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Contents

International Journal of Research in E-learning
Vol. 9 (2), 2023, pp. 1–5

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Editorial

The Editorial Board of International Journal of Research in E-learning (IJREL) is privileged to present a new volume 9(2) 2023. The content of the current issue was divided into two chapters. The first is devoted to Research on AI and VR in E-learning and Science. The second contains articles concerned with Innovative Methods, Technology and Open Educational Resources (OERs) in Education.

The first part of the volume Chapter I: "Research on AI and VR in E-learning and Science", contains two articles.

The article "Factors Enhancing Students' Views on Artificial Intelligence" was written by an international team of Authors from Poland and the Netherlands – Małgorzata Przybyła-Kasperek, Eugenia Smyrnova-Trybulska, Piet Kommers. The researchers stressed that *Artificial Intelligence* now is one of the most important and contemporary directions of development of science in an interdisciplinary context. The EU's approach to Artificial Intelligence centres on excellence and trust, aiming to boost research and industrial capacity while ensuring safety and fundamental rights. (A European approach to Artificial Intelligence). Strengthening the fostering excellence in AI will strengthen Europe's potential to compete globally. Simultaneously not yet solved are a lot of challenges and issues. The problem raised in the article is to explore and analyse computer science and education students' attitude to educational, social, and ethical aspects of AI implementation. The purpose is to discover and analyse computer science students' opinion and their pedagogical attitude towards education, social, and ethical aspects of AI implementation. Students of two faculties of the University of Silesia in Katowice, Poland, were asked to respond to a survey. They were mainly students of two specializations – Computer Science and Pedagogy. As many as 103 students have been surveyed. The Kruskal-Wallis tests were used for verification.

The Authors from Poland and France, Jan Waligórski, Aleksandra Cząstkiewicz, Zofia Samsel, Natalia Frys, presented the research on "Reimagining Online Academic Conferences: The Promise of Social Virtual Reality for the Return of Co-Presence". The experts note that new technologies and societal shifts are profoundly influencing communication and conducting meetings. Over the past few years, the number of online conferences has increased. The body of literature indicates that online events allow for reducing cost and social inequalities. Despite

this, they also present challenges in non-verbal communication, and diminish the sense of co-presence, thus affecting networking. The aim of the research was to explore the potential of virtual reality (VR) technology and social VR platforms as alternative methods for organizing online academic conferences. The Authors present the course of one of the first academic conference conducted entirely in social VR (Wirtualium 2.0), along with the survey outcomes regarding the potential of this environment for hosting academic conferences. The Authors' findings indicate that, compared to video-conferencing systems, social VR platforms offer for most participants a higher sense of co-presence, facilitating networking and engagement in informal conversations.

The Chapter II: "Innovative Methods, Technology and Open Educational Resources (OERs) in Education", contains six articles.

The article titled "Importance, Popularity and Elements of Educational Platforms – A Study of the Opinions of Students from Poland, Ukraine and Kazakhstan" was presented by an international team of Authors from Poland, Ukraine and Kazakhstan, Małgorzata Przybyła-Kasperek, Kornel Chromiński, Eugenia Smyrnova-Trybulska, Nataliia Morze, Ainur Bazarbayeva. The experts in their article present a comparative international research study analyzing the opinions of students from Poland, Ukraine, and Kazakhstan, regarding the importance, popularity, and elements of educational platforms in the field of computer science. The study employed the Kruskal-Wallis test for statistical analysis. Five hypotheses are proposed: The country of origin does not affect the frequency of use of educational platforms. The country of origin affects the topics of courses that students are interested in on educational platforms. The country of origin does not affect the motivation to take courses on educational platforms. The country of origin does not affect the evaluation of elements of the courses on educational platforms that students find most important or useful. The country of origin affects the evaluation of value of courses provided on educational platforms. The most popular topics on these platforms are programming and computer networks, with students from Kazakhstan also displaying a keen interest in subjects related to artificial intelligence and computer graphics. Additionally, this study analyzes the conditions of learning and teaching in specialized modules at each university, including teacher requirements, curricula, and the potential for practical implementation of new knowledge by students.

