stream included students from engineering studies (for example, BE, BTech etc.). The respondents from the management streams were from BHM (Bachelor in Hotel management).

3. Results

3.1 Sample characteristics

The participants' demographic characteristics included gender, education, age, and program of study. The total number of participants were 322. Out of these, 179 (55.6%) were males and 143 (44.4%) were females. Regarding their educational background, many of them were undergraduates (n = 258, 80.1%). The average age of the respondents was 20.5 years (SD=2.5). An almost equal number of respondents were from health science (n=106, 32.9%), technical (n=106, 32.9%), and Management discipline (n=110, 34.2%).

3.2 Hypothesis testing

Research question 1: Does gender divide exist about the usefulness of OERs?

An independent sample t-test was conducted to identify whether a significant difference existed between male and female students across the five different dimensions of perceived usefulness. The results pointed to no significant difference (Table 1). Therefore, hypotheses 1a to 1e were rejected. The possible reason for the non-significance difference in the usefulness of OERs could be the narrowing of the gender gap in terms of internet self-efficacy. However, the statistical mean was higher for females with respect to academic productivity, usefulness, and effectiveness. In the meantime, the statistical mean was higher for male students regarding the cost of education and access to more educational materials. In other words, female students perceived OERs as more effective, useful, and productive than male students. Similarly, in comparison to the female students, the male students felt the OER provided access to more educational materials and reduced the cost of the education.

Research question 2. Does a gender divide exist regarding the ease of use of OERs?

An independent sample t-test conducted to understand the possible difference in the perception of male and female students suggests that there was a significant difference in the perception of two dimensions of PEOU, namely, registration and enrolling on the OERs sites. Female students found it more difficult to register and enroll on the OER sites when compared to the male students. The perception mean for registration was higher for men (Mean=3.96, SD=0.64) than women (Mean=.75, SD=0.851) at the p<0.022 level. Similarly, the perception means of enrollment was also higher for male students (mean= 4.04, SD=0.721) than female students (Mean=3.85, SD=0721) at the p<0.017 level. Therefore, as postulated by hypotheses (H2a and H2b), there was a significant difference between male and female students with regard to the acceptance of their registration and enrollment. However, hypotheses H2c to H2e did not find any support and were, thus, rejected.

Research question 3. Does gender divide exist about the behavioral intention towards OERs?
Further, the independent sample t-test was conducted to examine the behavioral intention of respondents across gender. The results revealed that gender did not impact the behavioral intention towards the OERs. However, female respondents had slightly higher statistical mean on all the variables of behavioral intention.

Table 1 - Details of hypotheses testing concerning the research question 1.

Hypotheses	Perceived usefulness	Gender	Mean	SD	Sig.
H1a	OER increases my academic productivity	Male	3.78	0.98	0.21
		Female	3.9	0.76	
H1b	OER saves my cost on education	Male	3.98	1.07	0.14
		Female	3.82	0.89	
H1c	OER content is useful for my academic work	Male	3.98	0.89	0.25
		Female	4.08	0.59	
H1d	OER enhances my effectiveness in learning	Male	3.66	1.05	0.10
		Female	3.83	0.70	
H1e	OER provides access to more educational materials	Male	4.12	0.87	0.44
		Female	3.62	1.05	

*Significant at the 0.05 level

Table 2 - Details of hypotheses testing concerning the research question 2.

Hypotheses	Perceived ease of use	Gender	Mean	SD	Sig
H2a	Registering on OER sites is easy	Male	3.96	0.76	0.02*
		Female	3.75	0.85	
H2b	Enrolling for OER is easy	Male	4.04	0.67	0.02*
		Female	3.85	0.72	
H2c	The language used in OER is easily understandable and clear	Male	3.97	0.78	0.61
		Female	3.92	0.71	
H2d	I get what I look for in OER	Male	3.68	0.82	0.17
		Female	3.55	0.76	
H2e	OERs are student-friendly	Male	3.85	0.78	0.33
		Female	3.71	0.80	

*Significant at the 0.05 level

Table 3 - Details of hypotheses testing concerning the research question 3.

Hypotheses	Attitude	Gender	Mean	SD	Sig
H3a	I intend to use OER in the future whenever possible	Male	3.82	0.93	0.73
		Female	3.85	0.67	
H3b	I intend to continue to use OERs for all my learning purposes	Male	3.44	1.00	0.84
		Female	3.46	0.79	
H3c	I intend to enroll for more OERs available for my learning	Male	3.67	0.90	0.81
		Female	3.69	0.65	
H3d	I would recommend OER to someone who seeks my advice	Male	3.83	0.95	0.84
		Female	3.85	0.74	

*Significant at the 0.05 level

4. Discussion and Conclusions

The gender digital divide is the gap between males' and females' ability to access and use digital technologies. It impacts gender equality because it limits women's opportunities for education and financial independence. While few reports suggest the digital gender divide has narrowed (Facts and Figures, 2021), growing evidence suggests a digital divide between males and females still exists with regard to technology acceptance (Acilar & Sæbø, 2021).
India too has been battling with a widening digital gap for some time. Restrictions enforced in the private and public spaces have been extended to the digital world for young and adolescent females (Global GLOW Team, 2021). Gender norms, which are still rooted in patriarchal nations like India, frequently limit and hinder women's equitable access to technology, particularly those from underprivileged and resource-poor families (Global GLOW Team, 2021). Due to this, females are likely to have poor digital literacy rates, remain unfamiliar with digital technologies and have uneven access to digital or electronic devices. According to the report, Indian females are 56 percent less likely than males to utilize mobile internet. Only 35 percent of active users of Internet in India are females (GSMA Connected Women, 2019).
Against this backdrop, this study sought to explore the differences in how male and female students perceive the adoption of Open Educational Resources (OER) through the lens of the Technology Acceptance Model. The uses the three dimensions of TAM: Perceived usefulness, PEOU, and behavioral intention. Employing a quantitative survey methodology, data was gathered from 322 students attending a private university in Karnataka, India. An Independent t-test was used to analyze the differences in the perception of male and female students.

The results pointed to no significant difference across five sub-dimensions of perceived usefulness. However, regarding the PEOU, the t-test results suggest a significant difference in the perception of two dimensions of PEOU, namely, registration and enrolling on the OERs sites. Female students, according to the findings, encounter greater difficulty in registering and enrolling on OER sites compared to their male counterparts. This difference signals potential issues in the user experience design of these platforms, highlighting the importance of investigating the accessibility and user-friendly aspects of registration and enrollment processes. This finding is in line with (Saha & OhidurZaman, 2017) which reveals that there is a significant gender gap in the ability to use information and communication technology (ICT). Male participants are more efficient in using ICT than female participants.

Moreover, the observed gender difference may stem from broader societal attitudes toward technology use and the need for targeted interventions and support mechanisms. Educators and platform designers should take these findings into account to ensure an inclusive learning environment that accommodates diverse user needs, fostering equal access to online educational resources for all students. Further qualitative research is warranted to gain deeper insights into the specific challenges faced by female students in these processes. Further, the t-test results indicating a lack of significant difference in Perceived Ease of Use (PEOU) and behavioral intention between male and female participants suggest a promising scenario of gender equality in technology adoption. This implies that both genders perceive the ease of using the technology similarly and express comparable intentions to engage with it. Such uniformity in user perceptions is encouraging for technology developers, highlighting the potential for universally positive and user-friendly designs that cater to a diverse user base. While these findings are specific to PEOU and behavioral intention, it is crucial to acknowledge that other contextual factors may still play a role, necessitating continued exploration.

The absence of statistical significance in the t-test results for PEOU and behavioral intention between male and female students could be attributed to various factors. Potential factors include limited sample size, high variability within groups, the sensitivity of measurement tools, the homogeneity of participant characteristics, and the possibility that, in the specific context, there genuinely are no significant differences. This underscores the importance of considering study design nuances, sample characteristics, and measurement precision when interpreting results while also signaling the need for further investigation to elucidate the complexities of gender dynamics in technology acceptance and intention in OER adoption.

The non-significant difference across other variables could also be attributed to the fact that the respondents for this study were from the urban areas. Therefore, we recommend a similar study should be conducted using respondents from the rural areas of India.

Interestingly, a recent study conducted by Coursera (Chakrabarthy, 2022) indicates a narrowing gender gap in online learning in India. India ranks second worldwide for the highest number of women learners on Coursera. According to this study, Indian women are acquiring STEM subjects at one of the world's quickest rates. The same report also reveals that the overall course enrollments of women in India increased from 26% in 2019 to 36% in 2021, owing to the Covid-19 pandemic and a push toward online upskilling courses aided by a number of online learning websites. Owing to this rapid increase in the number of women upskilling themselves, governments, corporations, and higher education institutions must address the existing gender gaps in education so that the competent female workforce may participate seamlessly in economic activities (Chowdhury and Chakraborty, 2017). Further, the recent digital infrastructure boost promised by Government of India is likely to push up the number of online women learners even more in the future from the text and communicate clearly your most significant results.

However, a systematic review conducted to understand the gender digital divide suggests that despite a notable surge in global internet and ICT usage, women, particularly in developing nations, often find themselves on the disadvantaged side of the digital divide. Although gender disparities persist in ICT access within developing countries, more pronounced concerns about second-level digital divide issues emerge in developed nations. The authors emphasized that there is a need for actionable policies to bridge this gap. Additionally, the review identifies the significant influence of sociocultural factors in explaining the gender digital divide phenomenon (Acilar & Sæbø, 2021). In conclusion, there is a pressing need for the implementation of effective policies to address these disparities and an acknowledgment of the role sociocultural dynamics play in shaping the digital divide along gender lines.

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A methodology to design immersive Virtual Reality experiences for foreign language pronunciation training

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Abstract

Applications of immersive virtual reality (iVR) for language learning are on the rise due to enhanced interaction possibilities with virtual agents and objects. However, iVR environments for language learning are not yet supporting speech recognition, hence limiting the potential to use iVR for fostering users' pronunciation training. This is due to a lack of methodological guidelines helping education professionals to create iVR environments effectively supporting speech recognition and pronunciation feedback. Moreover, no matter how close to reality iVR settings are designed to be, users may miss the correspondence between virtuality and reality due to design issues and lack of realistic input, with detrimental effects on enabling users to transfer iVR-acquired language skills to real-life interactions. Attempting to address these gaps, this study examines the methodology adopted by a group of researchers at the AP University of Applied Sciences and Arts in Antwerp to design an iVR experience for learning the pronunciation of Flemish words. Following a participatory design approach, an iVR prototype was planned and designed with the game engine Unity and targeted to prospective international students at the University of Antwerp. Findings from user trials revealed that virtual agents' timed feedback, environmental real-likeness and users' involvement in completing linguistic challenges were considered to be essential tenets for fostering iVR-based pronunciation training. Additionally, results suggested that further developments are needed to develop a technology for speech recognition in iVR environments that foster students' pronunciation skills and cultural exposure through pre-reality language training.

KEYWORDS: Immersive Virtual Reality, Language Learning, Pronunciation Training, Spatial Affordances, Participatory Design.

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1. Introduction

Recent technological developments in language education have fostered advancements in the design of immersive and participatory learning experiences allowing students to interact with one another and their virtual surroundings. One type of technology which has received a lot of attention from scholars and instructional designers is immersive Virtual Reality (iVR), a three-dimensional digital space where users interact in a naturalistic fashion and which becomes their only perceivable reality (Eichenberg, 2012). Consequently, a rising number of iVR applications for language learning have appeared, targeting any schooling level and implying steadfast changes in teachers' roles as instructional designers who use technology to create experientially-rich and multisensorial language learning experiences (World Economic Forum, 2020). However, this process has also evidenced the inefficiency of in-person only instruction for boosting digital literacy, which is vital for the development of the necessary skills to professionally and socially interact in an increasingly digital world (European Commission, 2022). However, while the use of iVR in language education is encouraged, many teachers lack the necessary training to use this type of technology for designing language learning experiences.

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Moreover, while iVR language learning applications generally focus on hands-on experiences with virtual objects and avatar interactions, there is little evidence of existing iVR applications with embedded speech recognition features enabling live feedback on users' oral input. Recent developments in the field of Artificial Intelligence (AI) have opened new horizon for researching virtual speech recognition. In fact, VR companies have used AI-powered agents to provide real-time linguistic feedback to avatar-embodying users. These are pre-trained agents ready to respond to a limited set of questions sourcing information from AI platforms (WondaVR, 2023; Immerse 2023). The growing interest of companies to invite users to enhance VR experiences by programming virtual agents to recognize real-time linguistic feedback using AI powered tools highlight a major limitation of these technologies in terms of personalization of linguistic feedback. In fact, these agents are likely to provide a limited set of linguistic answers devoid of empathetic and realistic feedback which are likely to negatively affect the linguistic performance of application users. Moreover, AI speech may present limitations related to sound quality and type of conversational speech originating from written prompts (Mitsui et al., 2021). Therefore, there is a gap in the literature that needs to be addressed; as stated by Kumar Jang Bahadur (2022), providing effective solutions for iVR-based speech recognition may contribute to improve iVR design. However, guidelines are missing on the practices and training required to create pedagogically-effective language learning activities with iVR (Cook et al, 2019; Holly et al., 2021). This forces most teachers to rely on free web-based resources that lack immersive features and customizability. Moreover, from the perspective of designing effective pronunciation training experiences, language learning in iVVR must support motivation and engagement within culturally significant environments (Scovel, 1994), hence the need of incorporating these parameters into virtual platforms. This paper presents a methodology for designing iVR-based language learning experiences supporting pronunciation training in iVR and provides indications on the virtual environmental affordances needed to foster linguistic output. The two research questions that this paper addressed are:

- Which design practices can be applied by teachers to create language learning experiences for pronunciation training with iVR?
- Which environmental affordances can best support pronunciation training in iVR?

In an attempt to answer these queries, this paper illustrates the approach adopted by a group of researchers at the AP University of Applied Sciences and Arts in Antwerp (Belgium) to design a prototype of an iVR application for learning to pronounce basic Flemish words. The prototype was devised for prospective international students of the University of Antwerp. By following a participatory design methodology (Spinuzzi, 2005), researchers reviewed current gaps in the literature of iVR-based language learning design and pedagogy, and identified a profile of potential users. Subsequently, they planned the iVR prototype through story-making, spatial design, audio editing and user flow analysis. To design the iVR prototype, the researchers used the game engine Unity and subsequently tested the prototype on 8 participants who provided their feedback on usability and pronunciation training efficacy. Overall, this paper provides suggestions to structure language learning environments to support pronunciation training and highlights potential future developments in creating immersive language learning activities for speech recognition and pronunciation training. It is hoped that this research may also encourage language teachers to foster their instructional design skills with iVR to create interactive and socially immersive language learning activities.

2. Methods and Results

2.1 Prototype development

The study was planned as a pilot for the creation of iVR experiences incorporating real-time speech recognition using authentic people's speech. To plan and create the iVR experience, 4 researchers attending the summer school in "Storytelling with Virtual Reality" at AP University of Applied Sciences and Arts in Antwerp followed the 3 phases of participatory design, which include exploration, discovery and prototyping in Table 1. The group was given 2 weeks to design the iVR prototype, comprising pre-design data collection, prototype planning and post-design validation. Researchers utilized the facilities of the Immersive Lab

PARTICIPATORY DESIGN

Exploration	Discovery	Prototyping
Investigation on user types and needs Context identification Strategy formulation	Ideate a storyline Envision and develop solutions to task challenges Choose and storyboard ideas	Prototype building for usability focus Validation through prototype trial to real users Identification of potential adjustments and future developments of the prototype

Table 1 - Participatory design utilized by the researchers for iVR planning and design.

of AP University of Applied Sciences and Arts to test the iVR experience with Meta Quest 2 headsets and computers equipped with Intel i9 10940x core processors and Nvidia RTX 3070 graphic processing units.

The first part of the study consisted in identifying potential prototype users as prospective international students at AP University of Applied Sciences and Arts. Course interests as well as the academic and social involvement of these users were identified as paramount factors influencing their selections. Therefore, the group decided to set the iVR experience in a realistic environment. Inspiration was taken from the recommendations given by a group of 20 university students on local bars, which were subsequently visited for ambience recording through photos and videos. The environment of a bar was chosen to add familiarity to the experiences as it constituted a familiar setting for students to meet future friends and classmates. A survey on the identification of existing gaps in iVR language learning applications led to acknowledge a lack of speech recognition and live pronunciation feedback from a virtual agent in iVR environments. Further analysis also demonstrated a scant presence of phone-integrated iVR applications for the geo-localization of local bars and cultural landmarks of Antwerp. This process helped researchers to devise a phone-based application integrating pronunciation training with virtual representations of local bars in which users could collect virtual tokens redeemable as discounts through potential visits to the real bars portrayed in iVR. In terms of linguistic gains, users would benefit from a pronunciation training in Flemish provided by virtual agents whilst completing a series of challenges prompting them to utter words related to local food and landmarks. Once the above-mentioned exploration phase was completed, the group engaged in adopting a suitable methodology for designing the iVR prototype as a pronunciation-training experience.

2.2 The proposed method

In the discovery phase, researchers developed a methodology for designing effective learning experiences supporting iVR-based pronunciation training and speech recognition. This led the group to consider 4 planning aspects:

- Storytelling
- Immersion
- User flow
- Experience creation

Knowledge of storytelling principles was pivotal to create compelling iVR language learning experiences supporting pronunciation training since key aspects of user engagement, story immersion and willingness of continuous participation in iVR depend from it (Calvert & Abadia, 2020). For this reason, the researchers decided to opt for a linear narrative structure where events unfolded in a specific order following the interactional affordances of the iVR space. Once the storyline was completed, the experiences were planned considering the points of view of users entering the virtual space with VR headsets affording 6 Degrees of Freedom (6DOF) and enabling depth motion mapping (forward-backward, lateral-vertical).

To enhance empathy and emotional engagement, a second tenet of this method was identified as immersion in its strategic and narrative typologies. While the former happens in task-centered activities where individuals focus on goal achievement, the latter is the result of users' interest in the narrative dimension of immersive stories (Moeller, 2017; Visch et al., 2010). Therefore, both typologies are reliant on task design and user flow. Defined as the enjoyment resulting from balancing individual skills with challenges in task performance, user flow is contingent to the attainment of virtual goals with language and strategic skills (Brockmyer et al., 2009). For this reason, the researchers decided to have the iVR experience preceded by user training on headset use and content debriefing. The process followed for iVR design is outlined in Figure 1. The virtual experience was preceded by an explanation and tutorial phase where users were trained on the technology before emerging into real-life through an experiential reflection phase. Emersion was the last element to be considered within this methodology was emersion. Described as a "reawakening of human consciousness through recreational activities" (Chang 2021, p.26), emersion happens as users remove their headsets and return to real-life. To facilitate users' psychological adjustment to the virtual experiences and reflective practices on their virtual experience, the researchers decided to add post-iVR self-assessment phases on pronunciation skills and perceptual feedback. It was foreseen that these practices could help users to reconcile reality with virtuality and effectively reap the rewards of iVR exposure.

With language output being successfully triggered by social interactions, one of the main challenges of creating this iVR experience was ensuring that users' sense of immersion was maintained when interacting with virtual agents. In fact, due to time constraints of prototype design, the experience was not set as multiplayer. Therefore, it was decided to incorporate in the iVR experience humanoid characters reacting to user output to virtual agents' pronunciation prompts. In this way, interactional dynamics were maintained as real-like, enhancing immersion and user flow. Pedagogical considerations emerged when researchers integrated attainable and contextually-relevant tasks in the iVR experience ensuring the pronunciation accuracy of virtual agents interacting with real users. Following the guidelines of Saberi, Bernardet and DiPaola (2014) on fundamental parameters to facilitate users' feedback, virtual agents were designed with realistic attributes in order to be experientially well-received and avoid potential drawbacks related to the uncanny valley effect mentioned by Seyama and Nagayama (2017).

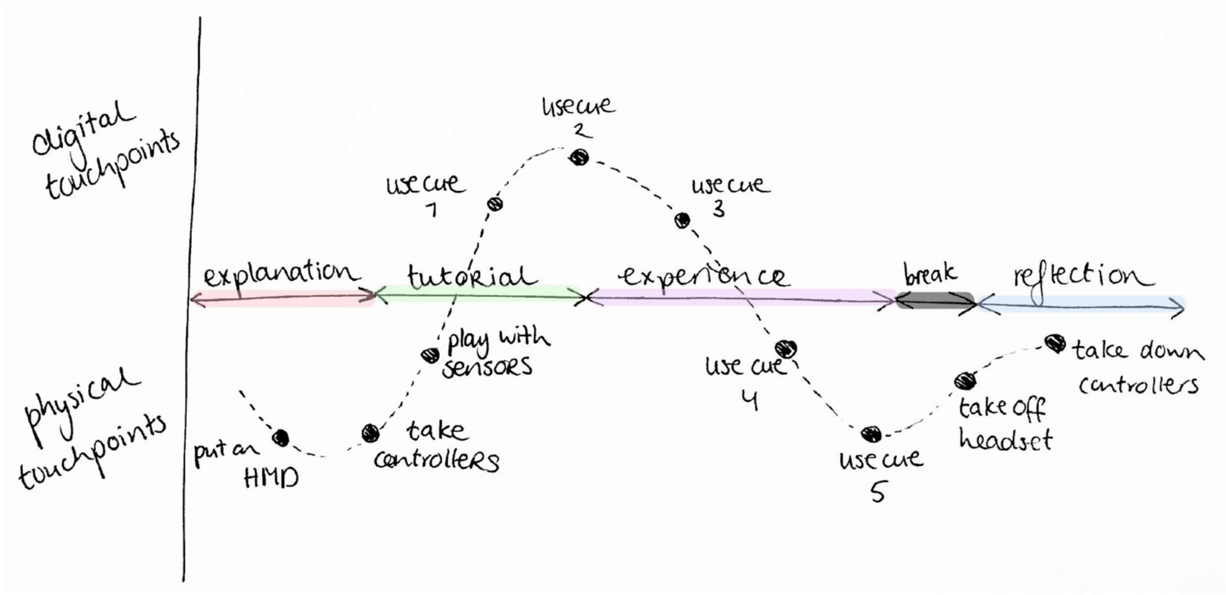

Figure 1 - User flow scheme followed by the research group in the proposed methodology.

Once the above-mentioned conditions were set, researchers proceeded to create the iVR prototype using the game engine Unity and virtual design applications.

2.3 The creation of iVR prototype

To create the iVR experience, researchers followed the participatory design outlined in Table 1. The prototype had to be activated on mobile phones, so that users could search for locations to visit on an app-integrated map. Upon selecting a location, users would be prompted to wear their Meta Quest 2 headsets before they were taken into the iVR experience.

Initially, the event sequence was planned using storytelling strategies such as reading out-loud the story script mimicking the potential movements required by users entering the virtual space. To encourage strategic immersion, the research group had to understand action feasibility in the iVR space and revise story flow, object location, interaction enactment and complexity as well as linguistic output. Guidelines for testing the above-mentioned parameters were taken from experimental research on screenplay writing in iVR (Luthy, 2017) and are outlined in Figure 2. In fact, in the planning phase, researchers utilized an A3 map mockup to reproduce the diagrams outlined in Figure 2. By placing user point of view at the axis intersection upon entering the iVR space, researchers could map user actions by locating objects, remove potential obstacles to virtual movements and perform gamified language challenges, which enabled the systematic planning of the virtual space and its affordances. Moreover, in order to ensure the native-likeness of word production, 2 native Flemish speakers (1 male and 1 female) were individually recorded whilst reciting a script in a quiet setting with a Zoom H2next recorder. An additional speaker was recorded while welcoming in English potential users in the virtual space. To increase resemblance to real-life ambience, sounds from the online database Freesound were incorporated in the experience together with background chatting and music. Audio files were then assembled with the software Audacity and inserted in the iVR space as monodirectional sounds coming from the virtual agents.

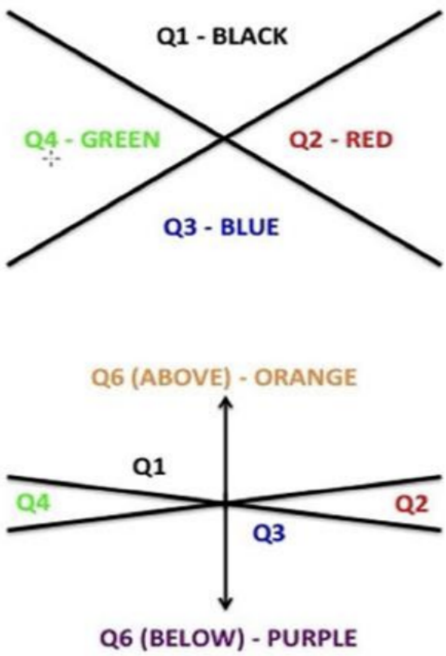

Figure 2 - Environmental mapping of iVR environments. The user point of view is considered to depart from the convergence of all lines. The first picture indicates forward-backward movements, the second lateral-vertical ones. Colors are used to identify spaces and their related affordances.