The Authors from Nigeria, Fabunmi Kazeem Olaiya and Yakubu Ibrahim Umar, presented the article "Assessing The Awareness and Perception of Open Educational Resources (OERs) among Nigerian University Students: A Case Study". This study investigated Nigerian university students' awareness and how this influences their perception and use of Open Educational Resources (OERs). The study adopted a descriptive method of quantitative research. 4 research questions were developed and answered a hypothesis was also tested to determine the relationship between students' awareness of and their perceptions of OERs. The percentage, frequency,

mean, standard deviation and t-test were used for the analysis. A correlation coefficient was employed to test the hypothesis. The findings of the study were: Nigerian university students have a high level of awareness of OERs; the most popular OERs among the Nigeria university students were Coursera, EdX, and OpenStax; OERs are generally well-perceived by Nigerian university students; lack of digital literacy skills and lack of adequate knowledge to determine the quality assurance of OERs are the only challenges hindering the effective use of OERs among the students, and there is a significant relationship between the awareness and perception of OERs by the students. The study concluded that the majority of Nigerian university students are familiar with OERs and have positive perceptions of OERs. Universities, lecturers and librarians should continue to promote OERs usage in teaching and learning activities to promote their adoption.

Artem Yurchenko, Volodymyr Proshkin, Olha Naboka, Volodymyr Shamonia, Olena Semenikhina, the Authors from Ukraine, written the article "The Use of Digital Technologies in Education: The Case of Physics Learning". The article reveals the trends in the use of digital technologies in teaching physics by summarizing scientific results over the past 20 years. To solve the problem, a bibliographic analysis of the sources of the scientometric database of the WOS was used with the involvement of the computer tool VOSviewer (for the construction and visualization of bibliographic data) as of June 2023. Modern trends in teaching physics are singled out: the use of environments where simulation, modelling, visualization, virtualization of physical processes, etc. are possible. The increasing popularity of virtual, augmented, and mixed reality tools; use of mobile applications for learning physics; using artificial intelligence to teach physics; organization of an educational environment based on mobile or online learning, where active learning methods are determined to be appropriate. The importance of developing young people's intellectual skills (computational skills, algorithmic thinking skills, modelling processes, etc.) and visual thinking for the successful mastery of various sections of physics has been confirmed. The demand for integration links between natural sciences, mathematics, engineering, and digital technologies for STEM education has been monitored. Recommendations for the training of physics teachers have been formulated.

The text "Successful Examples of Asynchronous Teaching in Polish Interactive Remote Medical Education" was preapred by a team of Authors from Poland – Anna Smelkowska, Agnieszka Karbownik, Barbara Purandare, Katarzyna Zaorska, Marta Jokiel, Maurycy Jankowski, Magdalena Roszak – experts in the area of e-learning in the medicine. A thorough theoretical and practical preparation is crucial in the education of medical professionals. The present-day knowledge recipients expect a broad range of multimedia and interactive resources in the consumed media. The article discusses examples of such implementations for the nationwide education of a pharmacy technician, massage technician, medical sterilization technician, and occupational therapy technician. These examples

were created for the Integrated Education Platform of the Ministry of Education and Science in Poland, as part of an EU-funded project. This study delineates the characteristics of e-materials, such as instructional and educational videos, film sequences, scenario-based learning games, interactive documentation, 3D animations, simulators and virtual tours. The Authors prepared a learner benefit analysis based on the e-materials discussed. The article aimed to formulate recommendations and guidelines for designing and developing multimedia and interactive resources, paying special attention to educational values and content for the medical industry. To design and produce high-quality multimedia, it is necessary to know their characteristics and to work with a team of subject matter experts experienced in e-learning development.