To implement user flow and enable its efficacy from pedagogical perspectives, the iVR experience was designed with the game engine Unity. Motion capture was recorded with the software Rokoko as one group member performed the actions of virtual agents wearing a sensor-equipped suit, which were transferred on Mixamo for character automation and matched with the bodies of virtual characters. Data was subsequently transferred to the prototype on Unity as virtual representations of students and bar personnel. User movement was enabled through hand controllers instead of teleportation to enhance real-like actions. User point of view was placed slightly higher than agents' height to enable a full view of spatial affordances. Using features of timeline adjustment, audio files were linked to cubes delimiting the range of motion of virtual agents and sequentially timed to play sounds at specific moments in the story flow. After each utterance, a time lapse of 5 seconds was left for word repetition. It was decided that virtual agents should speak in English apart from the targeted Flemish words so that an international audience could understand instructions. Haptic feedback was provided through vibrations in hand controllers each time users gained a token. Environmental navigation was fostered by interactions with virtual agents which directed users to interactional areas. The setting was created by modifying a bar environment downloaded from Unity Asset Store according to the features of a real bar in Antwerp. Daytime sky for lighting and a rooftop were subsequently downloaded from the store. Collectable tokens were designed with the software Cinema 4D while texture was added through Unity. Researchers also raised vertices allowance so that users' ability to explore and move around the virtual space could run smoothly. Figure 3 provides an outline of the prototype creation on Unity. Each step of the design process was tested on an Meta Quest 2 device set in developer mode to enable quick troubleshooting.

2.4 The final prototype

The researchers named the iVR experience "The FlemishTerp Bar" and made it last for 5 minutes. Upon entering the virtual bar, Character 1 would welcome users and gesture towards the counter to meet Character 2. The first language task would consist of Character 2 inviting the user to pronounce the equivalent of "beer" in Flemish. After each utterance, a time lapse of 5 seconds would be left for word repetition. Then, a third character would be introduced in the form of a lady coming from behind the user. The character would be the first token repository; by pointing at the top of her head, a token would appear in the shape of a hand-shaped biscuit representing a local delicacy called Antwerpse handjes (Antwerp hands). The token appearance would be followed by a "ding" sound. The character would start gesturing towards a table, on top of which users would see three dishes containing French fries, mussels and croquettes. Upon pronouncing the words and collecting a second token, the user would go to a gaming area consisting of a dart board and four darts. Upon being prompted to throw the darts at the board by Character 3, the user would see appearing 2D pictures of four Antwerp landmarks after each hit. In the last part of the experience, the user would return to the entrance to meet Character 1 summing up the number of tokens gained in the experience and encouraging users to visit the bar in Antwerp to redeem their discounts.

A full version of the characters' script was provided:

Character 1: "Welcome to the FlemishTerp bar! To get your discount, you will need to perform language tasks. If you are successful, you will collect tokens in the shape of Antwerp hands. Follow the instructions that you will be given starting from the bar!"

Character 2: "Come over here! - In Flemish, we call this 'bier'. If you repeat it after me, you will get your first Antwerp hand which will be your first discount. Ok, let's start: 'bier'... 'bier'."

Character 3: "Sorry, I did not hear you well, let's pronounce it together 'bier... 'bier'. Cool, you'll manage anyway. Here is your first token. Come with me and let's have something to eat!"

Character 3: "Now let's move on to our dining area. We have unique local dishes here in Antwerp, try to repeat them after me:

- *"Frieten" ... "Frieten"*
- *"Mosselen" ... "Mosselen"*
- *"Kroketten" ... "Kroketten"*

Great job! here is your second hand token!"

Character 3: "Ok, let's move to the next area and play darts! Grab your dart and try to hit one of the Antwerp

Figure 3 - Layout of "The FlemishTerp Bar" on the game engine Unity.

locations on the board. Once you hit a location successfully, a picture of it will pop up with its name in Flemish. Then, you will get your hand token! You can play the game more than once."

- *Brabo fontein*
- *Onze-Lieve-Vrouwkathedraal*
- *Havengebouw*
- *Treinstation*

Well done! here is your third hand token!"
Character 1: "Congratulations! You have now collected 3 Antwerp hands. You can claim them once you visit us at the FlemishTerp! You can also collect additional discounts by spreading the word about us! See you next time!"

2.5 Post-design survey

After the product design was completed, usability testing was conducted on 8 participants who tried the iVR experience. Participants performed their experiential evaluation on a voluntary basis and belonged to a population of undergraduate and graduate students attending summer courses at the AP University of Applied Sciences and Arts. This small number of participants resulted from the experimental nature of the study and the limited time availability in the recruitment process. They were all experienced iVR users but had received none or very little exposure to Flemish. They used a Meta Quest 2 headset connected to a computer monitor via Airlink, so that researchers could see participants' activities on the iVR platform. Once the experience ended, participants provided written comments on their experience by answering the question: "Which feedback would you give to the creators of this experience in terms of its design, effectiveness of pronunciation training and future developments?". Answers were provided in Table 2 and listed according to feedback type.

2.6 Design challenges

Researchers initially debated on whether opting for immersing users in a 360° environment or in iVR. In fact, the former would have enabled users to increase cultural exposure while limiting environmental interactivity. Moreover, capturing 360° videos and photos of real environments would have required permissions to reproduce locations and customers in the virtual space. Therefore, researchers opted for iVR due to its customizable interactive affordances. Another challenge encountered by the researchers consisted in creating an iVR experience based on linguistic aspects and bars of the city of Antwerp as none of the researchers was Flemish or had been in the city long enough to know its pubs. Therefore, researchers sought the advice of local students on cultural aspects Antwerp and its pubs. In this way, researchers gathered information on local dishes, popular pubs and student societies. Not only this helped with iVR spatial planning but also contributed to the realism of the virtual environment, such as coat of arms of student societies and university logos hanging on bar walls. Researchers were challenged to develop a shared imagery of the virtual environment where the activities would be set. They also struggled to design pedagogically effective activities for pronunciation training. In fact, only one of the researchers had previous experience of language learning in iVR. This required researchers to constantly negotiate and clarify planning operations. The group was also faced with challenges related to the types of actions allowed in the virtual space, which was overcome by refining motion capture and simplify agents' script.

Audio design constituted an additional challenge in the design process as the researchers struggled to balance background chatter with timed language prompts from virtual agents. Furthermore, agents' speech was edited as a single string of sounds incorporating pauses to allow for user production, which implied accurate audio editing though the software Audacity. The resulting audio files were then inserted into Unity as positional cubes activated upon user proximity as users moved within the iVR space. To enable audio production, virtual agents had to be set as audio sources, which consequentially restricted aerial availability to hear pronunciation prompts. Through C-sharp scripting, four additional audio sources were placed in the environment to amplify virtual agents' sounds. However, delays were reported between virtual agents' sounds and body movements as there was a mismatch between their gestures and speech content. This required further adjustments in virtual agents' movements and sound in order not to affect users' sense of immersion.

3. Discussion

The methodology outlined in this study has highlighted design practices for creating pronunciation training experiences with iVR. In fact, by adopting a participatory design methodology, researchers crafted an iVR experience by accurately designing environmental affordances and planning pedagogically-informed language learning activities. In particular, the methodology outlined that environmental credibility, sound quality and task challenge successfully determined the pedagogic effectiveness of the iVR experience for pronunciation training purposes. These findings were consistent with the results of a user trial, which highlighted that pre-reality exposure to socially-relevant spaces can help international students prepare to live in foreign social contexts. In fact, iVR design and its interactional affordances were praised by the participants who tested the prototype functionalities and appreciated the real-life accuracy of its environmental features, stating that they contributed to enhance sense of presence (Table 1; b, c, d). Positive feedback was also given to awarding pronunciation attempts with redeemable bar discounts (Table 2, a, d). Satisfactory comments were also provided on story flow as it facilitated spatial movement and prompted users to interact with virtual agents and the digital environment (Table 2, c, d). On the flip side, some participants were less positive about the richness of environmental details which distracted them from achieving activity goals. Motion sickness and viewpoint alteration were also cited as limiting experiential factors (Table 2; f). Others regretted not noticing when earning hand tokens and said they would have preferred to experience enhanced visual effects connected to their gains (Table 2, g). However, since positive comments were given to the experience outweigh the negatives, confirming the effectiveness of a participatory design methodology for creating an iVR environment supporting pronunciation training. In fact, participants highlighted that the culturally-rich immersive atmosphere of the experience fostered their motivation, engagement, curiosity and interest in the Flemish language, with benefits for their pronunciation skills (Table 2, i, l, m).

<table>
<tr><th>Design</th><th>Language learning experience</th></tr>
<tr><td rowspan="3">a. “From my experience, the storytelling, the 3D model environment settings are very elegant in this game, which really gave me the feeling of walking into a local pub. The idea of creating some game rounds to get discount was also brilliant, which made me feel immersed in this process and excited to see what would happen next.”
b. “I have no remarks about the design of the VR environment as it was pretty well depicted and cozy enough for its purpose. I have to highlight the sound work, which was magnificent regarding 3D forms and binaural features. It immensely helped the orientation in the VR space.”
c. “During the experience the first thing that caught my attention was a nicely made environment with well-devised interactions and avatars. I didn’t have any issues with understanding the experience and the order of the actions to perform. The idea itself I really liked, mostly the fact that the place was inspired by a real bar that users could visit during their stay in Antwerp.”
d. “Notion of space was interesting, with perceivable scene references to the Dutch culture. The atmosphere facilitated my sense of presence and spatial movements. Sound cues were seamlessly distributed to enable the exploration of the environment. Directional cues were easy to follow and I was engaged in trying to pronounce words. Since I was testing a low-fidelity prototype my expectations were not high, but the story flow worked to maintain me engaged until the end of the experience. I think this engagement and sense of presence associated with the actual contact with words in another language really support the language learning process.”
e. “I did admire the whole experience, and I was honestly astonished at what a team of experts from different backgrounds who have never met before can achieve in only a couple of days. And I am sincerely curious about what further development of this VR experience could be.”
f. “The only issue I had was feeling motion sickness during movement in the environment that disturbed the experience itself. My avatar was also placed in a lower position than it should have, which made me feel that ⅓ of my body was below the floor. It caused me to miss the intended purpose.”
g. “At some point I felt disconnected from the first activity because I could not notice what I earned in it. I was also expecting some visual effects expressing my success in the activity.”
h. “I regret that the challenge of playing darts in VR was a bit clumsy, because none of my darts actually reached the target.”</td><td>i. “After experiencing the Flemish bar in VR, I felt it was a very productive and interactive tool to learn a language. I was able to learn basic words that were taught to me there. It also came with the benefit of collecting rewards that can be utilised in a real bar setting. As a prototype, the experience was well made.”
l. “I had a nice and interesting experience visiting the Flemish bar, I learned how to pronounce one of the Flemish signature dishes and later on I played a game of darts. An immersive experience!”
m. “With “The Flemishterp Bar”, I experienced a unique, engaging as well as impactful way to learn Flemish. This immersive experience demonstrated that using virtual reality for educational purposes is efficient, and very promising!”</td></tr>
<tr><th>Suggestions for prototype development</th></tr>
<tr><td>n. “I can imagine with speech recognition technology, this iVR experience can do wonders.”
o. “Maybe the iVR prototype could be a good marketing experience for other places? If so, I believe that this VR experience could be used as a marketing tool for places wanting to be more recognizable for tourists and even local people, and not only as a way to learn a new language!”
p. “I think the graphical part of the language could also be explored further. Since I was saying a new word it would help me if I could see the written word and maybe the syllabic structure of it.”</td></tr>
</table>

Table 2 - Participants’ responses after iVR prototype testing.

Looking at potential future developments of this iVR experience, participants suggested increasing the number of visitable locations in order to promote local businesses and cultural amenities (Table 2; n, o). This entails that iVR experiences of this kind could enhance the quality of international students' academic and social lives, serving both as a learning and a promotional tool for local bars and cultural amenities. Furthermore, students hinted at further developments in speech recognition technology so that users could receive immediate feedback on their performance and improve language parsing (Table 2; n, p). This confirms the necessity to expand current research on pronunciation training in iVR by fostering real-time pronunciation feedback from agents and environmental affordances.

4. Limitations

Significant limitations of this study consisted in a lack of available technologies needed to incorporate iVR-based speech recognition and pronunciation training. Although this was partly compensated by timing virtual agents' responses to potential real-user feedback and environmental interactions, it highlighted that future investigations in iVR-based pronunciation training should consider a wide range of speech-recognition technologies for integration assessment. It is believed that joint efforts between instructional designers and technologists may help to develop interactionally effective language applications for speech recognition. Moreover, out of the 4 researchers who designed this experience, only one was an expert in language pedagogy, while just another had enough knowledge of Unity to design iVR components. A bigger research team with at least two highly skilled members per discipline might have widened the range of available iVR environments, added higher interactional and linguistic complexity to the experience once planified. The number of evaluators would have need to be expanded. As part of the evaluation process, these people would be requested to express their judgement in terms of acceptance, sense of presence, usability and comfort, using reference systems such as the Technology Acceptance Model of Davis (1989), Brooke (1995) and of Witmer et al. (1998). Lastly, time constraints significantly limited the team's possibilities to refine interactional and environmental details, which could have been avoided with a wider time availability to complete the experience. Further application development needs to be conducted within premises granting the availability of cutting-edge iVR tools and computers enabling effective design and testing.

5. Conclusions

This study has attempted to outline the design practices needed by language teachers to create an iVR prototype enhancing the pronunciation skills of students interested in pursuing their studies in Antwerp. To meet this goal, the iVR experience was designed to immerse users into social and cultural aspects of the city of Antwerp while learning to pronounce basic Flemish words. By using Unity, 3D designs and audio files, iVR realism was enhanced through cultural aspects of local bars in Antwerp, a story line depicting possible social scenarios and authentic examples of Flemish vocabulary related to food, drinks and cultural landmarks. Although the technology to record and provide real-time feedback on user pronunciation was not available at the time of this study, the level of interactivity provided by the iVR experience successfully encouraged users to repeat words said by virtual agents with consequential praises for environmental immersion. In fact, results from a user testing demonstrated that virtual environmental affordances, interactional realism and situated practice successfully fostered pronunciation training in a foreign language through enhanced immersion and action stimulation. However, the study also highlighted that further investigations are needed to develop suitable technologies for real-time speech recognition in iVR required to improve students' pronunciation skills. Considerations of this kind would need to include virtual agents' appraisal of users' non-native accents and further pedagogic planning of language activities, as well as the deployment of AI. As this study was specifically centered on Flemish, voice recordings of native Antwerp people would increase the real-likeness and pedagogical impact of spoken feedback in the iVR environment.

To conclude, the creation of this language learning experience has evidenced how iVR can foster students' interest in learning the local language via iVR involvement. Due to this efficacy, it is believed that designing iVR language learning experiences should be integrated in teachers' training background. In this way, language teachers could be part of a community of instructional designers with diversified skills deployed to create iVR-based language learning experiences. This may enable teachers to customise iVR activities for curriculum development and encourage partnerships between universities and VR-equipped laboratories, which are necessary practices in light of the progressive incorporation of iVR technology in language education.

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Interpreting students' perception of the e-Learning environments: determining optimal Cut-off Points for the e-Learning Educational Atmosphere Measure (EEAM)

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Abstract

There is a need for institutions to evaluate their e-Learning educational atmosphere to improve students' learning experiences. The E-Learning Educational Atmosphere Measure (EEAM) is a comprehensive tool focusing on the students' perception of the e-Learning environment. To be able to verbally interpret the results of the measure for better comprehension and more effective and consistent usage, it is essential to establish clear cut-off scores. We aimed to determine the optimal cut-off points for the EEAM scores by plotting them as the ROC curves versus a single global rating question. The findings showed that while the range of the possible EEAM scores was 40 to 200, cut-off points of equal or below 127, between 127 to 152, and equal or above 152 indicated students' perception of the e-Learning atmosphere as "poor to weak", "moderate", and "good to excellent" respectively. The Area Under the Curve for scores that reflected the "poor to weak" state was 0.875 (p-value=0.000) with a sensitivity of 84.8% and a specificity of 70.0%. This area was 0.947 (p-value=0.000) for the "good to excellent" state with a sensitivity of 100% and a specificity of 82.1%. Our findings are useful in studying, evaluating, and monitoring the e-Learning educational atmosphere of institutions or comparing the results of multiple settings.

KEYWORDS: e-Learning, Educational Atmosphere, Educational Environment.

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1. Introduction

E-Learning has been deployed by many higher education institutions for many years and the number of universities with clear strategies or policies for implementing e-Learning, its strategic utilization, and its uptake in regular teaching contexts has been rising (Gaebel et al., 2018). Although this trend began years ago, the recent disruption in education systems, caused by the COVID-19 pandemic, accelerated the adoption of e-Learning strategies more than before (Bevins et al., 2020; Gewin, 2020; Rose, 2020). This massive transition of academic institutions and programs towards utilizing more distant and e-Learning environments has raised quality concerns and made it a necessity for universities to evaluate their delivered e-Learning systems and services (Bevins et al., 2020). One example of such evaluations is assessing the e-Learning educational atmosphere of the institution.

In theories of adult learning, education is as much about setting the learning environment as it is about imparting specific knowledge and skills. Figure 1 shows a

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schematic representation of the educational environment within the educational process (Harden et al., 1999; Hutchinson, 2003).

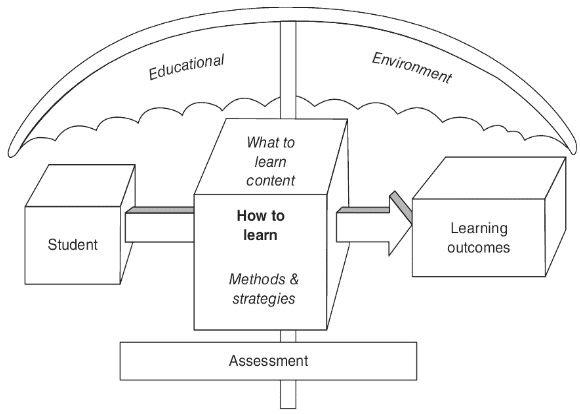

Figure 1 - The relation of the educational environment within the educational process (Adapted from Harden et al. 1999).

Students' perception of the learning environment, also known as "educational atmosphere", as the spirit of teaching and learning activities, have been shown to impact numerous educational outcomes: it is shown to be a main determinant of the students' academic behavior (Genn, 2001); A better educational atmosphere is also reported to be positively associated with higher academic achievements, learning satisfaction (Chan et al., 2018; Genn, 2001; Miles et al., 2012), perceived well-being and quality of life (Chan et al., 2018; Miles et al., 2012), academic aspirations (Miles et al., 2012), resilience, mindfulness, readiness for practice, peer collaboration, and less anxiety among students (Chan et al., 2018). A positive perception of the educational atmosphere within the international contexts has also been shown to improve students' social integration (Jean-Francois, 2019). On the other hand, a negative perception of the educational atmosphere has been reported to increase feelings of isolation and related academic dropouts (Rovai, 2002).

Understanding and evaluating the educational atmosphere is, therefore, an important part of curriculum development. Such evaluation is necessary to assess the departments' performance, identify possible areas of improvement, and facilitate the creation of an atmosphere that is conducive to learning (Jalili et al., 2014).

Considering the importance of the concept, multiple instruments have been developed for the assessment of educational atmosphere in various contexts. Due to the differences between face-to-face and online learning systems, different instruments have been developed to evaluate their atmosphere (Lee & Lee, 2008).

Using a valid and reliable instrument for quantitative measuring of the educational atmosphere offers several advantages as compared to qualitative assessment approaches, such as providing an overview of the institution's general educational environment status and details on the specific components and subscales, monitoring changes, evaluating interventions' effectiveness over time in an individual institution, and drawing comparisons between different institutions (Chan et al., 2018).

Despite these advantages, there is usually a lack of consistency in analyzing, interpreting, and categorizing the results of such opinion-based measures. To ensure an effective and consistent use of these measures for both evaluation and publication purposes, it is essential to develop uniform and clear guidelines to interpret their results (Miles et al., 2012). One common solution is to set up appropriate cut-off points which also provide a verbal interpretation and better comprehension of the results of the instruments. A cut-off point provides a categorical boundary on a continuous measure to allow intuitive interpretations of higher and lower scores (Barua, 2013).

Among multiple instruments available in the literature, the "E-learning Educational Atmosphere Measure (EEAM)" is a valid and reliable instrument, specifically tailored for assessing the educational atmosphere as perceived by the students in current e-Learning settings. The EEAM is a comprehensive instrument, adaptable to a wide range of e-Learning environments (Mousavi et al,, 2020). However, as any opinion-based measure, there is a need for developing clear guidelines for effective and consistent interpretation of its results. To the best of our knowledge, no optimal cut-off points for the EEAM have yet been identified.

In this study, we aimed to determine the appropriate cut-off points for the EEAM scores by using the Receiver Operating Characteristic (ROC) analysis to allow more effective and consistent interpretation of students' perceptions of the e-Learning environments.

2. Theoretical Background

We briefly review the existing literature in three sections: First, a brief overview of some of the most popular instruments for the assessment of educational atmosphere in traditional and e-Learning settings is presented; second, the use of cut-off points for such tools is discussed; and third, a method to optimize cut-off points, the Receiver Operating Characteristic (ROC) analysis, which we used in this study is reviewed.

2.1 Instruments for the Assessment of Educational Atmosphere

As mentioned earlier, educational environment is an important aspect of the curriculum and a crucial factor in the success of a program, and the students' perceptions of it heavily impact the quality of learning (Mohammad et al., 2010). As a result, multiple instruments have been designed and validated to assess it within different educational settings. On the other hand, the widespread uptake of e-Learning environments in the past decade has led to the development of specifically-designed tools which are compatible with the e-Learning and distance education contexts (Mousavi et al,, 2020).

Among the most widely-utilized tools for traditional settings, the “Dundee Ready Educational Environment Measure (DREEM)” was specifically developed and validated for the assessment of the educational environment in undergraduate medical schools. The 50-item DREEM questionnaire was developed through a Delphi panel and has been validated and used in multiple settings and languages around the world (Miles et al., 2012; Sue Roff et al., 1997). The 40-item “Postgraduate Hospital Educational Environment Measure (PHEEM)” questionnaire was developed through a similar procedure and with a focus on hospital-based learning environments in health professions education (Susanne Roff et al., 2005). PHEEM has also been widely used and validated in different clinical settings (Jalili et al., 2014).

Among more recently developed instruments which have included e-Learning and distance education elements, the “Web-based Learning Environment Instrument (WEBLEI)” (Chang & Fisher, 2001), the “Online Learning Environment Survey (OLES)” (Trinidad et al., 2005), and the “Online Learning Environment Survey (OLLES)” (Clayton, 2007) were developed in blended-learning settings, combining traditional face-to-face classroom with online teaching tools and communication platforms. Another similar instrument, the “Technology-Rich Outcomes-Focused Learning Environment Inventory (TROFLEI)” was developed to assess high school classroom environments in which computer-based tools such as internet forums and emails were used to aid teaching. However, they did not have a completely integrated e-Learning system (Aldridge et al., 2004). Another measure, the “Distance Education Learning Environments Survey (DELES)” was also developed to assess the distant learning environments; however, they were not necessarily enriched with e-Learning tools (Walker & Fraser, 2005).

The instrument we used in this study, the “E-learning Educational Atmosphere Measure (EEAM)” is a more recently developed questionnaire, specifically designed to assess the educational atmosphere of the current e-Learning systems. The EEAM was developed through multiple in-depth interviews with e-students and e-teachers involved in online MSc and PhD degree programs. In addition to the validity and reliability of the instrument, the EEAM is suitable for interactive e-Learning courses or programs that are delivered via a learning management system (LMS) and implement various synchronous and asynchronous strategies. It is also compatible with a wide range of educational contexts. These attributes make it more useful for the assessment of different types of e-Learning systems and programs (Mousavi et al., 2020).

2.2 Cut-off Points for Educational Atmosphere Measures

Most of the tools that are developed to evaluate the educational environment in traditional or e-Learning contexts are interpreted based on the total score and the scores obtained in each subscale (Mousavi et al,, 2020).

Among those for the evaluation of traditional settings, the 50-item DREEM questionnaire is the most popular and well-known instrument and consists of five subscales: 1) students’ perception of learning, 2) students’ perception of teachers, 3) students’ academic self-perceptions, 4) students’ perception of atmosphere, and 5) students’ social self-perceptions. The authors reported the achieved total and subscale scores as a percentage of maximum possible scores, without providing further recommendations on how to interpret them (Sue Roff et al., 1997). Subsequently, two of the authors provided guidance on the appropriate cut-off values to interpret the overall DREEM score, each five subscale scores, and individual items at three levels of “especially strong”, “could be improved”, and “needs particular attention”. (McAleer & Roff, 2001; Miles et al., 2012).

To the best of our knowledge, none of the instruments for the measurement of the educational atmosphere in e-Learning or technology-enhanced distance learning settings has determined clear cut-off points to effectively interpret their results.

2.3 Determining Cut-off Points by ROC Analysis

There are different methods for setting cut-off points to interpret the results of instruments, discussed by researchers in medicine, psychology, human resource, management, and education, such as Mean ± 2SD, the Youden Index, and the Receiver Operating Characteristics (ROC) analysis (Şahin Sarkın & Gülleroğlu, 2019). While there is no such thing as the “best” method, the ROC analysis has been frequently used for various psychometric and clinical diagnostic measures (Archer et al., 2013; Cho et al., 2021; Dunstan & Scott, 2019; Hajian-Tilaki, 2013; Lane et al., 2015; Larzelere et al., 2004; Nanishi et al., 2015; Oliveira et al., 2015; Şahin Sarkın & Gülleroğlu, 2019). Diagnostic accuracy and optimal cut-off points are considered as the two main outcomes of the ROC analysis. The ROC curves graphically plot sensitivity (true positive rate on the y-axis) versus 1-specificity (false positive rate on the x-axis) at every possible cut-off value. Subsequently, the Area Under the Curve (AUC) is used as the accuracy index to interpret the ROC curves. As it summarizes the overall location of the curve, the AUC can be taken as a general measure of sensitivity and specificity. The maximum AUC value of 1 means that the test is perfect in differentiation; whereas an AUC value of 0.5

indicates the minimum discriminatory power (Hajian-Tilaki, 2013). Optimal identification of the cut-off points requires simultaneous assessment of sensitivity and specificity as they dichotomize the scores to provide a binary classification. The optimal cut-off value is the point that classifies most of the individuals correctly (Unal, 2017).

There are multiple approaches for determining cut-off points according to the ROC analysis. In situations where there is considerable inter-subject variability and no gold standard reference test to compare with the results of the current instrument, a suggested solution is to determine the optimal cut-off points based on the participants' response to a direct question assessing the measured entity (Oliveira et al., 2015).

This study explores the appropriate cut-off scores for interpreting students' perceptions of the e-Learning environment as measured by the EEAM instrument through optimizing sensitivity and specificity by ROC analysis.

3. Methods

3.1 Participants

Participants were 126 MSc students of Medical Education, Educational Technology and e-Learning in Medical Education. The ages ranged from 21 to 41 years, with a mean of 29.90 years (SD = 4.32). 56.3% (71 participants) and 43.7% (55 participants) identified as female and male, respectively. Informed consent was obtained from the participants as they voluntarily submitted the survey. Ethical approval was granted by the Ethics Committee at Tehran University of Medical Sciences (IR.TUMS.MEDICINE.REC.1400.595).

3.2 Measure

The EEAM is a 40-item instrument. Each item has a five-point Likert-type rating, i.e., "totally agree", "agree", "neutral", "disagree" and "totally disagree" (rated from 5 to 1). The instrument covers the following six constructs as the domains of e-Learning educational atmosphere: 1) program effectiveness (e.g. learning academic-related knowledge and skills, attractive contents, and proper assessment), 2) teaching quality (e.g. appropriate use of e-teaching tools, strategies, and methods, taking advantage of the LMS capabilities, providing effective and in-time feedback), 3) ethics and professionalism (e.g. respecting social and cultural diversity, observing copy-right and intellectual property issues, tutor support), 4) learner support (e.g. technical and administrative support, educational counselling, access to digital library), 5) safety and convenience (e.g. user-friendly LMS), and 6) awareness of the rules (e.g. administrative regulations, educational and research guides). A higher total score indicates a better educational atmosphere as perceived by the respondents (Mousavi et al,, 2020).

To provide a refenrece for the ROC analysis in the absence of a gold-standard measure, an additional information on educational atmosphere was obtained from the same participants using a single global rating question: "How do you perceive the school's educational atmosphere in general?" with five response options: "The educational atmosphere is not good at all."; "There are problems in the educational atmosphere."; "The positive points of the educational atmosphere are somehow equal to the negative ones."; "The educational atmosphere is good."; and "The educational atmosphere is excellent."

3.3 Data Collection

Data from the EEAM and the single global rating question was collected online from the participants. After the first round of data gathering, we followed up the participants who had not filled the questionnaire and asked them to participate in the online survey.

3.4 Variables

The main outcome variable was the educational atmosphere, represented by the total EEAM score and treated as a continuous variable. The single question was used to analyze the distribution of the EEAM scores. Two cut-off points for the measure were determined by using the ROC curve, resulting in three educational atmosphere categories, i.e., "poor to weak", "moderate", and "good to excellent".

3.5 Statistical Analysis

Statistical analysis included descriptive statistics, the ROC curve analysis, ANOVA, and correlation coefficient. The significance level was set at 5% for all tests.

To calculate the ROC curves, we first coded the responses to the single question as a binary variable in order to distinguish between "poor to weak" and other categories. This dichotomization resulted in defining a cut-off point that identified respondents who believed that the atmosphere was "poor to weak". In other words, individuals who had selected the choices of "The educational atmosphere is not good at all." and "There are problems in the educational atmosphere." in response to the single question, were assigned to the "group 1" and all other participants to the "group 2" category.

Then, we applied a different binary categorization in order to distinguish between "good to excellent" and others. The respondents who had chosen the choices of "The educational atmosphere is good." and "The educational atmosphere is excellent." were assigned to the "group 1", and the rest to the "group 2" category. These two dichotomizations provided a basis for determining the cut-off points to identify individuals who believed that the atmosphere was "poor to weak" and "good to excellent".

Finally, the scores between these two cut-off points were considered as "moderate" perception of the educational atmosphere by the participants.

In addition, we used the Shapiro–Wilk test to assess the normality of the data and ANOVA test to associate EEAM scores to the responses to the single question.

The Statistical Package for the Social Sciences (Armonk, NY: IBM Corp. IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0) was used to conduct the statistical analysis.

4. Results

In total, 119 individuals filled out the EEAM and answered the global rating question (response rate of 94.4%). A statistically significant relationship was found between the total EEAM scores and the responses to the global rating question (r = 0.695, P-value = 0.000). Higher EEAM scores were more likely to be for the respondent whose choices were "The educational atmosphere is good" and "The educational atmosphere is excellent"; whereas lower scores were more likely to be for those who had chosen "The educational atmosphere is not good at all." and "There are problems in the educational atmosphere." Table 1 shows the details. The results of the ANOVA test showed significant differences between the EEAM scores in the groups based on the response to global rating question (Sum of squares = 24473.794, F = 37.019, P-value = 0.000).

Choices of the global rating question	Number of responses	Mean EEAM score*	SD**
The educational atmosphere is not good at all.	0	0	0
There are problems in the educational atmosphere.	20	116.8	17.43
The positive points of the educational atmosphere are somehow equal to the negative ones.	44	134.2	15.12
The educational atmosphere is good.	42	146.7	13.86
The educational atmosphere is excellent.	13	168.3	12.46
Total	119	139.4	20.55

* Out of 200, ** Standard Deviation

Table 1 - The mean EEAM scores based on the participants' responses to the global rating question.

Two cut-off points were determined based on the responses to the global rating question and the ROC curve analysis which resulted in classifying the EEAM scores into three educational atmosphere categories: "poor to weak", "moderate" and "good to excellent".

The AUC for the scores that reflect the "poor to weak" state was 0.875 (p-value = 0.000). The lower EEAM cut-off point which gave the best compromise between sensitivity (84.8%) and specificity (70.0%) was at 127 points. Figure 2 and Table 2 show the details of determining the lower EEAM cut-off point by optimizing sensitivity and specificity based on responses to the global rating question.

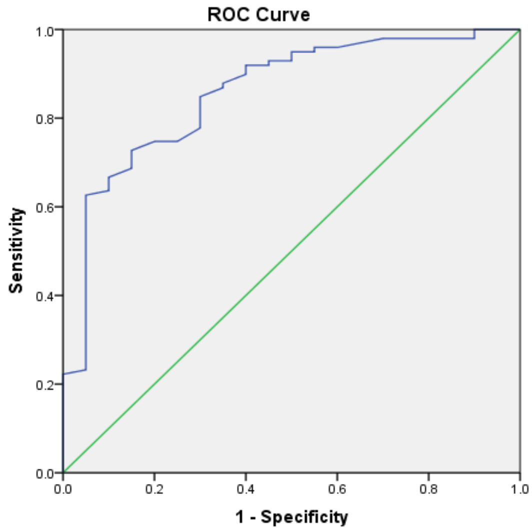

Figure 2 - Receiving Operating Characteristic (ROC) curve for the lower cut-off point of EEAM which is the score of 127.
Area Under the Curve (AUC) = 0.875 (p-value=0.000)

EEAM scores	"Poor to weak" versus "moderate" and "good to excellent"	
	Sensitivity	1 - Specificity
120.0000	0.899	0.400
122.0000	0.879	0.350
124.5000	0.869	0.350
127.0000*	**0.848**	**0.300**
128.5000	0.838	0.300
129.5000	0.808	0.300
130.5000	0.798	0.300
131.5000	0.778	0.300
132.5000	0.747	0.250
133.5000	0.747	0.200
134.5000	0.727	0.150
135.5000	0.687	0.150

Table 2 - Determination of the lower EEAM cut-off point.
*A score of 127, representing the best compromise between sensitivity (0.848) and specificity (0.700), was chosen as the lower cut-off point (in bold).

The second ROC curve for the binary categorization of "good to excellent" state from others had an AUC of 0.947 (p-value=0.000) and the upper EEAM cut-off point of 152 points corresponded to a sensitivity of

100% and a specificity of 82.1%. Figure 3 and Table 3 show the details of determining the upper EEAM cut-off point by optimizing sensitivity and specificity based on responses to the global rating question.

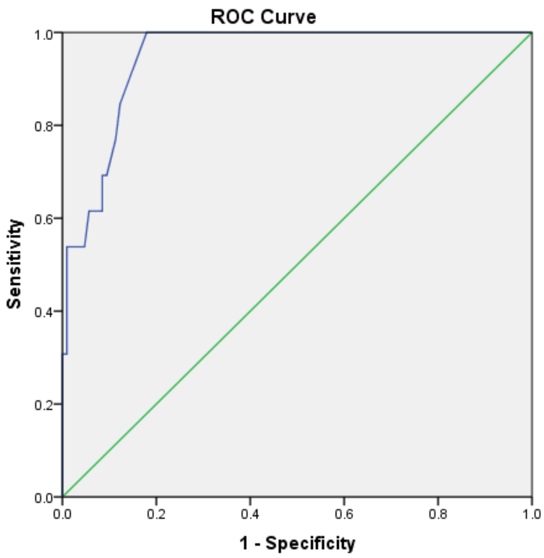

Figure 3 - Receiving Operating Characteristic (ROC) curve for the upper cut-off point of EEAM which is the score of 152.
Area Under the Curve (AUC) = 0.947 (p-value= 0.000)

EEAM scores	"Poor to weak" and "moderate" versus "good to excellent"	
	Sensitivity	1 - Specificity
145.5000	1.000	0.340
146.5000	1.000	0.330
147.5000	1.000	0.302
148.5000	1.000	0.283
149.5000	1.000	0.255
150.5000	1.000	0.245
151.5000	1.000	0.189
152.5000*	**1.000**	**0.179**
154.0000	0.923	0.151
155.5000	0.846	0.123
156.5000	0.769	0.113
157.5000	0.692	0.094
158.5000	0.692	0.085
159.5000	0.615	0.085
161.0000	0.615	0.066

Table 3 - Determination of the upper EEAM cut-off point
*A score of 152, representing the best compromise between sensitivity (1.000) and specificity (0.821), was chosen as the lower cut-off point (in bold).

Finally, from a range of 40 to 200, the cut-off points of equal or below 127, between 127 to 152, and equal or above 152 indicated students' perception of the educational atmosphere as "poor to weak", "moderate", and "good to excellent" respectively. Figure 4 shows the optimized lower and upper EEAM cut-off points on the basis of the Receiver Operating Characteristic (ROC) curve analysis for the responses to the single global rating question.

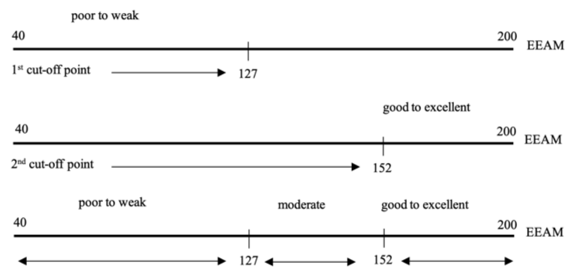

Figure 4 - Lower and upper cut-off points of EEAM (scores ranging from 40 to 200).

5. Discussion

This study aimed to determine the optimal cut-off points for interpreting the e-Learning educational atmosphere via the EEAM instrument, by plotting them as the ROC curves, versus responses to a single global rating question. While the range of possible EEAM scores is 40 to 200, points of equal or below 127 and equal or above 152 indicate the students' perception of educational atmosphere as "poor to weak" and "good to excellent" respectively. The EEAM scores in between these two cut-off points represent a "moderate" perception of educational atmosphere.

Among the educational atmosphere measures for e-Learning settings, we chose the EEAM due to its comprehensiveness, specific design based on e-Learning environments, and compatibility with a wide range of educational settings (Mousavi et al,, 2020). However, to enable a more effective and consistent interpretation, and provide a verbal description for numerical categories of the resulted scores, we used ROC analysis, a statistically supported method, to determine the optimal cut-off points (Oliveira et al., 2015).

Despite the importance of evaluating educational environment as a part of academic institutions' good practice (Soemantri et al., 2010), we could only find one tool, DREEM, that described clear cut-off points for its obtained scores. (McAleer & Roff, 2001; Miles et al., 2012). However, no clear statistical methodology was described for defining these cut-off values.

Our study has some significant implications for both educational evaluation and future research purposes. Setting EEAM cut-off points provides consistency in its analysis and increases the interpretability of its results. The cut-off points not only create direct meaning and relevance even in a single measurement attempt and in one institution but also provide a standard of comparison among institutions and are a clear benchmark for educational institutions' performance. Furthermore, it offers a measure of accountability for authorities to evaluate the educational atmosphere of their institutions. Also, the determined cut-off-points enhance the EEAM tool's utility in educational research and interventions. Finally, the method discussed in this study for cut-off-point determination can be applied to any opinion-based instrument.

Apart from the benefits, this study has some limitations. There was a lack of a previously existing gold standard for measuring the educational atmosphere in e-Learning settings. So, we could test neither convergent validity that is the correlation between two instruments, nor discriminant validity that is showing no correlation at all. This limitation led us to use a single global rating question as a reference for the ROC analysis. Moreover, the participants of this study were MSc students of specific disciplines in a country. We suggest further research in different e-Learning settings and with more participants' variety to confirm the generalizability of the findings.

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Virtual Reality Laboratories in Engineering Blended Learning Environments: Challenges and Opportunities

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Abstract

A great number of educational institutions worldwide have had their activities partially or fully interrupted following the outbreak of the COVID-19 pandemic. Consequently, universities have had to take the necessary steps in order to adapt their teaching, including laboratory workshops, to a fully online or mixed mode of delivery while maintaining their academic standards and providing a high-quality student experience. This transition has required, among other efforts, adequate investments in tools, accessibility, content development, and competences as well as appropriate training for both the teaching and administrative staff. In such a complex scenario, Virtual Reality Laboratories (VRLabs), which in the past already proved themselves to be efficient tools supporting the traditional practical activities, could well represent a valid alternative in the hybrid didactic mode of the contemporary educational landscape, rethinking the educational proposal in light of the indications coming from the scientific literature in the pedagogical field. In this context, the present work carries out a critical review of the existent virtual labs developed in the Engineering departments in the last ten years (2010-2020) and includes a pre-pandemic experience of a VRLab tool - StreamFlowVR - within the Hydraulics course of Basilicata University, Italy. This analysis is aimed at highlighting how ready VRLabs are to be exploited not only in emergency but also in ordinary situations, together with valorising an interdisciplinary dialogue between the pedagogical and technological viewpoints, in order to progressively foster a high-quality and evidence-based educational experience.

KEYWORDS: Blended Approach, COVID-19 Pandemic, Engineering Education, Streamflowvr, Virtual Reality Labs.

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1. Introduction

In engineering education, laboratories have always played a key role in understanding theoretical concepts and practising teamwork, observation capability, and communication, as well as in reinforcing important notions related to data analysis, problem solving, testing, and scientific interpretation. For this reason, the lack of laboratory classes during the global COVID-19 emergency phase has negatively influenced the quality of the academic courses, reducing not only the learners' possibility to better understand some real, physical phenomena and processes, but also the chance to obtain the technical skills needed to face future challenges in the labor market (Kapilan et al., 2021; Vasiliadou, 2020). In such a scenario, different European engineering universities have been working hard to improve the teaching curricula and the students' learning experience, trying to circumvent this crisis by moving the essential educational missions into Virtual Learning Environments (VLEs).

To this end, VRLabs could well fill the gap caused by the lack of traditional practical lessons, since students could continue to better understand the theoretical aspects, improve their technical skills and competences, and analyse phenomena in depth through online experiments and training exercises, without the need to physically reach the premises. In addition, well-planned VRLabs could allow social interaction and collaboration among students, reducing feelings of isolation and loneliness at the same time.

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In the last decades only, VRLabs have demonstrated their usefulness in increasing students' knowledge, skills, and performance in examinations, while reducing geographical limitations, health and safety hazards and training costs, thanks to their availability and affordability (Lewis, 2014). When properly planned and executed, VRLabs have been found to provide an equal, and often even enhanced, learning experience, with many benefits that traditional labs cannot offer (Lynch & Ghergulescu, 2017). Cheong and Koh (2018) underlined how VRLabs could increase the active participation of students and allow them to apply their knowledge to simulated real-world scenarios. The enhanced engagement of students in the learning experience using multiple teaching approaches was recognised also by Goudsouzian et al. (2018) and Toth (2016), who confirmed the role of VRLabs and their varied inputs in the form of animation, videos, and other teaching tools in improving students' learning outcomes. In particular, in VRLabs students can carry out experiments that would be too dangerous or impossible to perform in real life and can learn from their mistakes without causing any real damage to themselves, to others or to the equipment/facilities. In fact, they are able to manipulate virtual equipment and materials simply using a keyboard and/or handheld controllers and repeat the same experiment more than once, changing parameters and conditions, without incurring in extra cost or time. These experiences make use of low-immersion technology (desktop/laptop computer), if delivered in 2D, or high-immersion technology (Head-Mounted Display-HMD), if delivered in 3D. The level of immersion is thus an important parameter when evaluating the impact of the VRLab on students and how intuitively they manage to use the technological devices and tools (Cummings & Bailenson, 2016). The actions to be performed in a VRLab can vary from observing a phenomenon to testing theories and/or hypotheses through experiments (de Jong et al., 2014; Potkonjak et al., 2016), not only offering students a first-person experience similar to that of a teaching laboratory (Vrellis et al., 2016) but sometimes involving more complex analyses typical of an actual research laboratory (Makransky et al., 2016, 2019), with student achievements in line with those observed in a physical lab (Darrah et al., 2014; Ekmekci & Gulacar, 2015; Goudsouzian et al., 2018; Koh et al., 2010; Makransky et al., 2016; Ogbuanya & Onele, 2018; Vrellis et al., 2016). In such an environment, reproduced with very high fidelity, the knowledge students acquire in a familiar situation becomes transferrable to other unknown contexts (Kester et al., 2001), boosting their confidence especially in the future professions of engineering (Chemers et al., 2011).

Up until early 2020, VRLabs had been used in support of in-class theoretical lessons in a blended approach to teaching theory and practice. During the pandemic emergency, though, their importance and potential increased. Sometimes they had to completely substitute teachers and not only be of support as a module within a much wider course of studies (Reeves & Crippen, 2021).

It is a fact that the pandemic crisis has enormously changed the entire education model and universities need to reflect on how to establish a sustainable approach to teaching, doing research, and engaging with society. A new and robust system balancing online and physical presence is more and more required. Universities might want to keep using the technological tools they have lately learned to appropriately use to ensure more equality and inclusion, especially among groups of students who would not be able to follow a full-time course in attendance otherwise. Classes have become even more student-centred as learners have experienced a new interaction pattern with the technological content and have become active players in their learning process. They can keep building their ability to manage time, their learning autonomy, and their transversal competences if given the right support to do so. Of course, this revolution in teaching/learning methods requires conspicuous investments in equipment, infrastructures, and content development, thus profoundly transforming the way we teach and learn.

In such context, the present paper describes the limits and opportunities involved in a pre-pandemic experience of a VRLab, the StreamFlowVR, developed within the Hydraulics courses of the master's degree in Civil and Environmental Engineering at the University of Basilicata, in southern Italy (Mirauda et al., 2019, 2020). The StreamFlowVR tool was implemented on the measurement and analysis of water discharges in open-channel cross-sections, having the aim to train students on correctly using the equipment and following the different measuring steps, but also learning how to move within the river, in addition to improving the research methods and analysis techniques explained in class. Designed before the pandemic to fill the existing gap between the theoretical lessons in class and the practical ones in field, which are limited due to weather conditions, long organisational times, and high costs, the StreamflowVR tool is here revisited underlining its useful aspects in the hybrid teaching context and the features that might be improved in the future. At the same time, this work tries to analyse further opportunities of using appropriately designed VRLabs and the current challenges of online/in-class teaching of engineering subjects, starting from a literature recognition on the topic.

The rest of the paper is organised as follows. Section 2 describes the research questions and the methodological approach adopted, while Section 3 provides a review of the VRLabs developed in the last decade in some academic engineering departments, highlighting their potential in improving the practical competences of students in mixed educational environments. To this purpose, a pre-pandemic experience of a VRLab tool supporting engineering education - StreamFlowVR, developed at Basilicata University within the Hydraulics courses, is introduced in Section 4. Section 5 thematises, from a pedagogical viewpoint, how VRLabs can promote meaningful learning in the age of distance learning, suggesting some criteria for their possible future progress in the academic engineering education. From this perspective, rather than showing the results of a work, the present paper questions how VRLabs can be improved starting from the awareness of the educational and technological challenges and processes involved. Based on the scientific evidence produced by the pedagogical literature on blended learning and VRLabs, and reviewing a great amount of existing meta-analyses on the subject, some theoretical indications and methodological criteria useful for the design, implementation, and evaluation of teaching practices have thus been offered. Section 6 proposes the implementation of the StreamFlowVR tool in the near future, taking into account the guidelines extrapolated from the current literature. Finally, Section 7 gives the conclusions of the present work and future perspectives in terms of educational and technological objectives.

2. Methods

From a methodological perspective, the present work develops on two levels, each based on one specific research question.

The first research question investigates the literature on the topic in order to define what instructional guidelines should be considered for the implementation of VRLabs in classroom teaching of engineering subjects. A scoping review (SR) was thus conducted as a second-level study by mapping a reasoned portion of meta-analyses according to their objective, following the PRISMA methodology and guidelines (Tricco et al., 2018). The following keyword strings were used in all searched databases: “virtual reality” or “VRLab” AND “engineering education”, considering sources from 2009 to 2021. Nine databases were used (Virtual Health Library-VHL, PubMed, PsycINFO, Web of Science, Scopus, Scielo, Ebsco, Google Academic, and Embase). The “document type” filter (article, journal article, or conference paper) was employed in all databases. For data selection and eligibility, articles located in the databases were imported into the Rayyan website for screening. Rayyan is a free tool that helps researchers perform systematic or scope reviews through automatic identification of duplicated publications and uses a “blind mode” to reduce the risk of selection bias (Ouzzani et al., 2016). The data extracted included: 1) study identification (i.e., Authors last name, publication date); 2) study design (e.g., case study, quantitative/qualitative); and 3) university courses (e.g., engineering). The inclusion criteria were empirical studies that underwent peer review from 2009 to 2021 on engineering university courses. The exclusion criteria included duplicated articles, studies not in university courses, theoretical studies, and full texts not available online. Initially, 47 records were identified, 12 duplicates were removed, 35 records were screened, 14 were excluded, 21 assessed for eligibility, and 13 studies were finally included in the review.

The second research question explores the effectiveness of blended learning in the design, delivery, and evaluation phases of teaching. The goal for this second level was to examine pedagogical meta-analyses produced internationally and in English on “blended learning” to provide pedagogical criteria for the design, delivery, and evaluation of university courses offered in a “blended learning” mode. This was based on a previous study by one of the Authors (Patera, 2016) from 1994 to 2022.

3. VRLab Applications in Engineering Education

Over the last few years, Information and Communication Technologies (ICTs) have increasingly been integrated into traditional academic teaching by various universities and thus also by Engineering courses, to enhance students’ learning experience and practical skills.

Innovative VLEs have been designed, where interaction between teachers and students occurs through various tools like computer animations, audio and video devices, 3D graphics, and on-line databases, allowing a more immediate communication thanks also to e-Learning systems with Internet-based features such as e-mails, instant messaging, and cyber-platforms.

These VLEs have become more and more efficient recently as collaborative places where students can learn new contents and broaden their knowledge on topics of interest (Hernández-de-Menéndez et al., 2019). Besides, being virtual and not physical classrooms, they help to reduce the costs and times of traditional teaching methods (Manesh & Schaefer, 2010).

More recently, the level of interaction not only with the technological tools but also with the other students and their instructors has greatly increased. Well-designed and up to date VRLabs have been created and are among the most efficient VLEs in engaging students.

Most of the past decades’ research in the field of undergraduate education has been focused on mainly 2D experiences (Reeves & Crippen, 2021) and the area of robotics. Most of the VRLabs in the last ten years were of the non-immersive 2D type and not specifically designed for the course in which they were employed, and a great amount was mainly implemented in undergraduate or introductory courses. Overall, most of the experiences dealt mainly with one specific module of a related course (Reeves & Crippen, 2021).

Therefore, the question is: how much more efficient, in terms of gaining and retaining knowledge and practicing skills, but also of enjoying the experience, is the 3D environment compared to the 2D type? Some Authors have tried to answer this question. Johnson-Glenberg et al. (2021) have very recently come to the conclusion that, although the high immersivity provided by 3D is more presence-inducing, the performance of STEM students is not always comparably higher than the ones working on 2D platforms (e.g., desktop pc), especially due to the possibility of 'overload effects' of the 3D immersive environment. What makes all the difference, they state, is the level of 'embodiment', linked to 'agency' or 'personal empowerment', as they are defined in psychological terms; in other words, learners who can manipulate content via a mouse or other controllers have more chance of faster and better results. Their expectations of higher interaction are also fulfilled and their engagement functions as a motivator for learning. Having highlighted the potential of VR in enhancing kinesthetic interactivity (Johnson-Glenberg et al., 2021), which in turn improves the learning experience if added to the usual visual and auditory input, we move away from discussing the VR platform design itself, giving more space to the VR tools that allow for more body movement and interactivity (e.g., HMDs with tracking and VR hand controllers).

In view of this, VRLabs are very powerful tools that, being more and more affordable in terms of technology cost (Martín-Gutiérrez et al., 2017), can be applied to university education, shaping a new teaching approach by favoring the exchange of knowledge, skills, and technology between individuals (Fogarty et al., 2011). By expanding on the locations where laboratory learning can take place (Bortnik et al., 2017), they can solve most of the problems encountered during practical classes in real laboratories, where some students might not see all the details of an experiment being carried out, for example, or do not manage to listen to the teacher's explanations especially when in large groups. In VRLabs, instead, communication is easier and more immediate, visualisation is of high quality, and all students have the chance to 'virtually' handle and operate otherwise very expensive and not always available tools (Vergara et al., 2019). Learners are empowered through practical tasks, which can also be repeated without incurring in extra costs or even physical risks, aimed at refining their techniques and abilities, and are thus able to advance faster in their studies and meet the labour market needs once graduated (de Jong et al., 2014).

Their student-focused nature is a valid way to improve the learning of the science, and thus engineering, content (Ekmekci & Gulacar, 2015; Goudsouzian et al., 2018) and they make use of immersive technologies which motivate students and increase their enthusiasm for engineering subjects, even when physical resources are limited (Cobb et al., 2009).

Successful VRLabs have been implemented especially in courses of Mechatronics and Industrial Engineering, to provide undergraduate students with basic robotics knowledge and prepare postgraduate ones for more complex tasks, such as the creation of industrial robots which control and monitor manufacturing processes. The VRLab lets students practise automation tasks such as those of a warehouse storage, an elevator, a transport and sorting line, or a manufacturing cell, avoiding the high investment and operating costs the real systems would require if purchased and constantly updated by universities. An example is the virtual laboratory for teaching mobile robotics at the Department of Computer Science at Tecnologico de Monterrey (Mexico). It is based on a 3D simulation, which lets students explore the first concepts in the course (mechanical design, sensors, and control) before they start building a physical robot and includes an intelligent tutoring system that guides the students during their interactions with the virtual lab (Noguez & Sucar, 2006). Another interesting experience, aimed at postgraduate students, is RoboUALab, designed at the University of Alicante, Spain, to simulate and execute a manipulator robot. It allows students to practice movement commands with a simulated industrial robot and to handle a real robot, located in a laboratory of the university, through tele-operation. The latest version is based on Easy Java Simulations, an open-source tool for people who do not have advanced programming skills. The only equipment that the student requires is a computer connected to the Internet, the Java runtime library, and either the VRML software or the Java 3D runtime library, depending on the version of the RoboUALab being used (Jara et al., 2011; Torres et al., 2006).

Recently, Grodotzki et al. (2018) have developed a virtual lab in manufacturing and materials testing in a joint project by three universities in Germany (RWTH Aachen University, Ruhr-Universität Bochum, and TU Dortmund University) called Excellent Teaching and Learning in Engineering Science (ELLI). In detail, the VE-Lab is a web- and app-based environment with access to a library of pre-run virtual experiments based on Computational Fluid Dynamics (CFD) and other numerical simulation methods. The latter, in fact, can reproduce real experiments (material tests, forming and machining processes, product tests, etc.) at a good level of accuracy, supporting problem-based learning courses.

As demonstrated by the above-mentioned experiences, not only are VRLabs able to reduce the daily issues of traditional in-class methodologies, but also to foster a more student-based learning process, where learners are stimulated to take initiative and to reach autonomy while enjoying the process.

In view of this, the VRLab "Ironmaking", designed at the RWTH Aachen University in Germany, provides a deep understanding of the blast furnace process (Babich & Mavrommatis, 2009). The latter is a complex technological procedure, characterized by a range of phenomena (mechanical, hydraulic, physical, chemical, and physical-chemical ones) and reactions, which occur simultaneously and affect one another. The peculiarities of such a process include: interconditionality, non-linearity of relationships, inertia and transport delays, ambiguity, and loss of information. Similarly, the Department of Chemical Engineering at the Oregon State University created the CVD Virtual Learning Platform, simulating the process of the chemical vapor deposition (CVD), in which students synthesize engineering science and statistics principles (Koretsky et al., 2008). The simulation of the reactor is based on the fundamental concepts of mass transfer and chemical reaction, obscured by added disturbance (noise), using advanced software features (a 3D graphical user interface, an instructor Web interface with integrated assessment tools, and a database server).

More recently, still focused on the engineering control systems, the VRLabs designed at the Slovak University of Technology in Bratislava (Kalúz et al., 2012), at the Universitat Politecnica de Catalunya in Barcelona (Fernández-Cantí et al., 2012), and at the Loughborough University in the UK (Abdulwahed & Nagy, 2013) are worth mentioning. The first virtual laboratory provides for virtual simulations of three technological plants (liquid storage tank system, tube heat exchanger, and continuous stirred-tank reactor), originally using the Adobe Flash programming platform, and later employing Java Server Pages. The experience of Barcelona University allowed implementing a multiplatform virtual laboratory, using a Java language-based tool (Easy Java Simulation) and the Matlab software, to analyze two engineering control phenomena: inverted pendulum cart system and magnetic levitation. The experiments introduced root locus controller design, ITAE (Integral Time Absolute Error) optimal controller design, and PID (Proportional-Integral-Derivative) controllers. The same controllers, together with the main components and instruments of feedback loops and the concepts of open-loop and feedback control, were included in the Process Control Virtual Laboratory (PCVL) designed at the Loughborough University to simulate the Armfield PCT40 tank filling process. This laboratory combines the three access modes (Hands-On, Virtual, and Remote) in one unifying software package (the TriLab), by using LabVIEW. More recently, Hu et al. (2017) implemented a plug-in free online 3-D interactive laboratory based on the networked control system laboratory (NCSLab) framework which, despite being based only on HTML5, supports control engineering experimentation, and provides all services such as monitoring, tuning, configuration, and control algorithm implementation. By replacing the real physical devices with virtual ones, the NCSLab was later extended to the 3D-NCLab, as described by Liang and Liu (2018), which offers an extensible framework for collaborative experiments. Various virtual devices were created by designing accurate mechanical movements using real-time data from hardware-based simulations and the system was efficiently applied to a creative automatic control experiment course in the Harbin Institute of Technology.

Over the years, VRLabs have progressively become more interactive, enabling students to switch from being passive listeners to active participants in their learning process. A good example are VR platforms implemented in the field of architectural and construction engineering as well as in the facility management industry (Whisker et al., 2020), including fully immersive CAVETM or HMD environments and semi-immersive screen display systems to support the design review process of courtrooms, nuclear power plants, patient rooms, and educational buildings. This way, students can understand various planning issues, practice in conditions normally restricted in the real world but without real consequences, and despite their little present knowledge concerning buildings and infrastructures. Therefore, they are also guided towards a more informed and faster decision on the best choice of design, being also able to make any changes to the project in real time. In the same period, in the sector of Hydraulics Engineering, Pieritz et al. (2004) developed an interactive, web-based virtual laboratory with OpenGL technology to simulate and study fluid flow problems, while Pauniaho et al. (2005) introduced a three-dimensional model in a Hydraulics course at Tampere University of Technology (TUT), in Finland, using the virtual reality modelling language (VRML) to teach the structures and functions of fluid power systems and hydraulic components.

Later, the Virtual Electric Machine Laboratory created at Firat University (Turkey), based on HTML (Hypertext Markup Language), ASP (Active Server Pages), and Borland C++ Builder (Tanyildizi & Orhan, 2009), allowed the students to immediately see the effect of loading different synchronous motors by changing all parameters, such as simulation time, sampling frequency, and voltage, and graphically visualize the outputs (e.g., the velocity of the synchronous motor).

Incorporating the students' real-world interests into the classroom has always been a challenge, satisfyingly met using advanced technology and popular computer games in the educational VRLabs, so that the learning process becomes overall more enjoyable. The Stevens Institute of Technology (USA) developed an innovative online virtual laboratory, enabling students to learn by interacting in a virtual environment very similar to massively multiplayer online games, such as Half-life 2, The Sims, WoW (World of Warcraft), and Second Life (Aziz et al., 2009, 2014). The game-based laboratory environment was created as part of the course "Mechanisms and Machine Dynamics" to introduce the principles of kinematics and dynamics and apply them to linkages, cam systems, gear trains, belt and train drives, couplings, and vibrations. Students, teaching assistants, and professors could design their own avatars and discuss projects through instant messaging, manipulate equipment and machinery to set up their experiments, and visualize data based on the interactions of the parts. The Virtual Engineering Sciences Learning Lab (VESLL), designed at the Loyola Marymount University in California, is also based on the Second Life multiplayer online game, where a private "island" was created specifically for students to explore content, solve puzzles, and participate in activities regarding engineering science, as well as interact with other users (August et al., 2016).

Most research in the field has so far investigated the influence of VRLabs on positive students' outcome in terms of content knowledge (Chini et al., 2012; Darrah et al., 2014) and retention (Vergara et al., 2019) and on analysing students' perception and attitude towards the use of virtual labs (Dyrberg et al., 2017) as well as their level of motivation (Koh et al., 2010), while few studies have focused on the improvement of practical and critical-thinking skills. Cheong and Koh (2018), for example, described how students can solve math problems and Ogbuanya and Onele (2018) expressed their idea of VRLabs enhancing students' learning through engineering practice. Nedeljkovic et al. (2019, 2018) and Sivapragasam et al. (2020) analysed how students build confidence with hydraulics and fluid mechanics issues, using the LabVIEW platform, to test hydraulic pumps tracking the profile of the jet trajectory.

From the same perspective, de Jong et al. (2021) focused their research both on the designing issues of the Go-Lab ecosystem, a STEM-related online laboratory supported by multimedia materials and learning apps, from a teacher's point of view and on the development of inquiry learning spaces (ILSs) where students can acquire twenty-first century skills while engaging in the process.

Finally, some interesting and recent studies have researched on the importance of the VRLab planning and designing phases, instead, as much as on the teacher's and, more broadly, the creative team's perspective, presenting some supporting case studies. Vergara et al. (2020b), for example, has thoroughly discussed the process behind the design and development of these VRLabs together with the teachers' perception of the VR employment in university education. The same author (Vergara et al., 2020a) extensively analysed the important aspect of technological obsolescence and how it can influence the efficacy of VRLabs.

4. The StreamFlowVR Tool

StreamFlowVR was developed in order to support the theoretical lessons and the in-field activities in the Applied and Fluvial Hydraulics course for the master's degree in Civil and Environmental Engineering at Basilicata University. These courses are structured to guide learners from the knowledge of basic principles of fluid mechanics to their applications in real-world problems. The expected learning outcomes are represented by the ability to analyse and solve simple and complex hydraulic problems using analytical and numerical models, as well as the technical ability to plan and perform laboratory and in situ experiments. In fact, some problems can be solved in the classroom by applying standard textbook techniques, while other problems require some practical experimental activities to develop the specific skills that cannot be obtained during frontal lessons.

The VRLab implemented and widely described in Capece et al. (2019), Mirauda et al. (2019) and Mirauda et al. (2020) is mainly focused on the measurement of the water discharge in open-channel cross-sections according to the international standards ISO 748/1997 and ISO 1100-2/19 rules. Such data are an important input for the hydraulic sector. The combination among the standard measurement methods explained in the classroom, the use of the VRLab, and the experimental activities in situ allow students to obtain general and specific learning objectives.

The first ones include:

- Improving the understanding of theoretical concepts;
- Preparing the students for forthcoming field activities;
- Increasing the students' interest in the academic subject;
- Boosting the students' curiosity, critical thinking, and problem solving, while developing related soft skills and increasing motivation.

The second ones are:

- *Knowledge* - Familiarising students with the classical and advanced equipment employed for the measurement of the water discharge in open-channel flows and memorising the whole sequence of measurement steps through the use of the virtual laboratory;
- *Skills* - Combining the theoretical knowledge with the use of measurement sensors and techniques in a protected fluvial environment through repetitive training;

- *Competence* - Learning to accurately and autonomously apply the standard measurement methods and methodologies in a real fluvial environment, with the possible support of innovative technology.

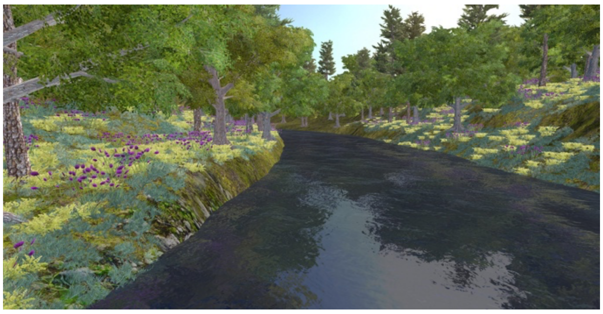

Figure 1 - A reproduced 3D VR scene of a fluvial reach.

This VRLab was designed with high fidelity graphics and immersive content accessible by using HMDs, which allowed students to explore complex subjects in a way that usually teachers and students develop during field activities. It can be used in a classroom setting or at home, in distance learning mode, as there are no significant differences in hardware / software requirements in either environment.

An important development requirement was to devise a VR application that adopted some state-of-the-art user's features but still immediately approachable by both VR experts and non-experts. In the case of non-expert users, in fact, a short training phase (about a quarter of an hour) was considered. Another important aspect to tackle was the motion sickness caused by virtual reality applications, which occurs when our eyes tell us we are moving while our vestibular system is perfectly still. Trying to resolve motion sickness during the development of VR tools is crucial for students to perform long immersive sessions during the lesson in the classroom or at home. Due to the nature of a VR headset, many of the solutions proposed are very difficult or impractical to adopt, e.g., using a fan when wearing a VR headset, taking regular breaks from VR immersion, and so on. Therefore, common strategies were adopted in this VRLab such as: forcing the user to move linearly; keeping the user in control of their movements; avoiding accelerating the camera; and maintaining a steady frame rate at all times.

Figure 1 shows a reproduced 3D VR scene of a fluvial reach generated through the Unity 3D terrain editor, while the free surface waves and light refraction phenomena as well as the water colour, bank fade, bank and depth transparency, flow velocity value and direction were created with the AQUAS Unity 3D asset. Figure 2 shows the different steps to measure the water discharge in an open-channel cross-section, which should be carried out in the field.

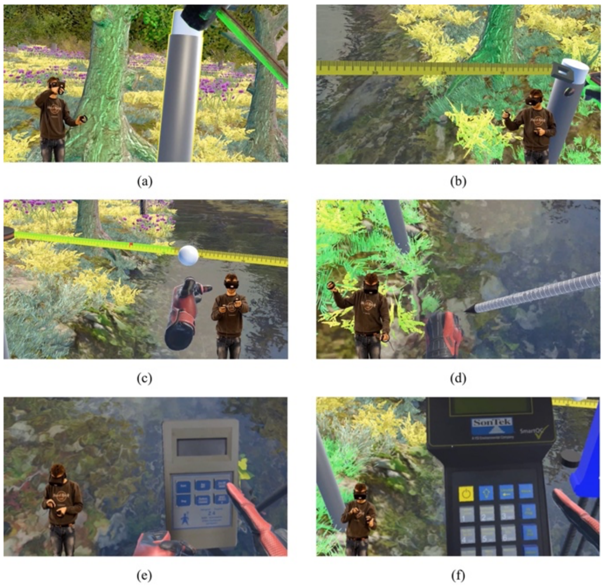

Figure 2 - Steps of water discharge measurement within the VRLab: a) demarcation of the site; b) acquisition of the channel width; c) identification of the verticals; d) evaluation of the flow depth; estimation of velocities with e) current meter and f) acoustic doppler velocimeter.

5. Blended Learning and VRLabs: an Overview of Educational Literature as 'Lesson Learnt' for the Pandemic and Post-pandemic Age

In a historical moment in which the theoretical and methodological discussion on distance learning is still mandatory and urgent, it is necessary to increase opportunities for interdisciplinary work among technologists, engineers, and media education experts, in order to consider the educational experiences of the pandemic not as a temporary misfortune but as a constant terrain of confrontation and dialogue: a 'lesson learnt' useful for facing but also for anticipating the educational challenges brought by contemporaneity. In the case study considered, the 'lesson learnt' consisted in opening a field of dialogue not only between researchers and teachers of the engineering field, but also with media education experts, sharing theoretical and methodological perspectives based on an interdisciplinary reflection and re-elaboration of what was didactically achieved during the pandemic.

Over the last decade, and thus even before the pandemic, the pedagogical literature has offered precious indications for the planning, implementation, and evaluation phases of educational activities that can be considered a great opportunity for the reflection on and redesigning of VRLabs in the engineering field. In this perspective, we intend to avoid falling into easy oppositional reductionisms to the extent that face-to-face and distance learning methods are opposed a priori, taking into consideration blended learning too.

In fact, the most significant meta-analyses both on the effectiveness and the design, teaching, and evaluation of this approach in educational contexts supported by ICT offer some clear indications. In this regard, we critically investigated the main existing meta-analyses to offer a synoptic epistemological and methodological perspective useful for rereading the experience in the case study and providing indications for the subsequent design activities of the VRLab in the next academic years.

The first meta-analyses of the early 2000s (Cavanaugh et al., 2004; Liao, 1999) were characterised by more robust methodological studies. Cheung and Slavin (2011), although referred to K-12, have the merit of dispelling the myth of the beneficial effects of educational technologies *tout court*. Starting from these first results, the milestone works carried out in the last decade by Means et al. (2010), among others, highlight the educational effectiveness of blended learning interventions compared to exclusively traditional or technological ones. Bernard's significant work (Bernard et al., 2004) is based on a meta-analysis published in 2004, and further deepened in 2014, starting also from the evidence provided by the two works of Means et al. (2013). Bernard's first meta-analysis (Bernard et al., 2004), based on 232 studies, states that there is no a priori efficacy of technologies applied to learning and, in fact, he finds an almost zero effect size. Learning technologies are effective due to a more general and coherent planning / evaluation of educational activities in different contexts. Among the many aspects, Bernard highlights: the quality of educational design; the authentic involvement of students; and the active support from the providing organisation. In other words, the effectiveness of ICT on improving the teaching-learning relationship depends on the quality of the pedagogy used, and the inclusion of multiple media in the same educational project does not seem to bring advantages by itself, in terms of greater learning effectiveness. Based on Barnard's work, the milestone meta-analysis carried out by Means et al. (2010) on 51 studies states that "students in online learning conditions performed better than those receiving face-to-face instruction" (Means et al., 2010, p. 5-6), considering the relevance of some pedagogical criteria, such as the fact that effectiveness must be assessed on the basis of a design and formative evaluation model adapted to the contexts and profiles of students as well as to the different levels of education. Later, Castaño-Muñoz et al. (2014) focused on Higher Education and stated that "the principal cause of the improvement is not, in itself, the increase in time spent online for educational purposes. Rather, increasing the time devoted to studying online is only useful when it takes place as some form of interactive learning" (Castaño-Muñoz et al., 2014, p. 149). In this regard, the meta-analysis carried out by Schneider and Preckel (2017) specifies the variables associated with achievement in Higher Education: the stimulation of meaningful learning by presenting information in a clear way or, in other words, the use of conceptually demanding learning tasks. Vo et al. (2017) investigate the impact of blended learning on academic achievement, confirming that it is significantly associated with greater learning performance of STEM-disciplined students than with traditional classroom practice. The latest meta-analyses considered on the topic of blended learning, ~~were~~ published in 2020, ~~and~~ focus mainly on its use during the period of the COVID-19 pandemic. In particular, the work by Camargo et al. (2020) on 38 studies highlights that "the pandemic situation requires a well-integrated trained team to detect students' and teachers' needs and provide prompt answers and support with digital tools" (Camargo et al., 2020, p. 3). In a nutshell, the indications provided by the above-mentioned meta-analyses concern not only how to design blended learning interventions, but also how to improve self / hetero / co-evaluation processes in the framework of formative evaluation.

At the same time, the opportunity given by the pandemic is related to a reflection on how both blended and synchronous hybrid learning environments (on-site and remote) can be designed to promote students' effective and meaningful learning. On the basis of a systematic literature review on hybrid learning, Raes et al. (2020) adopt a rather optimistic view about synchronous hybrid learning as it provides a more flexible and engaging learning environment than a fully online or fully on-site one. They also formulate several design guidelines in order to face the pedagogical and technological challenges of such a new learning context.

The pedagogical-didactic literature on VRLabs, together with that on blended learning just presented, while considering the increase in learning methods related to digital developments, offers some elements for reflection to qualify the adoption of these innovative teaching practices. In the light of the current situation, i.e. the shift from the Information Age to the Experience Age (Wadhera, 2016), large evidence underlines the educational value of VRLabs in the Experience Age (Bailenson et al., 2008; Dalgarno & Lee, 2010; Lau & Lee, 2015), where "the best way to use virtual reality in learning is to create experiences that help students to understand the learning context better" (Lau & Lee, 2015). In line with these preliminary considerations, the meta-analysis by Kaplan et al. (2021) aims to explore, through empirical research, the transferring of training from virtual (VR), augmented (AR), and mixed reality (MR), and to determine whether such extended reality (XR)-based training is as effective as the traditional training methods. The results highlight what has already been reported in the meta-analyses on "blended learning": it is never the technologies themselves to be more effective, but the quality of the pedagogical proposal that guides their use in educational activities. At the same time, the meta-analysis by Howard & Gutworth (2020) focuses on virtual reality training programs as useful tools for the social skill development to determine: (a) whether these programs are effective and (b) the attributes of these programs that lead to success. The main finding is that VR training programs, on average, perform better than alternative training programs for developing social skills, even considering that programs using immersive technologies produce slightly worse outcomes than those using non-immersive displays, also confirmed by Angel-Urdinola et al. (2021). A further suggestion for reflection coming from the pedagogical literature, and useful for re-reading and redesigning the past VRLab experience, is the meta-analysis carried out by Howard and van Zandt (2021) on 149 studies, which discusses individual differences and predicted VR sickness in such immersive environments: motion sickness susceptibility; gender; relevant real-world experience; technological experience; suffering from a neurological disorder; and having a phobia (Howard & van Zandt, 2021, p. 26).

In the light of the reflections and indications offered by the pedagogical-didactic literature on blended learning and on VRLabs, we can state that the future redesign of the VRLab cannot be reduced to a mere technological level but needs to consider: an "aesthetic" dimension, relating to codes and languages; a "critical" dimension, with respect to semantics, social and cultural meaning; and an "ethical" dimension, in reference to values, responsibility, and citizenship. For this reason, the criteria identified in section 5 represent a pedagogical-didactic orientation both to reflect on the experience achieved in the case study presented here and to guide the educational activities that will be carried out in the next academic years.

6. Designing a VRLab in a Blended Learning Environment

Starting from the indications offered by the pedagogical-didactic literature (Section 4), some heuristic criteria are explicitly used both to re-read the experience presented by the StreamFlowVR and to redesign the VRLab tool for the next academic years, in order to carry out an educational planning / evaluation suitable for both face-to-face and blended learning (Castro et al., 2020).

Below are some observations to consider in the future VRLab experience.

Regarding the planning and design phases:

- Besides training the students on the technological aspects involved, it is extremely important to carry out professional training for teachers on: technological skills; digital skills; and active teaching methodologies;
- Additional time for blended learning activities should be taken into consideration;
- Since it is never the technologies themselves that are more effective, the quality of the pedagogical proposal is what guides their use in educational activities;
- Students' outcomes are strictly connected to their motivation, which should be explored in more depth, and partly by using an initial student profiling (diagnostic evaluation) to discover their disposition to learn, learning style, background, attitudes, etc.;
- There is the need to strengthen students' support, guidance, and tutoring by defining clear guidelines to be delivered both in the technological environment (e.g., online instructions) and face-to-face, when possible;
- The design of a VR tool promotes opportunities for co-planning between designers in the educational field and technologists;
- HMDs are the most common part of a VR configuration but in the last years several input devices and innovative user interfaces have been developed, which require an in-depth exploration to understand the real benefit from a pedagogical perspective. For example, one of the obstacles highlighted in the literature is motion sickness, which continues to be a problem for some users, although later improvements in the refresh rate of the HMDs and the publication of general guidelines can be adopted to produce minimal VR sickness;
- The application has to be supported by empirical evaluations during the implementation phase, in order to avoid disparate treatment when using VR;
- Attention needs to be paid to the design phase of the intervention (use of systematic instructional design), which is more important than the question of which media to choose or its characteristics. In particular, media should support and promote interaction, as the inclusion of multiple media in the same educational project does not seem to bring further or incremental advantages in terms of greater learning effectiveness;
- Virtual Reality training is more effective than traditional training in developing technical, practical, and socio-emotional skills because the students learning in VR environments are able to make better use of inputs and time, avoiding performance errors;
- Real tasks, connected to their every-day environment, and tasks where problems can be solved with reasoning should be preferred, making students accountable for their learning and aware of the fact that their skills will be employed in future work and social-life related contexts.

Regarding the teaching phase:

- The blended-learning situation requires a well-integrated and trained team able to stimulate meaningful learning, by presenting information in a clear way while promoting the development of technical, social, and emotional skills, and including different types of students, in the same way one would do in traditional learning contexts;
- Small group work and collaborative learning activities, stimulating active - inquiry and problem-based - learning, are even more preferable within online learning environments;
- In blended learning contexts, not only the time of teaching activities but also the time spent on the content and the processing of assignments is greater than the time employed when working only face-to-face; that said, improvement is not measured against the time spent online but rather occurs through interactive learning, which should occur especially in totally online or hybrid situations, avoiding feelings of isolation.
-
- Regarding the evaluation phase:
- It is necessary to develop a valid theoretical and methodological framework for the design and evaluation of blended learning from an evidence-based research perspective;
- Moderator variables influencing the identified effects are to be employed;
- Rigorous research and evaluation models should be used;
- (Fine-grained) Data from the online interactions of the participants in the research should be included;
- Research on effectiveness and efficiency should be carried out with regard to the costs of blended learning;
- Reflective processes should be enhanced, not only on what has been learned but mainly on how it has been learned and on the learning strategies used (formative evaluation);
- Summative evaluation should also be enhanced as triangulation of viewpoints: hetero-evaluation by teacher; self-evaluation by student; peer-evaluation between students; co-evaluation between teacher and students.

7. Discussion and Conclusions

An opinion in the educational community, and society at large, that the 2020 lockdown has reinforced is that online learning could be the future of education. In this case, VRLabs have similar benefits to traditional offline labs with real equipment (Wiesner & Lan, 2004). It could be argued that properly adopted VR-based courses could potentially raise good, qualified specialists all around the globe, not only in local regions, thus democratising education in hands-on skills. A remote course based on a VRLab could be used to transfer knowledge where it is effectively required - to prepare learners to tackle natural disasters or medical interventions, for example. The use cases are innumerable.

However, VR includes complex and expensive technologies. A decision for their use must be based not on technological hype but on scientifically validated outcomes. In addition, VR devices cannot be adopted instantly by teachers and students because they are not yet as intuitive and straightforward as a typical personal computer. To prepare teachers and students to the use of these technologies and to introduce VR smoothly in the classroom, three steps are required:

1. Creating training plans for teachers and lecturers on how to prepare courses for VR;
2. Creating a framework that would allow teachers to easily prepare their material and quickly adapt it to VR;
3. Not overloading students with the need to familiarise with VR in a short time. There should be the possibility for them to still use classical methods, even partially, in order to get through the course.

In recent years, technological advances, coupled with the proliferation of affordable hardware and software, have made VR more commercially feasible than ever. Many investments into these new devices will continue to fuel the market, which will grow in the coming years. VR will impact the world around us in several exciting and beneficial ways, but two are the important aspects to consider for its improved adoption.

The first one is the need for more ways to design efficient and engaging entertainment. Software companies must develop tools which simplify the VR experience-making process for teachers and students. Today, there are several advanced tools to create a hyper-realistic VR environment, but they are for software developers and artists. Creating a new 3D/VR scene authoring tool will allow multiple and different stakeholders to create and manipulate virtual spaces in collaboration, either recreating real-world scenes or constructing new digital environments using their imagination. The objective must be to develop an immersive, collaborative, and open authoring tool software that can assist teachers in building a VR lesson. The tool must feature an intuitive and easy-to-use graphical user interface (GUI) appropriate for non-expert users, allowing them to position 3D contents in the virtual environment and simultaneously view and manipulate scenes of interest. This immersive VR content creation approach must enable teachers and students to reach out, grab, and manipulate objects just as they would do in real life. Working directly in a virtual environment will provide users with a sense of scale necessary to create a realistic scene, while using appropriate tools will enable them to build environments with natural motions and interactions.

The second aspect is the possibility for users to take rich data from various data formats, such as building information models (BIM), and send them to a VR application. The integration of diversified 3D models will enable the integration of dissimilar models from photogrammetry, laser scanning, or 3D modelling software, incorporating heterogeneous formats, scales, and styles into the same VR scene. This feature will emphasise the use and reuse of 3D content. As a result, rather than building 3D content on a 2D screen, teachers could quickly import high-quality contents to better communicate their ideas and intent to students.

Having confirmed their potential through the critically reviewed literature in the field, this paper was aimed at highlighting not only the technological requirements of VRLabs in order for them to be more consciously adopted in the future academic environment, but also the pedagogical criteria to keep in mind when planning a VRLab-supported educational experience or, even, an educational experience occurring completely from the distance, with the VRLab acting not only as a temporary substitute for practical classes or in blended/hybrid learning situations, but as the only available 'virtual classroom'.

Reflecting on the experience carried out with VRLabs in the light of the most recent acquisitions of the scientific literature on the subject was useful to propose some criteria for the design of future VRLabs aimed at encouraging the development of effective learning. In fact, the explanation of the training activities carried out at the University of Basilicata through the StreamFlowVR tool in the pre-pandemic academic year is presented as an opportunity for the improvement of the forthcoming VRLab planning. Unquestionably, despite the fact that the experience presented in Section 3 pertains to the field of hydraulics engineering education, these observations cannot remain in entirely separate epistemological compartments (technologists, engineers, media education experts) but need the interdisciplinary perspective of a laboratory for re-thinking and re-designing the practices implemented.

This paper does not intend to and cannot answer all the questions on the subject nor offer a training model through the VRLab. However, re-reading the experience from different heuristic perspectives can enable both the Authors and the readers to find themselves in the questions, perplexities, and proposals that, starting from a concrete experience, this work has tried to explain.

In the field of media-education, today's challenge concerns: the understanding of teaching and learning methods in large part due to the pervasiveness of new technologies; the emergence of new cultural models that profoundly modify the teaching-learning experience; and the consequent need for teachers to have to adapt their teaching methods (Castro et al., 2020; Griffin & Care, 2015). However, a central theme is the teachers' acknowledgment of the transformation that is taking place in the new generations of students, with reference to the cultural models for which meaning is attributed to learning practices mediated by new technologies (Castro et al., 2020; Fullan & Langworthy, 2011; Martín-Gutiérrez et al., 2017). It is thus essential to explore the cultural changes referring to the modalities of teaching and learning, so as to be able to re-calibrate planning, teaching, and evaluation while promoting digital competence as an indispensable prerequisite for carrying out educational activities based on new technologies.

As Caena and Redecker (2019) and Castro et al. (2020) underline, "Teaching strategies need to change, along with the competence profiles teachers need to develop, so as to deploy innovative pedagogies and empower responsible learners". (Caena & Redecker, 2019, p. 356).

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Students in Italian online universities: enrollments time series analysis from 2005 to 2021

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Abstract

The advent, in 2004, of online universities in Italy followed the global trend of open and distance learning institutions. Within a brief span, the authorization of as many as 11 online universities was granted. Despite ongoing regulatory revisions and a prevailing skepticism regarding the actual quality of education these institutions furnish, student enrollment continues to rise annually. This study explores enrollment trends in Italian online universities from their inception through 2021, considering concurrent enrollment trends in traditional public and private universities. Additionally, we examine in detail the gender composition, subject areas of degree programs, and, most importantly, the geographic origins of enrolled students.

KEYWORDS: Online Universities, Distance Education, Quality Assurance, Italian University System, Students' Enrollment.

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1. Introduction

In this study, we analyze the enrollment trends in Italian online universities compared to public or private ones that deliver courses in the traditional mode. The analysis considered gender composition, subject areas of degree programs, and geographic origins of enrolled students since the early 2000s (when online universities in Italy were first established) till 2021.

Universities and colleges began experimenting with online courses in the early to mid-1990s, with the introduction of the Internet and the development of digital technologies, but it was in the early 2000s that they started to gain traction (Kentnor, 2015).

At the beginning of 2000, the role and the pedagogical, economic, and organizational implications in the education and training systems that open, digital and distance learning will have to assume were almost clear. By that time, distance education occupied an important role in more regions of the world, where single-mode public institutions were founded, traditional institutions passed to dual-mode, and the interest of private institutions or founders came to the fore (Patru & Khvilon, 2002).

Defined as a method of teaching where the student and teacher are physically separated, still today, *distance education* concerns the utilization of a combination of technologies: correspondence, radio, TV, and CD-ROM, Internet-based information technologies, and World Wide Web (Roffe, 2004; Zawacki-Richter & Jung, 2023).

This term overlaps with most recent *online education*, but not all distance education is online, and not all online education is via distance; online education can be considered a "type" of distance education, the more recent.

Online universities (also known as virtual universities, virtual campuses, off-campus universities, distance universities, or cyber universities) refer to institutions that offer higher education online courses and can have one or more physical sites. Some conventional

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universities provide online courses in addition to traditional offerings although they are not virtual.

Speaking of universities, the adjective *open* is sometimes used as a synonym for *online*, but the overlapping is not complete also in this case. The first open universities were established more than fifty years ago with the objective of inclusion for all people who, for various reasons (inability to access schooling, lack of resources or qualifications etc.) could not attend a traditional university. These institutions are based on an open-door academic policy, with minimal or no admission requirements (Garavaglia & Pasta, 2021). Distance education added flexibility to this model, making higher education available also from remote locations, offering possibilities (sometimes second opportunities) to adults, workers, people with disabilities, dropouts, and so on. Today, they are spread worldwide (see Table 1 for a non-exhaustive list), including developing countries such as Nigeria, Argentina, and India where there is Indira Gandhi National Open University, one of the biggest in the world. Some open universities are considered *mega* universities based on the fact that their enrollment is more than 100 thousand students (Quayyum & Zawacky-Richter, 2018).

Table 1 - A (not-complete) list of open universities in the world.

University	Type	Headquarters	Inception
Universidad Abierta Interamericana	private nonprofit	Argentina	1995
University of the West Indies Open Campus	public	Barbados	1960
Botswana Open University	public	Botswana	2011
Athabasca University	public	Canada	1972
Télé-université	public	Canada	1972
Thompson Rivers University, Open Learning	public	Canada	2005
The Open University of China	public	China	2012
Universidad Nacional Abierta y a Distancia	public	Colombia	1981
Open University of Cyprus	public	Cyprus	2002
Hellenic Open University	public	Greece	1992
Indira Gandhi National Open University	public	India	1985
The Open University of Japan	private	Japan	1983
Korea National Open University	public	Korea	1972
Open University Malaysia	private	Malaysia	2000
Open university of Mauritius	public	Mauritius	2012
Universidad Abierta y a Distancia de México	public	Mexico	2009
Open Universiteit of the Netherlands	public	Netherlands	1984
National Open university of Nigeria	public	Nigeria	2002
Virtual University of Pakistan	public	Pakistan	2002
Universidade Aberta of Portugal	public	Portugal	1988
Universidad Nacional de Educación a Distancia (UNED)	public	Spain	1972
Universitat Oberta de Catalunya (UOC)	private	Spain	1995
The Open University of Tanzania	public	Tanzania	1992
Sukhothai Thammathirat Open University (STOU)	public	Thailand	1978
The Open University	public	UK	1969
Open University of Human Development “Ukraine”	public	Ukraine	1999
Taras Shevchenko National University	public	Ukraine	2017
Intercultural Open University Foundation	private	US	1981
Zimbabwe Open University	public	Zimbabwe	1999

Online education's popularity is largely attributed to its flexibility, aligning with the goal of inclusion. This mode of learning allows students to engage with their coursework on their own schedules, from any location globally. They have access to course materials, multimedia resources, and interactive activities through digital technologies. Additionally, they can collaborate with instructors and peers in virtual environments. This flexibility is particularly beneficial as it enables students to reside in their preferred locations, harmonizing their educational pursuits with existing work and family responsibilities. This approach also circumvents the challenges associated with the student rental market, an issue that has become increasingly pressing in Italy recently.

Online education, while presenting challenges such as the necessity for learners to be self-directed and motivated, has seen significant advancements in information and communication technologies. These advancements make online learning more viable from technological, economic, and operational standpoints (Palvia et al., 2018). Achieving cost efficiency in this domain often hinges on massive enrollments and the effective utilization of technology, strategies that typically entail substantial initial investments and yield benefits over the long term (Paul, 2023).

Furthermore, online and distance education, with their lower physical infrastructure requirements and associated costs, are increasingly viewed as solutions to meet the growing global demand for education. This demand is driven by the rising world population and concerted efforts by governments and policymakers to promote education, innovation, and lifelong learning (Qayyum & Zawacki-Richter, 2019).

The proliferation of distance education varies across countries, influenced by distinct policy decisions, government regulations, and the ways in which nations and their educational systems respond to the overarching process of digitization (Qayyum & Zawacki-Richter, 2018).

We start by exploring the evolving landscape of open and online university education globally and within Europe, outlining key trends in enrollment and diffusion. This overview provides a broader context, highlighting how various regions and countries are adapting to and embracing digital education platforms.

After establishing this international and European backdrop, the paper will then narrow its focus to the Italian context.

Brazil

In Brazil, we are assisting a general increase of enrollments in higher education (9 million, around +33 percent from 2012) together with a diffusion of the private sector, representing 88 percent of HE institutions (32 percent, private nonprofit; 56 percent, private for-profit).

Distance education enrollments achieved more than 4 million in 2022, which is 45.9 percent of total degree enrollments. The public institutions covered only 4 percent of distance learning course enrollments in the same year.

Between 2012 and 2022, the percentage of first-year students enrolled in distance learning degree courses increased by 288.8 percent, while in face-to-face mode, there was no growth but a decline of -13.7 percent (República Federativa do Brasil, 2023).

United States

In the United States, after a general increase in university enrollments from 2000 to 2010, a decline began from 2010 onward, affecting undergraduate enrollment mostly instead of growth in post-baccalaureate courses. In 2021, 61 percent of the 15 million undergraduate students attended a distance education course; those enrolled exclusively in distance education mode are 28 percent. For post-baccalaureate, 56 percent of the 3 million enrolled have participated in at least one distance education course, and 40 percent attended exclusively distance education programs (NCES, 2023).

Compared to 2015, the percentages have greatly increased: undergraduate students enrolled in single courses represented 29 percent, and exclusively in distance education, 12 percent; post-baccalaureate students in single course, 34 percent, and exclusively in distance education, 26 percent (McFarland et al., 2017).

In fall 2021, for-profit institutions gained the highest percentage of distance education enrollments on those in their courses, although students choosing this type of institution is the lowest compared to public and private nonprofit institutions (5 percent). Anyway, distance education enrollment rates have increased in public, for-profit and nonprofit institutions with the highest percentages in the first one (NCES, 2023; McFarland et al., 2017).

Asia

In Asia, distance education allowed increasing access to and equity in education, particularly at the higher education level. By 2011, around 70 open universities offered online learning mode courses, together with printed and multimedia learning materials, broadcast radio and television, and an increasing number of traditional schools and for-profit providers offering distance education. South Korea has the Korea National Open University (137 thousand enrollment) and 19 cyber universities (147 thousand enrollment); Malaysia has at least two open universities and one cyber university, and open universities are also in Thailand, Japan, Sri Lanka, Philippines, and Indonesia (Belawati, 2022; Ministry of education of Korea, 2023).

The trends in India and China, the countries with the highest populations in the world, deserve special mention.

India

The educational system in India (Government of India, Ministry of Education, n.d.) has dizzying numbers: around 41 million students were enrolled in higher education in 2020-21 (+21 percent from 2014-15) in more than 56 thousand universities, colleges, and other HE institutions.

Distance enrollments represented about 11 percent of the total enrollment in higher education. In particular, enrollments in distance mode at universities corresponded to 51 percent of university enrollment, of these 65 percent at undergraduate level and 28 percent at postgraduate level.

In 2020-21, 16 Open universities (1 Central University, 14 State Universities, and 1 State Private University) and 112 Dual Mode Universities offered education through distance mode (Government of India, Ministry of Education, n.d.). The Central Open Universities, the already cited Indira Gandhi National Open University (IGNOU), which defines itself as the world's largest university in terms of enrollments, recorded about 1.3 million enrollments in a.y. 2021/22 (+200 thousand since 2017) (IGNOU, 2022).

China

In China, the Ministry of education declares that in 2022 there were 46 million students in all higher education institutions and over 3 thousand HE institutions (Ministry of education of China, 2023).

In the country's official statistics pages, 8.7 million enrollments as web-based undergraduates are recorded in 2021 compared to 6.2 million in 2013 (Ministry of education of China, 2022; 2014).

The Open University of China, as a governance initiative derived from China Central Radio and TV University (CCRTVU), offers degree and non-degree courses together with many local open universities (Li & Chen, 2019).

Australia

Moving to Australia, today, 26 universities delivering undergraduate and postgraduate degrees, university certificates, pathways and pre-university, single subjects, microcredentials, and short courses make up Open Universities Australia, a nonprofit organization founded in 1993 (Latchem, 2018), which in its three decades of existence, has provided a wide catalogue of higher education programs to 500,000 learners.

Africa

The open universities of Tanzania, Nigeria, Mauritius, Botswana, Zimbabwe are located in Africa, a continent that has a lower gross enrollment ratio in tertiary education (Sub-Saharan Africa = 9 percent, 2021) but also a higher percentage of young population (Sub-Saharan Africa, 0-14 ages = 42 percent, 2022) that hopefully will access to tertiary education in the coming years (The World Bank, 2023a; 2023b).

The best-known university with a longer history in distance education is University of South Africa that annually gives study opportunities to over 370,000 students from South Africa and about 110 countries in Africa and other countries in the world. Traditional universities deliver online programs, for example, the University of Pretoria in South Africa (Prisloo, 2019), Mulungushi University in Zambia, and Kenyatta University in Kenya. Private intra-continental online campuses are offering online education, such as Botho University (campuses: Botswana, Lesotho, Namibia, Eswatini, Ghana) or Unicaf University (licensed in Malawi, Zambia, Uganda, Zimbabwe).

Europe (Spain and United Kingdom)

Europe has seen a growing of open public universities since the 70s' such as The Open University in UK, Universidad Nacional de Educación a Distancia (UNED), and later, in the 1980s, Open Universiteit of the Netherlands, and Universidade Aberta of Portugal (see Table 1). Currently the scenario of public European open universities is enriched in the Greek area by Hellenic Open University founded in 1992 and the smaller Open University of Cyprus (2002), or by the Ukrainian universities called Open University of Human Development "Ukraine" (1999) and Taras Shevchenko National University (2017). Among the private open universities we cannot fail to mention the Universitat Oberta de Catalunya (UOC) established in 1995 and among the best known in the Ibero-American context.

Many European universities are expanding the programs delivered in a fully online or hybrid mode. Examples are FernUniversität in Hagen (Germany), University of Oxford (UK), European University Cyprus, and Swiss School of Business and Management (Switzerland).

We assist in developments in ICT, the growth of marketization, and the increase in private and for-profit online companies involved in education (Sursock, 2015).

In 2013, almost all of the 249 European HE institutions (among 800) from 38 European systems (EU and wider Europe) in a survey from the Europe University Association (EUA) declared to have started to use e-Learning: 91 percent offered blended learning integrating traditional teaching and 82 percent online courses. However, initiatives were mainly introduced by individual faculties and staff members; only half of the respondents indicated to use e-Learning throughout the institution; the distance education activities of less than one third of institutions involve all or most of students, and only 20 percent in all disciplines. The initiatives' implementation seemed inconsistent and patchy, so it appears to be a recent development and a cautious exploration (Gaebel et al., 2014). Compared to 2014, in a following survey administered to European HE institutions in 2020 (Gaebel, 2021; 2023), institutional approaches towards distance learning tend to be more centralized, systematic and strategic. 88 percent of 368 institutions have a strategy for distance education (63 percent in 2014), and 57 percent of the respondents reported that digitally enhanced learning and teaching were widely used throughout their institution in 2020 (53 percent in 2014).

Situations in each country deserve an in-depth study, and they differ in policies, development possibilities, and educational systems.

In Spain, only six of the 86 universities in the country are distance education universities; of these, only one, Universidad Nacional de Educación a Distancia (UNED), is a public university. In a.y. 2021/22 in the the country, the first-year students enrolled in courses in online mode represent 17.3 percent (total first-year students: 1.7 million). Some minor changes can be recorded compared to a.y. 2011/12, when the percentage was 15.2 percent (total first-year students: 1.6 million) (Ministerio de Universidades, Gobierno de España, 2023; Ministerio de Educación, Cultura y Deporte; 2012).

Report on the United Kingdom by the Higher Education Statistics Agency (HESA, 2023) shows that in a.y. 2021/22, 2.8 million students were enrolled in 285 HE providers. Of these, 153 entities were offering distance education, reaching 9.7 percent of students. The UK Open University covered 150 thousand students, 5.3 percent of all British students and 54.4 percent of those in distance education. Few years before, in a.y. 2014/15, 2.3 million students were enrolled in higher education in 226 institutions; 8.3 percent of students attended distance education courses in 112 institutions; UK Open University had 132 thousand students, that is 5.7 percent of the total enrollments and 68.7 percent of distance education enrollments. Over the years, learners enrolled in the Open University have increased, but it involves fewer percentage of students in the UK.

Having examined the global and European landscapes of online and open university education, we now turn our attention back to Italy.

In Italy, some public universities, together with traditional degree courses, offer blended or online programs since decree No. 635/2016 by Ministry of education, university and research that distinguished them into four typologies based on the percentage of online activities proposed: traditional courses till 10 percent; blended courses with less than 2/3; mainly online with more than 2/3; fully online with all activities at a distance. In all cases, exams are given face-to-face even if the COVID pandemic changed this scenario.

In the country, there aren't public fully online (nor open) universities but 11 private universities (Table 2), whose enrollment trend is the focus of the paper. Their institution has been proposed by decree dated 17 April 2003 by the Italian Ministry of education (in Italy, as understood, the institution of new degree courses and universities is managed through a centralized process). They were established in the following three years after the decree. The headquarters of six of them are in Rome. The others are distributed in the North (1, Lombardia), Center (2, Abruzzo and Toscana), and South (2, Campania). Three of them are under public control.

Table 3 shows the number of courses delivered by Italian traditional and online universities in a.y. 2023/24 and divided according to the four types described above. See Table 4 for the correspondence between Italian and English terms in identifying higher education programs.

Unexpectedly, online universities offer courses principally in mainly online mode; in fact, 143 of 155 courses (92 percent) fall into this category, evidencing that they have abandoned fully online mode and moved toward mainly online including on-campus activities. Traditional universities offer 96.5 percent of courses (4,913) in the first category (face-to-face). The remaining 3.5 percent is divided among blended, mainly, and fully online modes, with a clear predominance for blended courses representing 2.9 percent (149) of those by traditional universities.

Traditional universities prefer to deliver master's courses in the blended and mainly online mode more frequently; instead, 4 of the 5 courses in the online mode are bachelor's courses. Online universities, on the other hand, have more bachelor's courses in the mainly online mode. There is a tie in the online mode between bachelor's and master's programs delivered by online universities.

As we will see in Section 3, the enrollment percentages in these universities, so called "telematiche", go from a few hundred to tens of thousands. Beyond online delivery mode, these universities frequently have in common: year-round open enrollment, discounts in tuition for particular categories or conventions, unrestricted access to degree programs, provision of numerous professional development short programs, tutoring processes, and simplified access to single courses.

Table 2 - Description of Italian online universities (data from universities' websites, USTAT and CercaUniversità, open data services of Ministry of Universities; the values in the last column refer to 2022.
T = tenured professors and researchers; C1 = contract faculty; C2 = contract faculty from other universities).

University	Establishing decree	Headquarters	Sites	Courses	Faculties/Main Themes	Professors/ researcher/ faculty
Università telematica Guglielmo Marconi	1.3.2004	Roma	25 sites for guidance and exams	12 bachelor's and 10 master's courses, 1 five-years course, 10 basic and 17 advanced specialization courses + others 30 with 24ORE Business School, Ph.D. programs, 39 training courses for students and professionals, more than 30 specialization and short courses for teachers	Faculties in Humanities, Law, Political science, Economics, Engineering, Education Departments in Humanities, Law, Economics, Engineering	68 (T) 134 (C1) 3 (C2)
Università telematica Unitelma Sapienza	7.5.2004	Roma	27 teaching centers	4 bachelor's and 3 master's courses, 1 five-years course, more than 50 specialization courses (39 basic and 11 advanced), 35 short training courses	Law, Economics, Computer Science, Psychology, and Archaeology	33 (T) 30 (C1) 22 (C2)
Università telematica Leonardo da Vinci	27.10.2004	Torrevecchia Teatina (CH)	9 sites for exams	1 bachelor's, 1 master's, and 1 five-year courses, Ph.D. programs, 23 basic and 1 advanced specialization courses	Humanities, Law, and Economics	1 (T) 30 (C1) 90 (C2)
Università telematica internazionale Uninettuno	15.4.2005	Roma	105 national/ international technological poles 26 sites for exams in Italy	6 bachelor's and 7 master's courses with more curriculums, Ph.D. programs, 29 specialization courses, around 20 short learning programs, a program for refugees	Faculties in Cultural Heritage, Economics and Laws, Engineering, Psychology, Communication Sciences	34 (T) 339 (C1) 476 (C2)
Università telematica degli Studi IUL	2.12.2005	Firenze	More than 40 sites	5 bachelor's and 2 master's courses, 15 basic and 1 advanced specialization courses, and around 15 training courses	Psychology, Sport, Economics, Communication sciences	8 (T) 122 (C1) 11 (C2)
Università telematica e-Campus	30.01.2006	Novedrate (Co)	58 sites, 34 guidance points, approximately 500 study centers	15 bachelor's and 9 master's courses, 1 five-years course, Ph.D. programs, more than 100 specialization courses, around 50 short training courses for teachers, healthcare and public administration workers, CME courses	Faculties in Law, Engineering, Economics, Psychology, and Humanities	103 (T) 305 (C1) 30 (C2)
Università telematica Giustino Fortunato	13.4.2006	Benevento	4 sites for exams 29 guidance centers	5 bachelor's and 3 master's courses, 1 five-years course, Ph.D. programs, 20 basic, 6 advanced, and 2 international specialization courses, 26 short courses and teachers' training	Psychology, Law, Economics, Sport Science, Education, and Engineering	44 (T) 73 (C1) 0 (C2)
Università telematica Pegaso	20.4.2006	Napoli	82 sites for exams around 1,000 e-Learning Center Points	8 bachelor's and 5 master's courses, 1 five-years course, Ph.D. programs, 95 basic, 23 advanced specialization courses, 40 training courses, teachers' training	Faculties in Economics and Law, Engineering and Informatics, Education and Sports	64 (T) 335 (C1) 0 (C2)
Università telematica San Raffaele	8.5.2006	Roma	50 sites for exams	4 bachelor's and 3 master's courses, Ph.D. programs, 26 basic and 30 advanced specialization courses and for teachers' training	Fashion and Industrial Design, Economics, Education, Psychology, Health, Food and Sport Sciences	57 (T) 129 (C1) 2 (C2)
Università telematica Mercatorum	10.5.2006	Roma	66 sites for exams	14 bachelor's and 5 master's courses, 24 basic and 8 advanced specialization courses, Ph.D. programs, projects for schools and enterprises, teachers' training	Economics, Engineering, Humanities, Design/Fashion, Psychology, Law, and Political/Social/ Communication Science	60 (T) 158 (C1) 24 (C2)
Università telematica Niccolò Cusano	10.5.2006	Roma	83 learning centers	12 bachelor's and 14 master's courses, 1 five-years course with more curriculums, Ph.D. programs, around 200 specialization courses and nearly 70 short programs, teachers' training	Engineering, Law, Economics, Psychology, Political/Social Science, and Education, Sport, Humanities, Health	109 (T) 737 (C1) 7 (C2)

Table 3 - Number of courses by typologies, a.y. 2023/2024. (Source: Universitaly).

Courses and Universities	Bachelor's	Five/Six-year courses	Master's	Total
Traditional (less than 10%)	*2254*	*347*	*2312*	*4913*
Traditional universities	2254	347	2312	4913
Online universities	0	0	0	0
Blended (less than 2/3)	*55*	*4*	*90*	*149*
Traditional universities	55	4	90	149
Online universities	0	0	0	0
Mainly online (more than 2/3)	*90*	*7*	*69*	*166*
Traditional universities	10	1	12	23
Online universities	80	6	57	143
Fully online	*10*	*1*	*6*	*17*
Traditional universities	4	0	1	5
Online universities	6	1	5	12
Total	*2409*	*359*	*2477*	*5245*
Traditional universities	2323	352	2415	5090
Online universities	86	7	62	155

Table 4 - English translation of the Italian terms referred to higher education programs adopted in the paper.

English translation	Italian term	Description	ECTS
Bachelors' degree courses	Laurea (1° ciclo)	Three-year basic programs accessed with a high school diploma	180
Masters' degree courses	Laurea Magistrale/ Specialistica (2° ciclo)	Two-year advanced programs accessed with bachelors' degree	120
Five or six-year courses	Lauree a ciclo unico	Long programs such as in Medicine or Law accessed with a high school diploma	300/ 360
Basic specialization courses	Master di primo livello	Program lasting one or two years on a specialized topic accessed with bachelors' degree	60/ 120
Advanced specialization courses	Master di secondo livello	Program lasting one or two years on a specialized topic accessed with masters' degree or five or six-year courses	60/ 120
Training courses or short courses	Corsi di perfezionamento/ aggiornamento/formazione	Courses of various kinds that do not always require a degree for entry and that address specialized topics often for professional training	-

The first online university officially recognized by the Italian Ministry of education in 2004 is "Università telematica Guglielmo Marconi" which currently has six faculties and four departments (Humanities, Law, Political science, Economics, Engineering, and Education), and 12 bachelor's and 10 master's degree, 1 five-years course, Ph.D. programs, teachers training initiatives, around 30 basic and advanced specialization courses and more than 30 others in collaboration with another private entity, 24ORE Business School.

In the same year, the ministry also instituted the "Università telematica Unitelma Sapienza" and "Università telematica Leonardo da Vinci". Both universities are linked to public ones: the first one is managed by a consortium whose majority shareholder is Sapienza University of Rome (a mega university) and offers degree courses in Law, Economics, Computer Science, Psychology, and Archaeology. The second one, the smallest for enrollments, was wholly owned by the public University of Chieti and offers three degree courses in Humanities, Law, and Economics together with Ph.D. programs and specialization courses.

“Università telematica internazionale Uninettuno” and “Università telematica degli Studi IUL” were established in 2005.

Uninettuno started from Nettuno Consortium, a network of 43 Italian and foreign universities already active in distance education since the 90s that provided a degree to thousands of students via television and internet. It maintained an international approach in the years with a focus on the Mediterranean area: students come from 167 countries around the world, courses are taught in five languages (Italian, French, English, Arab and Greek), and 105 National and International Technological Poles are distributed globally (26 sites for exams in Italy). It offers nowadays courses (6 bachelor’s and 7 master’s degree courses with more curriculum, 29 specialization courses, short learning programs, Ph.D. course, a program for refugees) in Humanities, Economics, Laws, Engineering, Psychology, Communication Sciences.

IUL is currently promoted by the public University of Foggia (succeeded the University of Firenze) and INDIRE (National Institute for Documentation, Innovation and Educational Research, Ministry of Education’s research organization). The proposed courses focus mainly on Education but also Psychology, Sport, Economics, Communication sciences.

In 2006, the institution of the last six online universities completed the scenario that remains *unchanged* to date. We described them according to their institution’s data.

“Università Telematica e-Campus” is organized into faculties and offers 15 bachelor’s and 9 master’s degree courses, 1 five-years course, Ph.D. programs, numerous specialization courses also for teachers, healthcare and public administration workers. E-Campus is a provider of continuing medical education (CME) credit activities. It has around 60 sites, more than 30 accredited guidance points, and approximately 500 study centers in private secondary schools located throughout Italy to support teaching activities, enrollments, and guidance activities.

“Università Telematica Giustino Fortunato” offers 5 bachelor’s and 3 master’s degree courses, 1 five-years course, and about 30 specialization courses and teachers’ training as well as short courses. Behind 29 guidance centers, examination sites are located in big Italian cities: Milan, Rome, Palermo, and Padua.

“Università Telematica Pegaso”, with its vast network of educational centers and examination sites that extend nationwide (+80) and around 1,000 e-Learning Center Points qualified for carrying out teaching, educational and training projects linked to the territory, is the largest online university in Italy. Pegaso currently offers 14 degree programs and around 160 specialization and training courses in Law, Informatics, Engineering, Tourism, Economics, Sports, Humanities, Health, Education, Philosophy, Linguistics, and so on.

“Università Telematica San Raffaele” offers 4 bachelor’s and 3 master’s degree courses, Ph.D. programs, and specialization courses focusing on Fashion and Industrial Design, Economics, Education, Psychology, Health, Food, and Sport Sciences.

“Università Telematica Mercatorum” started from a public-private partnership with the system of Chambers of Commerce and deals with training on entrepreneurship, the labor market, and corporate law. The main fields of courses (14 bachelor’s, 5 master’s, 1 five-years course, 32 specialization courses, Ph.D. programs, projects for schools and enterprises) regard Economics, Engineering, Humanities, Design/Fashion, Psychology, Law, and Political/Social/ Communication science. It has around 60 sites for exams throughout the national territory.

“Università Telematica Niccolò Cusano” formed a network of companies composed of TV, radio, a publishing house, a research center, a soccer team (Ternana), and other entities. It offers degree programs (12 bachelor’s and 14 master’s) that can be attended fully online or face-to-face, Ph.D. programs, and more than 200 specialization courses. Exams can be taken online or at the central campus; more than 80 learning centers in all Italian regions (except Valle d’Aosta) provide secretarial services, counseling, computerized workstations, and classrooms.

Pegaso, Mercatorum, and San Raffaele, have joined together with other not university education companies in an expanding group in the education sector in Italy called Multiversity S.p.A., which also includes training and certification entities and have a total of 40 degree courses, 200 specialization courses, 200 examination locations, and 1,000 e-Learning center points (https://multiversity.it/).

By the end of 2022, seven online universities, namely Pegaso, Mercatorum, San Raffaele, IUL, e-Campus, Leonardo Da Vinci, and Giustino Fortunato, have formed an association of Italian online universities called United (https://www.associazioneunited.it/). The association aims to become an advisory body of the Minister of University and Research and to promote the digital transformation of the Italian university system, implementing the dialogue among universities and with local, national, and European institutions.

Even though the awareness of opportunities for innovation, inclusion, and lifelong learning represented by distance education, the establishment of online universities at first was frowned upon by some bodies such as the CUN (Italian National University Council) and CNSVU (National Committee for the Assessment of the University System), a body that was in charge of university evaluation, before ANVUR which we will introduce in a few lines. The intervention appeared to be without any planning of the university system: there were doubts (not fully resolved) about the aims of these institutions (only teaching or also research?), the number and selection of faculty and the management of changes in the programs offered (less strict than in traditional universities), the processes for assessing the quality of teaching (CUN, 2007; CNSVU, 2010).

Quality assurance of teaching, learning, and research is a hot topic for all educational providers, especially in distance and online education.

In Italy, Law No. 286 of 24 November 2006 (based on Decree No. 262/2006) established ANVUR, the Italian National Agency for the Evaluation of Universities and Research Institutes. The agency plays a central role in the accreditation and periodic assessment of universities and degree courses. ANVUR oversees the national public system of quality assessment of universities and research institutions and develops its policies according to the European Higher Education Area (EHEA) guidelines adopted in 2015 by the European Association for Quality Assurance in Higher Education (ENQA), initiating constant change and updating. ENQA documents and frameworks focus on the need to foster and facilitate student-centered approaches to a greater extent, to promote adaptable and customizable learning pathways, and to develop a system of differentiated and flexible quality assurance made of a recursive internal and external evaluation process (Figure 1; ENQA, 2005; 2008; 2015; 2020).

These processes involve public, private, and online Italian universities and aim to develop a participatory quality management system.

According to decrees on quality assurance processes and for the enhancement of the efficiency of universities (Law No. 240 of December 30, 2010; L.D. No. 19 of January 27, 2012, and subsequent decrees), ANVUR (2023a; 2023b; 2023c) defines and applies the modalities, criteria and operational guidelines in a model for evaluating and improving research and higher education systems.

While VQR is the acronym that identifies the Italian system for the Evaluation of Research Quality, the accreditation criteria and general guidelines for the planning of universities are organized in the system called AVA, which has been active in Italy since 2013. In the acronym AVA, A ("Autovalutazione" in Italian) stands for Self-assessment of universities and their courses, V ("Valutazione") for Periodic Evaluation, and A ("Accreditamento") for Accreditation. Both the last two processes are managed by ANVUR at the moment of the institution of a new degree or a new university (*Initial Accreditation*) and after, in periodic phases (*Periodic Accreditation*, at least every five years for the universities and three for courses). ANVUR updated AVA to the model of periodic accreditation of universities and courses defined AVA3 (after AVA1 e AVA2), implementing new guidelines for the Quality Assurance System of universities and their degree programs and for their evaluation in view of periodic accreditation in universities and the scopes provided by M.D. No. 1154/2021. Previous Ministerial Decrees defined the accreditation criteria (e.g., M.D. of April 17, 2003; M.D. 635 of August 8, 2016; M.D. No. 289 of March 25, 2021) and the requirements of degree courses (e.g. M.D. No. 47 of January 30, 2013; M.D. No. 987 of December 12, 2016; M.D. No. 6 of January 7, 2019; D.D. No. 2711 of November 22, 2021).

In the whole completed cycle of periodic assessment that involved traditional and online universities (Table 5), most of the latter obtained a *Satisfactory* rating (8 universities, 73 percent), only one *Fully Satisfactory* (1 percent), and two universities obtained a *Conditional* rating (18 percent). Traditional (public and private) universities received higher ratings: 7 awarded the maximum score of *Positive*, and 30 universities (38 percent) awarded *Fully Satisfactory*. The first three levels allow accreditation after five years, and the *Conditional* one implies a new accreditation in a shorter period in which the university has to overcome the critical issues found under penalty of closure. None of the traditional or online universities received an *Unsatisfactory* assessment, that means the deletion of the university (ANVUR, 2023a, p. 94).

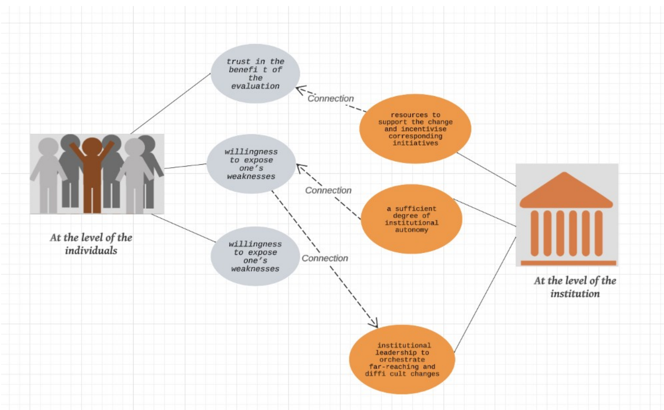


Figure 1 - Six conditions to ensure that Quality Assurance (ENQA, 2008, authors' production).

These ratings are achieved by checking the university as a whole and degree programs and attributing score to a list of criteria (M.D. No. 1154/2021; M.D. No. 6/2019; ANVUR, 2023c; 2023d) that concern both the design and delivery of courses (e.g., educational objectives and output profiles) and the management of resources (e.g., teaching staff and tutors). As clarified in the guidelines for planning of newly established courses for a.y. 2024-2025 (ANVUR, 2023c, p.15-17), for mainly or fully online courses, it is necessary to verify requirements related to methods for interaction between students and teachers, the involvement of the figures responsible for assessments (teachers and tutors); technologies and methodologies used for substituting face-to-face interaction; training for teachers and tutors to conduct online teaching; features/skills possessed by the tutors; technological infrastructure used for synchronous or asynchronous activities.

Other relevant criteria in Initial, Periodic Accreditation, and Assessment processes concern quality requirements of teaching and research. We focus, in particular, on the number and role of teachers.

In Law No. 240 of December 30, 2010, we found the internal articulation and criteria for the organization of departments in public universities to ensure an adequate number of tenured professors and researchers (more than 35).

Instead, speaking of the courses, we have to consider Annex A - Course Accreditation Requirements, M.D. No. 1154/2021. The decree calculates the minimum number of teachers according to the teaching planning in the Single Annual Forms (SUA "Scheda Unica Annuale") filled for each already accredited course that has completed at least one entire cycle of studies and for any newly established courses.

Table 6 contains the number of total and tenured teachers required for courses delivered with less than 2/3 of online activities and those delivered in mainly or fully online mode (the decree proposes other particular criteria for Health Professions courses and other selected courses which we don't mention). Professors and researchers are included in the total count; contract faculty may be counted within the maximum limit of 1/2 of the share not reserved for tenured professors. Along with these, lecturers/teachers on contracts from other universities (including foreign ones) and public research institutions or on three-year contracts even with full professor's qualifications may contribute to the teaching requirements to the limit of 1/3 of the number of total teachers.

In addition, for already accredited courses, the number of teachers has to increase proportionally to the number of students enrolled if this exceeds the thresholds established by law (Annex D, M.D. No. 1154/2021).

For online courses, legislative indications require a lower number of teachers, probably considering a reduced commitment for the teacher (to verify!), supported by tutors (disciplinary, guidance or technical).

However, if the courses reach high enrollment numbers (and this may happen in an online course where there are no constraints of classroom dimensions for universities and participation constraints for users), the number of faculty has to increase.

Table 5 - Results from periodic assessment by ANVUR for 80 traditional (public and private) and online universities (11).

Universities	**Positive**	**Fully Satisfactory**	**Satisfactory**	**Conditional**	**Total**
Final Score (*fs*)	$fs \geq 7.5$	$6.5 \leq fs < 7.5$	$5.5 \leq fs < 6.5$	$4 \leq fs < 7.5$	$fs < 4$
Traditional	7 (9%)	30 (38%)	42 (53%)	1 (1%)	80 (88%)
Online	0 (0%)	1 (9%)	8 (73%)	2 (18%)	11 (12%)
Total	7 (8%)	31 (34%)	50 (55%)	3 (3%)	91 (100%)

Table 6 - Number of teachers in traditional, blended and online degree courses (Annex A, M.D. No. 1154, 2021).

	Traditional o blended courses		**Mainly or fully online degree courses**		
Courses	Teachers	Tenured teachers	Teachers	Tenured teachers	Tutors (on subject)
Bachelors' degree	9	5	7	3	3 (2)
Masters' degree	6	4	5	2	2 (1)
Five year degree	15	8	12	5	5 (3)
Six year degree	18	10	-	-	-

At the national level, the whole number of in-service faculty members has gone from 57,305 at the end of 2012 to 61,099 in the year 2022 (+6.6 percent) according to the latest ANVUR data (2023a); 57,115 professors are employed at public universities (93.5 percent of the total); 3,402 professors at private universities (5.6 percent); 582 professors at online universities representing 1 percent of the total.

Ministerial data show that the percentage of contract faculty for public universities in 2022 is 23.3 percent, for private (online or traditional) 70.2 percent (https://ustat.mur.gov.it/dati/didattica/italia/atenei).

The most recent available data, collected from the service platforms of Italian Ministry of education and merged in the last column of Table 2, shows that there were 3639 faculty members at online universities in total in 2022. Tenured professors (582, as just said) account for only 16 percent of the total faculty at online universities. The remaining positions (3057) are covered by contract teachers, of whom 665 (18 percent) are professors from other universities, a higher number than tenured faculty.

Our research, aimed at analyzing the enrollment trend in Italian online universities, started from the analysis of the distance education practices and focused on the diffusion of online and open universities and the trends of enrollments to online courses in most populous countries of the world and Europe. We have presented in more detail the eleven Italian online universities established since 2004, their features, and courses, with particular attention to the process of quality assurance in the Italian system involving criteria on universities, courses, research, and teaching.

In the next Section, we describe the dataset and list the research questions that guided our study. Section 3 presents the results of our analysis considering enrollment trends according to gender, subject areas of degree programs, and geographic origins of enrolled students. Section 4 contains the discussion and conclusions of the research.

2. Materials and Methods

2.1 Data

We have collected data related to enrollments in bachelor's (Laurea Triennale in Italian) and master's (Laurea Magistrale in Italian) degree courses from the National Student Registry provided by the Italian Ministry of Universities through the OPENDATA service of the USTAT portal (https://ustat.mur.gov.it/).

Table 7 lists the datasets used with a short description and the variables recorded. The datasets, also analyzed in a previous study (Minerva et al., 2022), referred to the academic years from 2000/2001 to 2021/2022 (in the text, we use the beginning year to indicate the academic year, aka: 2004 refers to the 2004/2005 academic year; 2010 refers to 2010/2011, and so on). Some datasets start from 2010, and dataset X14 containing more information reaches only 2020.

Checking data consistency, we observed an underestimation of enrollments in online universities for the last academic year in the dataset, 2021/2022, due to different methods of enrollment in these entities where students can enroll during the whole year differently by "traditional" universities where the enrollments usually stop on November. By contacting the statistics offices of the online universities, we could add 59,713 students missing from the official data.

So, the number of records in the whole dataset, updated to December 6th, 2022, is just over 550,000.

For the analysis in this study, we used data starting from 2004, when the first online universities were established after the M.D. of April 17th, 2003.

A complete list of public, private, and online universities in Italy can be found in Tables 8 and 9. In particular, Table 8 presents the classification of public universities in the three geographical macro-areas into which Italy is usually divided: North, Centre, and South.

Table 7 - List and description of datasets used in the study retrieved from USTAT portal.

Dataset	Description	Academic years	Variables
X02	Enrolled by University	2000-2001 to 2021-2022	Universities, Male students, Female students
X03	Enrolled by Disciplinary Group	2000-2001 to 2021-2022	Subject groups of degrees, Male students, Female students
X06	Enrolled by Age	2010-2011 to 2021-2022	Students' birth year, Male students, Female students
X07	Enrolled by Residence	2010-2001 to 2021-2022	Residence province, Male students, Female students
X14	Enrolled by Residence, University, Group	2010-2011 to 2020-2021	Residence province, University, Subject groups of degrees, Enrolled students

Table 8 - Public universities divided by macro-regional areas (*names in Italian*).

* The Free University of Bozen-Bolzano and the University of Aosta, although not state universities, have been included among the public ones as they directly controlled by the local autonomous public institutions.
** Abruzzo and Molise (and the universities in the regions) have been classified as regions of Central Italy (from a geographical point of view) even though ISTAT classifies them as being in South Italy (from a socio-economical point of view).

Macro-area	Regions	Public universities	#
North	Valle d'Aosta, Piemonte, Lombardia, Trentino Alto Adige, Friuli Venezia Giulia, Veneto, Liguria, Emilia Romagna	Aosta*, Bergamo, Bologna, Bolzano*, Brescia, Ferrara, Genova, Milano Statale, Milano Bicocca, Milano Politecnico, Modena e Reggio Emilia, Padova, Parma, Pavia, Piemonte Orientale, Torino, Torino Politecnico, Trento, Trieste, Udine, Varese e Como Insubria, Venezia Ca' Foscari, Verona	23
Center	Toscana, Umbria, Marche, Lazio, Abruzzo**, Molise**	Camerino, Cassino e Lazio Meridionale, Chieti e Pescara, Firenze, L'Aquila, Macerata, Politecnica delle Marche, Molise, Perugia Stranieri, Roma Foro Italico, Roma La Sapienza, Roma Tor Vergata, Roma Tre, Pisa, Siena, Perugia, Siena Stranieri, Teramo, Tuscia, Urbino	20
South and regional Islands	Campania, Puglia, Basilicata, Calabria, Sicilia, Sardegna	Bari, Bari Politecnico, Basilicata, Cagliari, Calabria, Catania, Catanzaro, Foggia, Messina, Napoli Federico II, Napoli L'Orientale, Napoli Parthenope, Napoli Vanvitelli, Palermo, Reggio Calabria Mediterranea, Salento, Salerno, Sannio, Sassari	19

Table 9 - List of online and private universities.

	Universities	#
Online universities	Benevento Giustino Fortunato, Chieti Leonardo da Vinci, Firenze IUL, Napoli Pegaso, Novedrate e-Campus, Roma Mercatorum, Roma Marconi, Roma San Raffaele, Roma Niccolò Cusano, Roma UniNettuno, Roma UniTelma	11
Private universities	Bra' Scienze Gastronomiche, Casamassima LUM Degennaro, Castellanza LIUC, Enna Kore, Milano Bocconi, Milano Cattolica, Milano IULM, Milano San Raffaele, Napoli Benincasa, Reggio Calabria Dante Alighieri, Roma Campus Biomedico, Roma Europea, Roma Link Campus, Roma LUISS, Roma LUMSA, Roma Saint Camillus, Roma UNINT, Rozzano (MI) Humanitas	18

2.2 Methods

The descriptive and exploratory analysis presented here compares time series on student enrollments in Italian online universities by total, gender, fields of study, and geographical areas of origin (residence).

The study's main objective is to analyze the development of student enrollment in Italian online universities with respect to the national university system.

In particular, the analysis tried to reply to the following research questions:

1. what has been the enrollment trend in Italian online universities since their establishment?
2. what is the enrollment trend in online universities in terms of gender and disciplinary areas?
3. what are the enrollment rates in Italian online universities in terms of students' geographical areas of residence?

The study focused on the number of enrolled students in online universities. We compared those values with the general population of Italian academic students to detect to what extent this phenomenon is affecting the national educational system.

The analysis was conducted in the R v.4.2.1 environment using a computational Linux Ubuntu 20.0.4 server with an RStudio Server interface.

A complete and dynamic visualization of data realized using Flourish can be found at URL: https://public.flourish.studio/story/2137357/

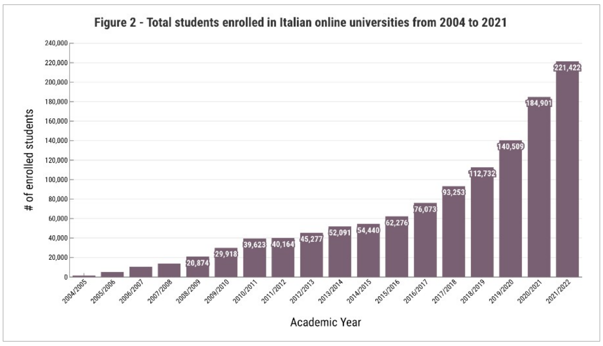
3. Results

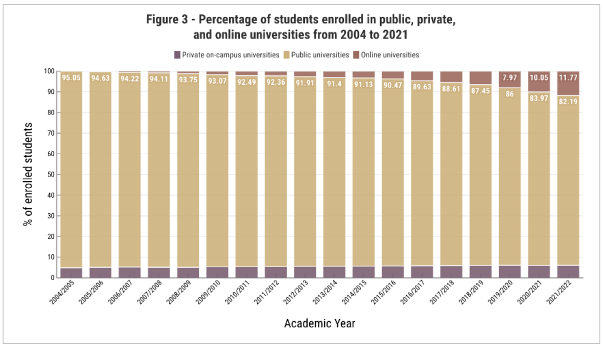
This section describes the main results of the analysis following the three research questions previously listed.

Q1 - What has been the enrollment trend in Italian online universities since their establishment?

Figures 2 and 3 show the progressive increase in enrollments of students in online universities since their establishment which, after the M.D. in 2003, became effective in 2004-2006 as said. In the academic year 2021/22, students enrolled in online universities accounted for almost 12 percent of the total number of university students in Italy, more than 220 thousand.

While the percentage of students enrolled in private universities has remained almost stable over the years, the percentage of students enrolled in online universities has gradually increased at the cost of public universities.

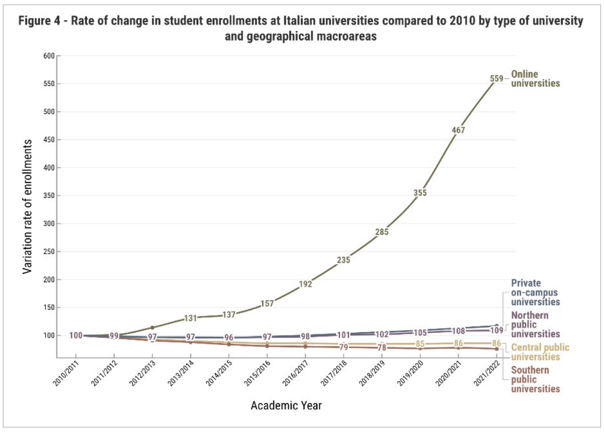


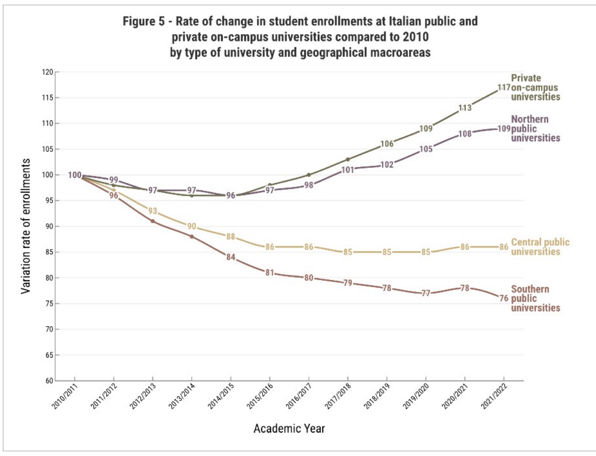


Figures 2 and 3 - Students enrolled in Italian online universities from 2004 to 2021.

Taking 2010 enrollment as a reference, private universities, both online and on-campus, see increases in student numbers compared to public universities (Figures 4 and 5). Online universities have quintupled their enrollment numbers over the past decade. The rate of change stands at 559 percent. More moderately, private on-campus universities have improved their recruitment by 17 percent.

Enrollments at public universities follow different trends depending on their geographical location. Universities in Central Italy have seen a loss of 14 percent since 2010; even worse, universities in the South have a 24 percent loss rate. By contrast, universities in the North are holding up. After a slight decrease until 2015/2016 shared by private on-campus universities, they have grown by 9 percent.





Figures 7 and 8 - Students enrolled online Italian universities by university location and kind from 2010 to 2021.

Figures 6 and 7 depict, in particular, the enrollments in each of the eleven Italian online universities.

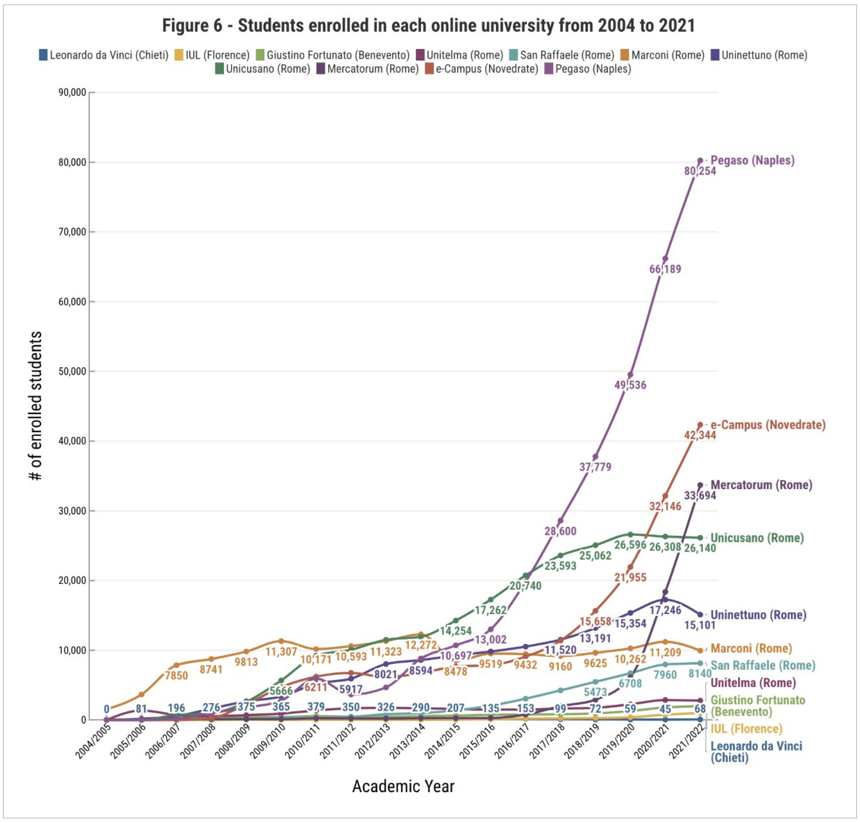
We can divide them into four categories according to the number of students in 2021:

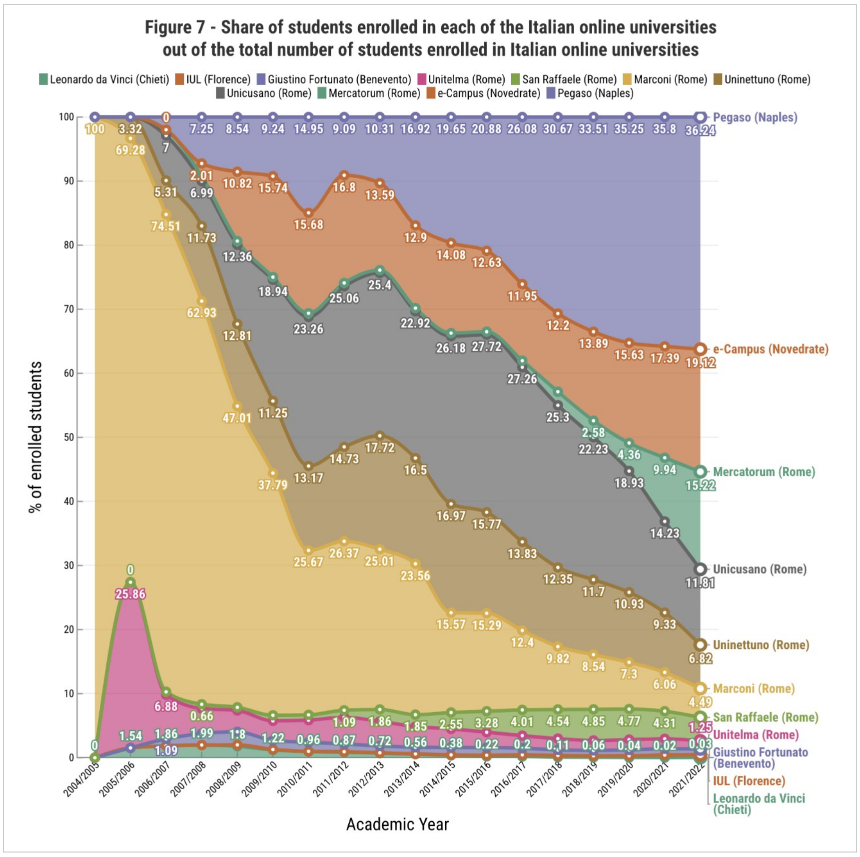
- *small* universities, till 10 thousand students;
- *medium* universities, between 10 and 20 thousand;
- *big* universities, between 20 and 40 thousand;
- *mega* universities, over 40 thousand.

Online universities of *small* dimension, till 10 thousand students, are six and together capture 10.8 percent of enrollment:

- Leonardo da Vinci, as said the smallest one, has less than one hundred enrolled students since its inception.

- IUL has around 1,000 students enrolled in degree courses, more than doubled in the last two years.





Figures 6 and 7 - Students enrolled in each online university from 2004 to 2021.

- Giustino Fortunato doubled enrollments in the last four years: without decreasing, it gathered 1,962 students in 2021, representing 0.9 percent of those enrolled in online universities.

- Unitelma, stable over the past year with previous incremental increases, collects less than 3 thousand students, covering 1.2 percent of enrollments of total online universities.

- San Raffaele counts 8,140 students, 3.7 percent of enrollments in online universities after achieving significant growth between 2015 and 2020.

- Marconi had a fluctuating trend in enrollment, with two peaks in 2013 and 2019-2020. In 2021, it collected about 9 thousand students (4.5 percent).

The only university of *medium* dimensions with around 15 thousand students is Uninettuno.

Cusano and Mercatorum are the two universities of *big* dimensions with, respectively, 26 and 34 thousand enrollments (11.8 and 15.2 percent of total).

Cusano has roughly stable enrollment numbers as of 2018 after experiencing a substantial growth phase from 2014.

On the contrary, Mercatorum is the university with the highest enrollment increases as Pegaso and e-Campus (*mega* universities). Suffice it to say that it doubled enrollments in one year and quintupled in the last two years.

Pegaso, which had an impressive growth rate since 2015, covers 36 percent of online university enrollment in Italy, with 80,000 students in 2021. It is followed by e-Campus, which gained 20 thousand new enrollments in two years, doubling the number of students to 42,344. Together they gather 122 thousand students, 55 percent of students enrolled in online universities.

All online universities have seen an increase in enrollment since their opening except for Marconi, which has a less stable trend, and Uninettuno, which has lost students in the past year.

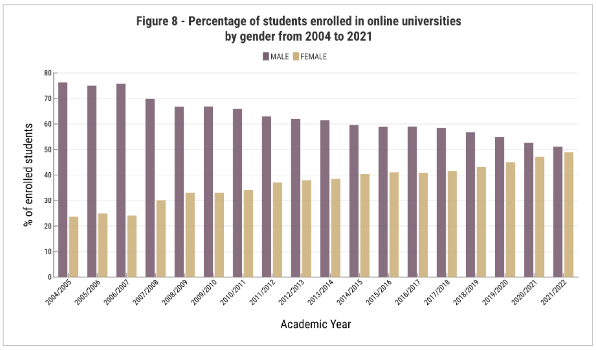
Q2. What is the enrollment trend in online universities in terms of gender and disciplinary areas?

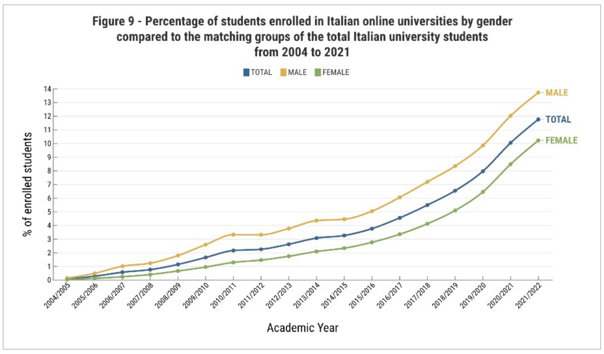
<u>*Gender*</u>

Since 2004, the prevalence of enrolled students has been men.

The trend has changed over the years, reaching a tie. In 2021, the percentages of men and women enrolled in online universities equalized (Figure 8).

If, on the other hand, we look at the percentages of enrollment in online universities compared to the total number of Italian students (Figure 9), it appears that the number of men is and has been – in past years – overrepresented compared to women who are however more numerous in Italian universities (in 2021: women, 1,063 thousand; men, 819 thousand).

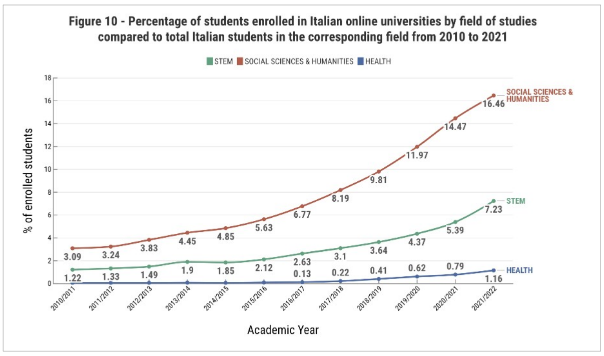




Figures 8 and 9 - Students enrolled in Italian online universities by gender from 2004 to 2021.

<u>*Disciplinary areas*</u>

Compared to students enrolled in the entire university system, the most represented subject area is Social Sciences and Humanities, where those enrolled in online universities correspond to 16.5 percent of total enrollments. These sectors are followed by Stem and Health, with 7.2 percent and 1.2 percent, respectively (Figure 10).



Figures 10 - Students enrolled in Italian online universities by degree subjects from 2010 to 2021.

As seen in Figures 11A and 11B, in 2021, the following fields are particularly overrepresented: Sport Sciences (43.5 percent), Psychology (31.6 percent), Education (21.1 percent), Law (19.1 percent), and Economics (15.3 percent).

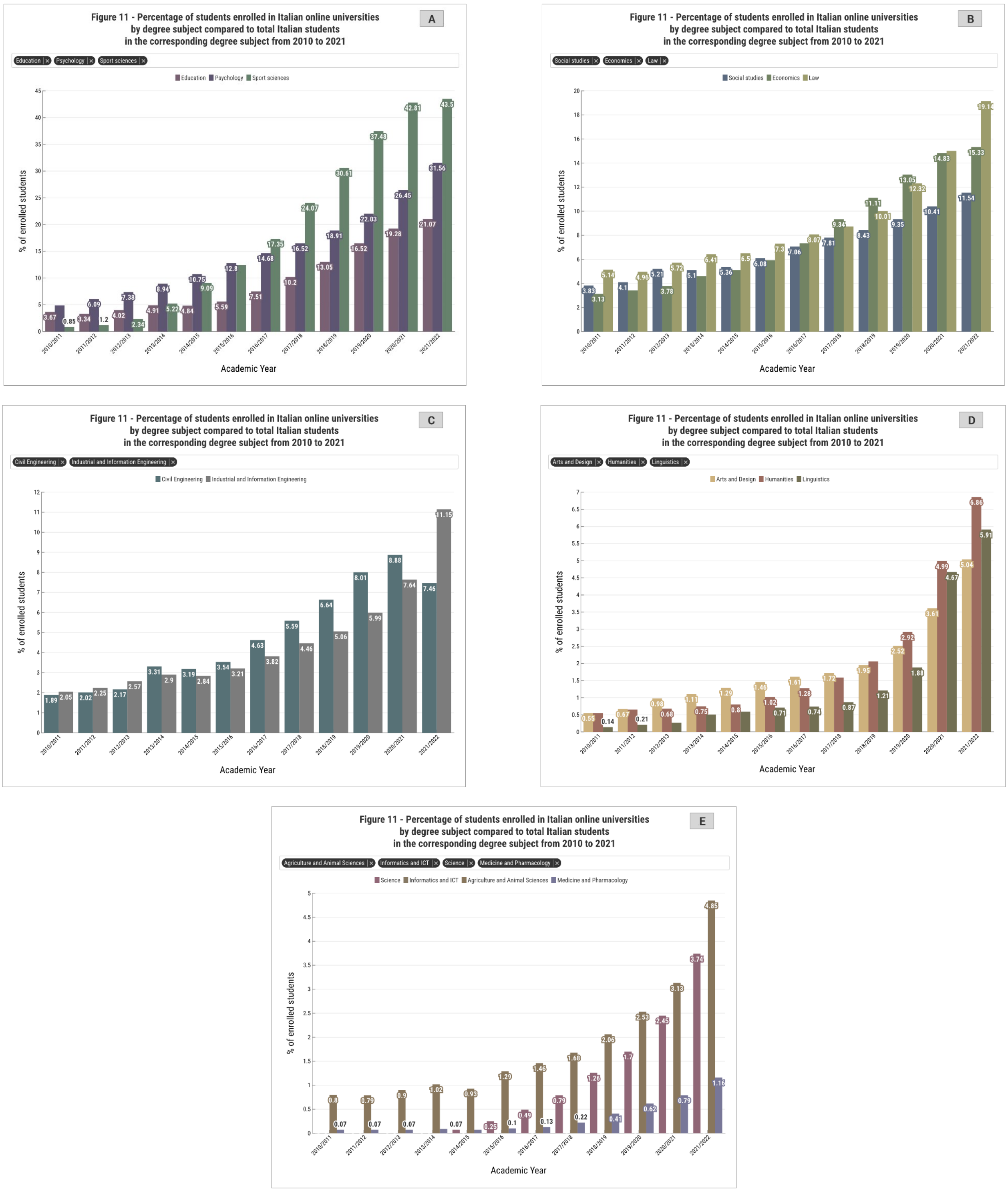
The more underrepresented fields (Figure 11E) are Science (3.7 percent), Medicine (1.2 percent), and Computer Science and ICT (0.0 percent).

This situation has remained relatively stable since the launch of online universities.

In fact, over the years since 2010, the Social Sciences area has always been the most represented, followed by Engineering (Figure 11C), Humanities (Figure 11D), and, finally, Agriculture, Science, Medicine, and Computer Science (Figure 11E).

In the Social Sciences area, Psychology has prevailed since 2011 without change.

The Sport Sciences area has risen to the pole position since 2016.



Figures 11A/E - Students enrolled in Italian online universities by degree subjects from 2010 to 2021.

Q3. What are the enrollment rates in Italian online universities in terms of students' geographical areas of residence?

Figure 12 shows that enrollments in online universities are increasing from all three geographical areas. Students from Southern Italy are the most numerous, followed by those from the North, which in the last three years have taken second place from students from the Center. In fact, since 2019 students from Northern Italy have increased by +30 thousand enrolled, compared to +26 thousand from the South and only +17 from the Center.

Confirmation comes to us by looking at the percentages (Figure 13): Southern Italy is the primary geographic area of students enrolled in online universities. Over the years, students residing in the South have accounted for roughly half of those enrolled in online universities. Since 2020 they have lost some amount to students residing in the North. The latter, that until 2017 was stable at around 23 percent, since 2018 has started to increase. On the contrary, the percentage of students from the Center is slowly decreasing.

Our analysis also compared the number of students enrolled in online universities with the total number of academic students in the same geographic areas (Figure 14).

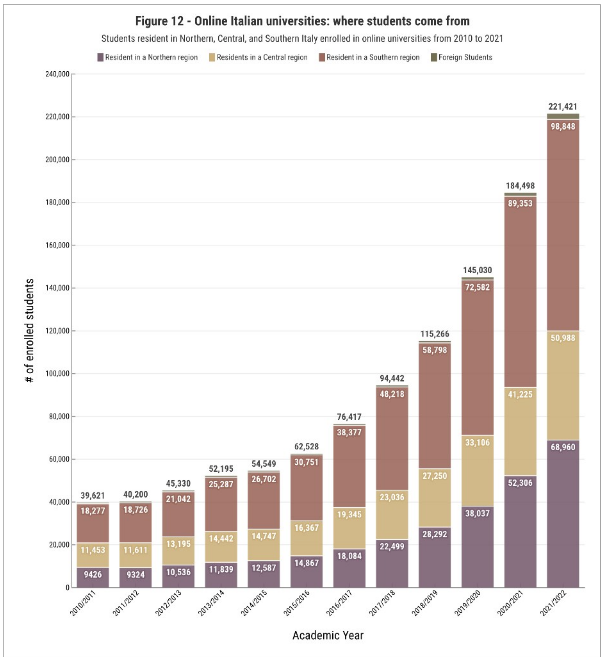
In all three macroareas, there has been a continuous increase since 2010. In the Center and South Italy, there were similar percentages of students enrolled in online universities compared to those enrolled in the national academic system between 2010 and 2012. Even in this comparison, it appears that the percentage of enrollments of students from the South is increasing steadily, that of students from the Center has slowed down, and that of students from the North is slowly growing with rising rates of increase in the last years.

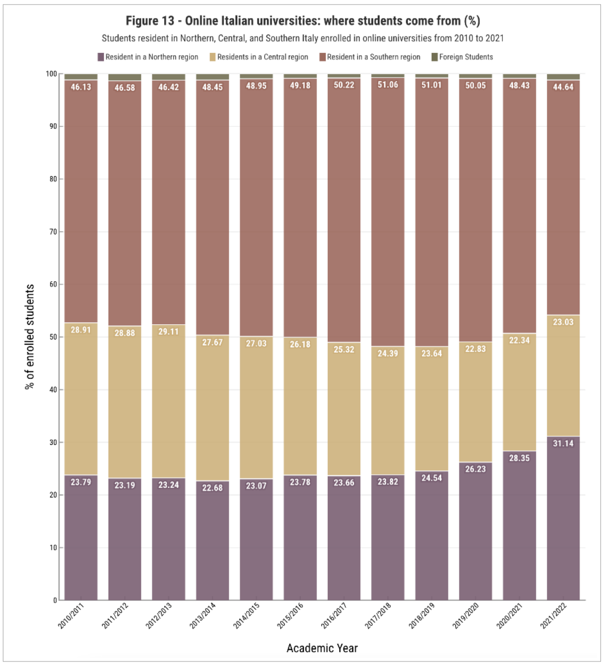
A focus on the regions and provinces into which the macroareas are divided follows.

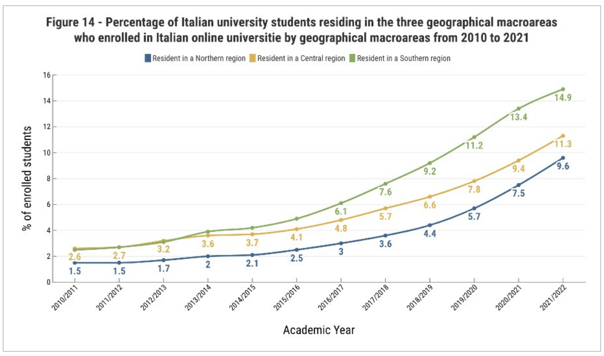
Figures 15 and 16 focus on the percentage of students enrolled in online universities by region.

In 2021, the first positions of the list of (20) regions with the high percentage of students enrolled in online universities were occupied by the regions of Southern Italy, in particular, Calabria (17.4 percent), Sicilia (16.6), Campania (15.6). The percentage of enrollment in Sardegna is unexpected compared to that of Sicilia: the two Italian islands have different trends. Sardegna, in fact, has half of the students from Sicilia enrolled in online universities (only 8.7 percent).

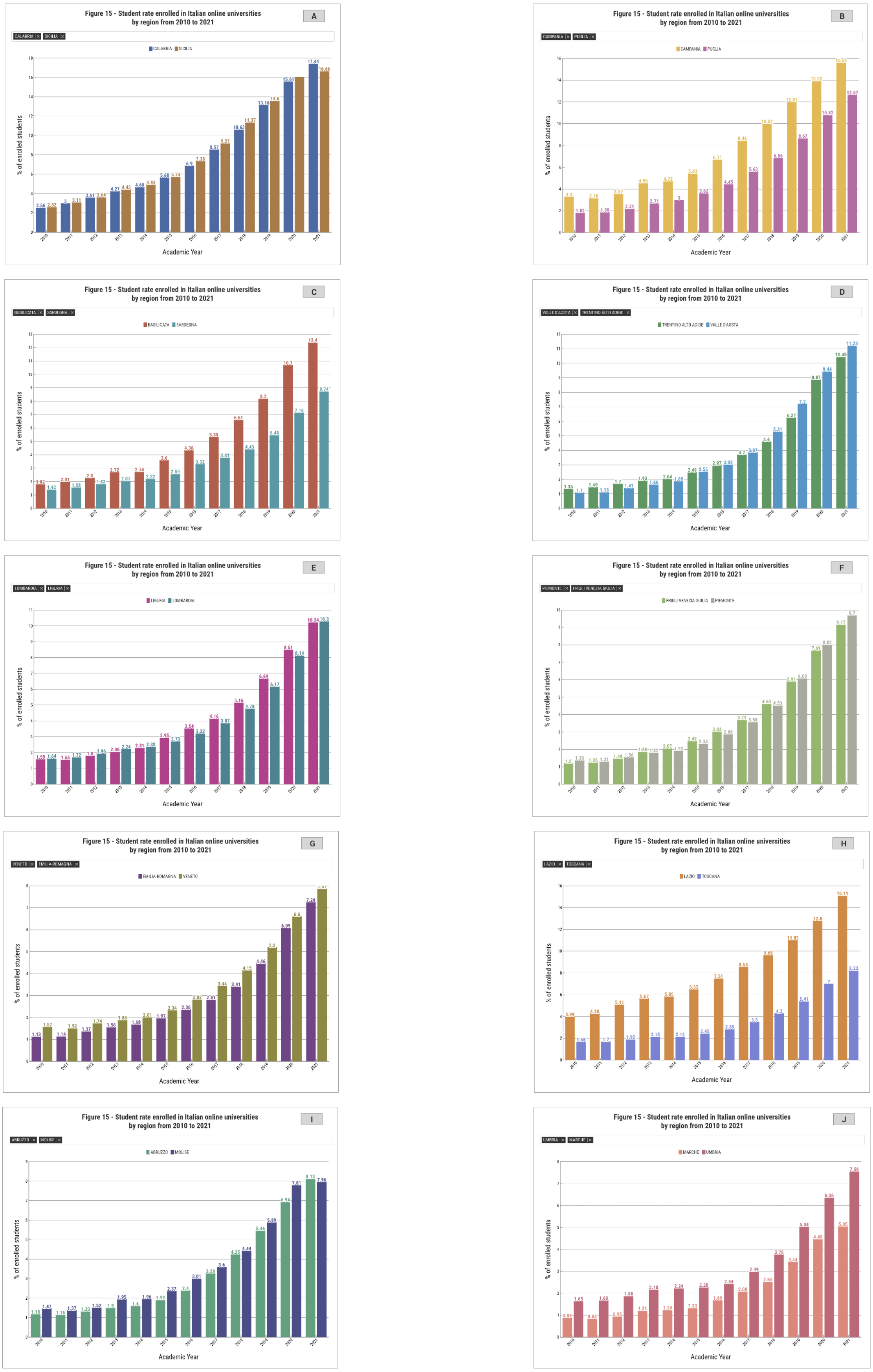
Among the Central regions, Lazio stands out with a rate of enrollment of 15.1 percent. Valle d'Aosta (11.2 percent), Lombardia (10.3 percent), and Trentino (10.5 percent) are the regions of the North area that have higher enrollment percentages, although lower than those of most of the Southern regions.







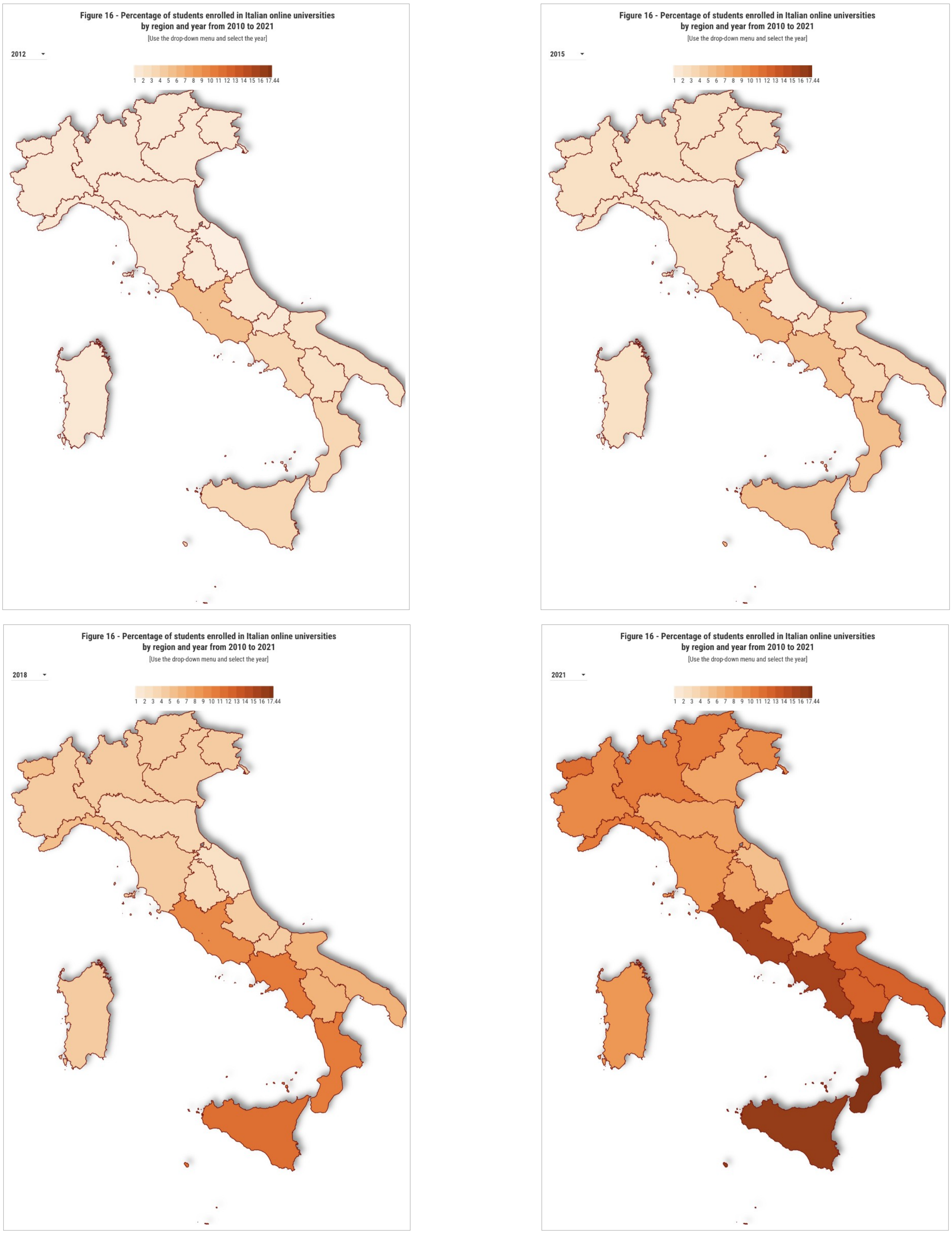
Figures 12, 13 and 14 - Enrollments in Italian online universities based on students' residence from 2010 to 2021.



Figures 15A/J - Students enrolled in Italian online universities by region from 2010 to 2021 (A/C = South, D/G = North, H/J = Center).

Marche, a Central region, is the one that, since the first years, occupies the last position of the list of regions with 5.1 percent of the enrollments in 2021.

From 2010 to the present, the percentages have increased in each region, leaving the ranking by macro-areas almost unchanged and testifying to a phenomenon that is increasingly rampant in the South, growing in the North, and more contained in the Central regions.



Figures 16 - Students enrolled in Italian online universities by region and year (2012, 2015, 2018, 2021).

The rates of students enrolled in online universities by (107) provinces broadly mirror the situation by regions with some exceptions.

In 2021, the top thirty provinces with higher percentage of enrollments in online universities belong to the South area or Lazio (Central Italy). Some examples in Figures 17A, B, C are Trapani and Caltanisetta, Sicilia (23.8 and 20.0); Reggio Calabria and Crotone, Calabria (22.2 and 22.0); Benevento, Campania (21.9); Latina, Lazio (17.5).

Among the highest percentages, we find three border provinces from the Northern area with percentages that exceed the regional ones (Figures 17D, E, F): Verbano-Cusio-Ossola, Piedmont (20.0 percent); Imperia, Liguria (15.6 percent), Bolzano, Trentino (15.2 percent).

To confirm the rates by area and by region (Figures 17G and H), the provinces of Marche have lower percentages of enrollments: Fermo (5.2), Ancona (5.0), Macerata (4.5), and at last Pesaro-Urbino (4.4).

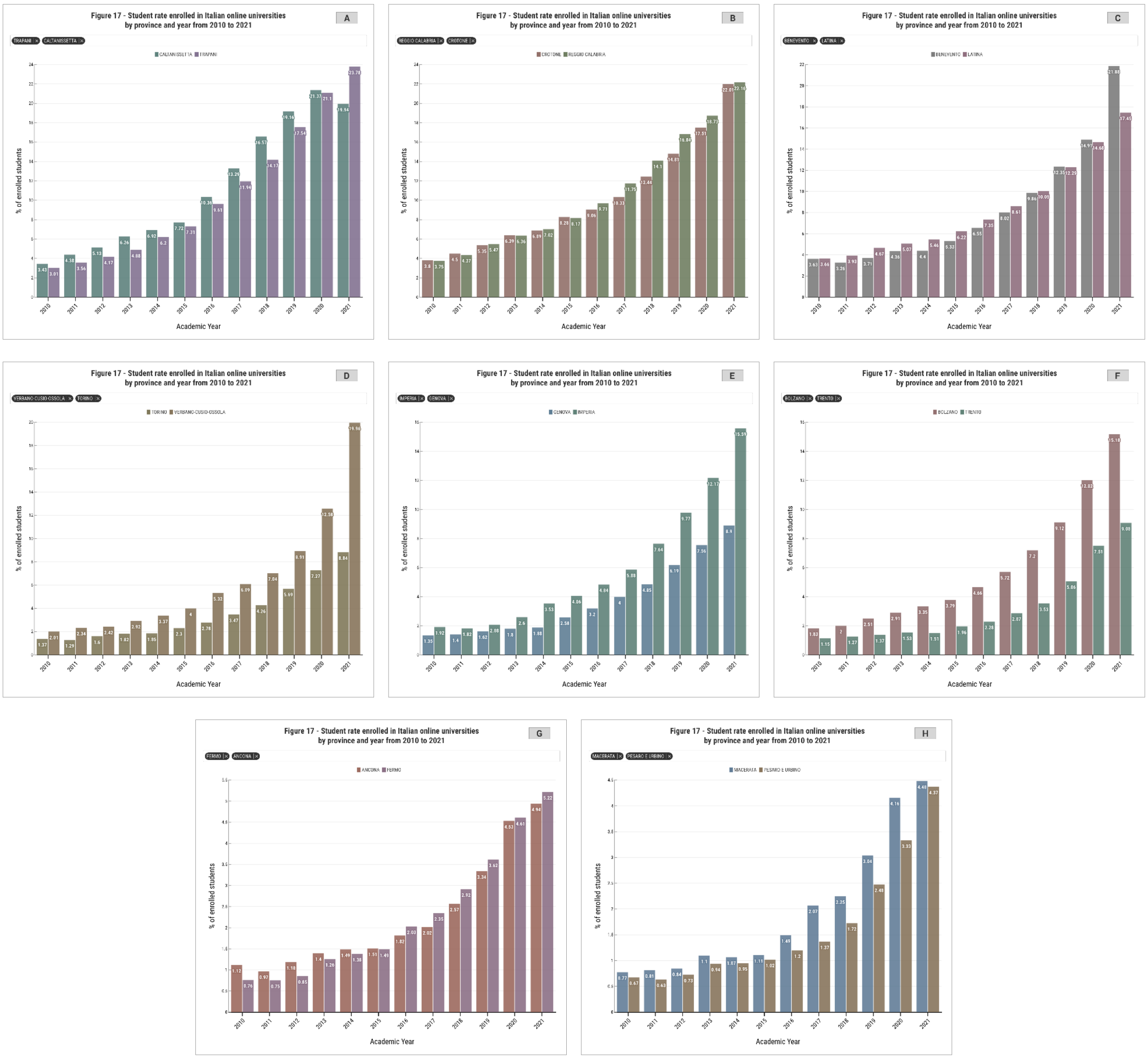
Let us take as a reference the lowest value recorded in 2021 for a province (4.4) and compare it with the previous ten years (Figure 17).

In 2018, the provinces with a higher enrollment percentage than 4.4 were 61 from the regions of the three geographic macro-areas.

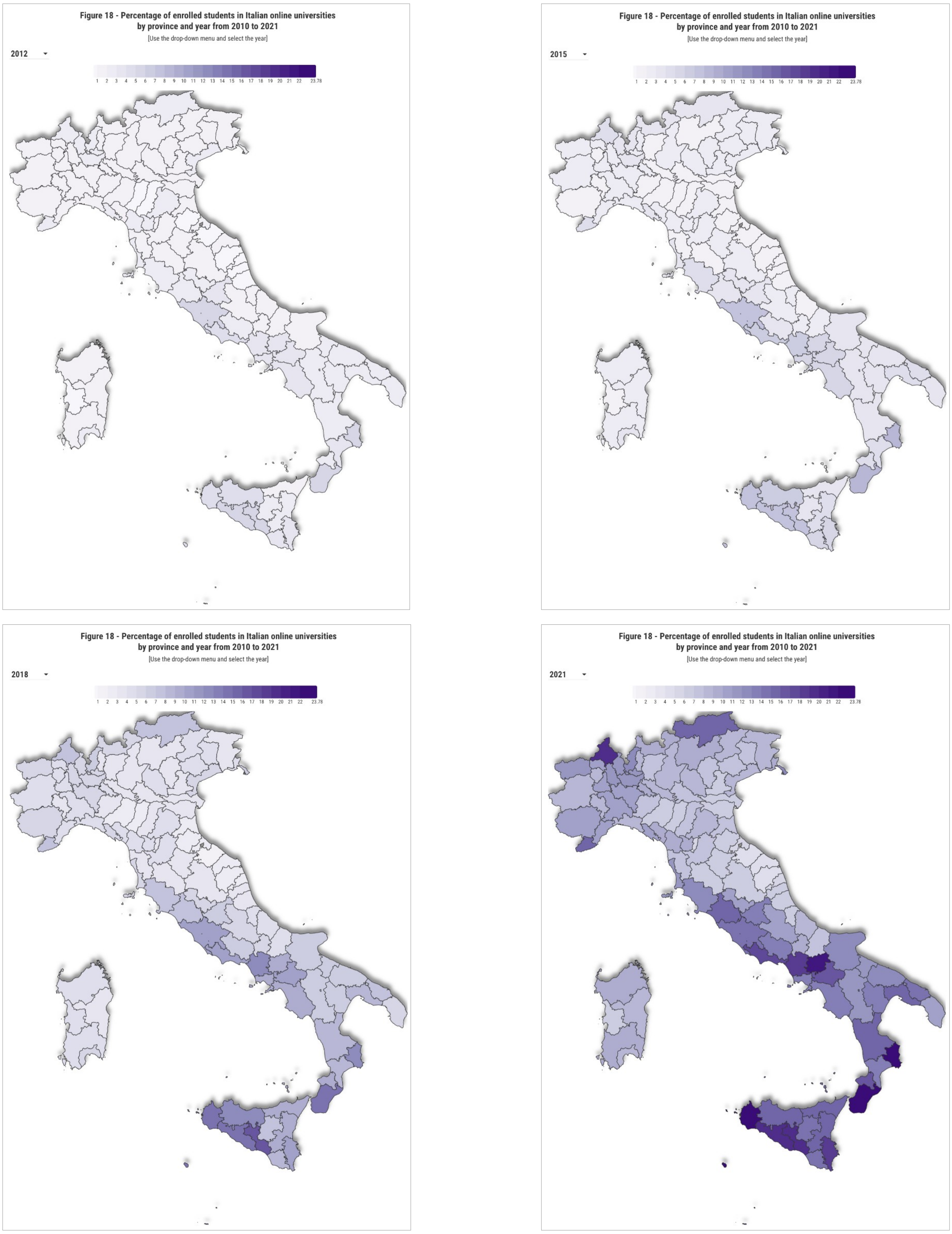
In 2015, the provinces with a percentage of enrollment higher than 4.4 were 17 and belonged to the regions of Calabria, Sicily, Campania, and Lazio.

In 2010, the only province with a similar percentage than this was Rome, Lazio (slightly above the order of hundredths, 4.37 vs 4.44).

Within ten years, the maximum value turned into the minimum, demonstrating the power of a phenomenon spreading to the entire country.



Figures 17A/H - Students enrolled in Italian online universities by province from 2010 to 2021.



Figures 18 - Students enrolled in Italian online universities by province and year (2012, 2015, 2018, 2021).

4. Discussion and Conclusions

In our previous analysis on time series in enrollments to Italian universities (Minerva et al., 2022), we identified some dynamics emerging in the last 20 years:

- increase in enrollments in online and private universities;
- increase in enrollments at universities in the North;
- decrease in enrollments at universities in the Center and South;
- increased migration of Southern students to online universities.

We continued investigating how this scenario is shaping up in our national context.

We were able to add more findings to what we had already deduced before:

- except for Marconi and Uninettuno, all online universities have stable or increasing enrollment numbers, even though they belong to the category of small universities. Launched between 2004 and 2006, the percentage of enrollments is now seeing a dramatic increase. Taken together, all the online universities gather more than 221,000 students; in particular, Pegaso and e-Campus account for 55 percent of the enrollments. Mercatorum, which had low numbers until 2018, is following an upward trend.
- Social Sciences and Humanities is the field of study most affected by enrollment in online universities. Sport Sciences, Psychology and Education are the areas in which enrollment in online universities has a higher percentage than the total number of enrollments in Italian universities. The more underrepresented fields are Science, Medicine, and Computer Science/ICT. An explanation of this rate is that M.D. 289/2021, Appendix D prevents courses in the medical, health, and architecture area and requiring special laboratory activities from being conducted in a telematics mode.
- more men enrolled in online universities in the first years after their launch. Nowadays, the proportions of women and men are equal. Men are still overrepresented if compared to total enrollments in Italian universities.
- students from South Italy, Lazio, and then North are the most likely to enroll in online universities. Compared to the other geographical macro-areas, the percentage of students from the Center making this choice is decreasing. Enrollment data are not sufficient to explain the regional effects and the motivations behind students' choices. Further investigations are needed.

Table 10 depicts the Italian university system scenario that compared the most recent data. The percentage of traditional and online universities overlaps those of the enrollments. Compared to traditional universities, the percentage of courses and teachers is very low, showing the presence of few courses with very high student numbers and a faculty composed mostly of contract teachers.

Table 10 - Universities, courses, enrollments and teachers in Italian university system.

Universities	Number	Courses (a.y. 2023/24)	Enrollments (a.y. 2021/22)	Tenured teachers (2022)
Traditional (public and private)	80 (88%)	5,090 (97%)	1,660 thousand (88%)	60,517 (99%)
Online	11 (12%)	155 (3%)	220 thousand (12 %)	582 (1%)

Despite this, online universities are replying to training needs that the traditional educational system is unable to satisfy. An increasing number of students are choosing private universities and their online training solutions.

Among the online universities, we reported three cases in which public universities support private online ones (Leonardo da Vinci, IUL, and Unitelma), in order to offer a broader range of courses. These institutions remain among those with lower student numbers (*small* universities).

There are, however, several elements that distinguish public universities from online ones and that can encourage enrollment in online universities:

- distance education and the provision of asynchronous activities increase autonomy and personalization of learning times, enrollment, and plans. This solution adapts to the needs of adult students, workers, students with disabilities, but also young students;
- enrollments are open throughout the whole year in most cases (sometimes with discounts or special offers), differently from public universities where they are available in a specific period, between July and November;
- online universities often have (many) locations throughout the country where information and examinations can be taken without the need to move;
- personalized tutoring activities for students are promoted at online universities;
- many degree courses are open access, unlike some at public universities;
- numerous short and single courses solutions are offered.

One possibility for developing online courses and introducing digital innovation in public universities is currently represented by the actions promoted by the

Decree n. 983 del 24.07.2023 that has recently been published within the actions of the National Recovery and Resilience Plan (NRRP), part of the European program Next GenerationEU and, in particular, in Mission 4 dedicated to Education and Research.

It promotes the establishment of three Digital Education Hubs (DEHs) in the country (two in the North-Central area and one in the Southern). The DEHs are conceived as networks of universities (including also those private) that work together to reinforce the higher education system and offer digital education to students, professionals, and enterprises in order to create pathways for flexibility and inclusion. The program supports the diffusion of MOOC (Massive Open Online Courses) and micro-credentials, the creation of inter-universities training solutions and digital platforms. An important action goal is to increase the number of graduates in Italy. The country, in fact, is second to last in the ranking of European countries by the number of graduates followed only by Romania (Tertiary education, ISCED 2011, 5-8 levels). The percentage of Italian graduates (Figure 19) is very low if compared to European percentage, respectively 18.1 percent (Italy) and 30.2 (Europe) in 2022.

Similarly, the percentages of university dropouts in Italy and those aged 18-24 who are not engaged in study and work (NEET) remain worrisome (ANVUR, 2023a).

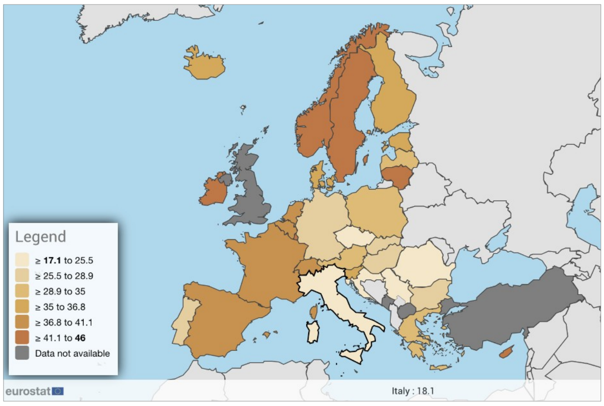


Figure 19 - Percentage of graduates in European countries (Eurostat, 2023).

Digital education, focusing on teaching quality and technological innovation, may be one of the possible ways to invest in and improve the tertiary education system in Italy.

Notes

According to CRediT system: Tommaso Minerva: Conceptualization, Methodology, Software, Project Administration; Annamaria De Santis: Resources, Writing - Original Draft, Writing - Review and Editing, Formal analysis, Data Curation, Visualization; Claudia Bellini: Resources, Writing - Original Draft, Writing - Review and Editing; Katia Sannicandro: Resources, Writing - Original Draft, Writing - Review and Editing.

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