Krzysztof Dziedzic, Marcin Barszcz, Tomasz Wiśniewski present the research on "Adaptation of the E-Learning Exercise Creator to the Needs of People with Disabilities with Impaired Access to Education". This article focuses on the implementation of the WCAG 2.1 guidelines into e-learning courses. The Quizer e-learning platform, which enables the creation of interactive multimedia courses, has provided the basis for the introduction of the WCAG component. The platform includes two basic tools: an exercise creator and an exercise presenter. Once the Quizer Platform Exercise Wizard was analysed, a component was conceptualised and implemented to create e-learning courses compliant with WCAG guidelines and dedicated to people with disabilities. The technology for the implementation of this component was also presented. The research on the correctness of the WCAG standard implementation into e-learning courses was conducted with the use of designed cyber security quizzes. The final results of quizzes prepared according to WCAG guidelines and without WCAG were also compared. The research involved students majoring in computer science at Lublin University of Technology. Its results indicate the validity of using the WCAG guidelines in the design of educational content for students with disabilities and equalizing their educational opportunities.

Tetiana A. Vakaliuk, Oleksii V. Chyzhmotria, Svitlana O. Didkivska and Illia Linevych from Ukraine presented the article "Development of a Web Service for Creating Tests Based on Text Analysis Using Natural Language Processing Technologies". The purpose of the work is to analyze models, natural language processing methods, and select modern technologies for training these models, as well as to develop a web service for creating tests based on text analysis using natural language processing technologies. The study considers methods and algorithms for intelligent data analysis to generate questions and correct and incorrect answers from the text. The study also describes the activity of the proposed model, which will serve as a basis for creating a web service. After a detailed review of these datasets, the necessary data for the experiment were extracted and transformed into a convenient format for use. The training algorithm for 6 models was designed and implemented, and valuable metrics were obtained

after their training. Additionally, a server-side and web interface were developed to interact with each other.

We hope that studies and solutions in the present IJREL volume will be inspiring and encourage reflection on how to manage the increasing demand for online education in the current situation.

Eugenia Smyrnova-Trybulska
https://orcid.org/0000-0003-1227-014X

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Małgorzata Przybyła-Kasperek
University of Silesia in Katowice, Institute of Computer Science
https://orcid.org/0000-0003-0616-9694

Eugenia Smyrnova-Trybulska
University of Silesia in Katowice, Faculty of Arts and Educational Science
https://orcid.org/0000-0003-1227-014X

Piet Kommers
University of Twente, Netherlands
https://orcid.org/0000-0002-4738-3016

Factors Enhancing Students' Views on Artificial Intelligence

Abstract

Artificial Intelligence (AI) is now one of the most important and contemporary directions of development of science in an interdisciplinary context. The EU's approach to artificial intelligence centres on excellence and trust, aiming to boost research and industrial capacity while ensuring safety and fundamental rights (A European approach to artificial intelligence). Strengthening the fostering excellence in AI will strengthen Europe's potential to compete globally. Simultaneously not yet solved are a lot of challenges and issues. The problem raised in the article is to explore and analyse computer science and education students' attitude to educational, social, and ethical aspects of AI implementation. The purpose is to discover and analyse computer science students and pedagogical attitude towards education, social-, and ethical aspects of AI implementation. Students of two faculties of the University of Silesia in Katowice, Poland, were asked to respond to a survey. They were mainly students of two specializations – Computer Science and Pedagogy. As many as 103 students have been surveyed. The Kruskal-Wallis tests were used for verification. The main issues studied were the students' level of competence in AI, their awareness of AI applications in

various areas of life and economy, and the importance of the AI field. The study also included the level of confidence towards AI and the level of anxiety towards AI. Various types of dependencies and connections between these aspects were investigated. The hypotheses were mostly confirmed. Finally, the article presents the discussion and main conclusions.

K e y w o r d s: Artificial Intelligence (AI), educational, social and ethical aspects, students of computer science and education, opinion, Kruskal-Wallis tests

We live in a modern technological society driven by intelligent human systems and machines. This is due to advances in artificial intelligence (AI) (Yu and Nazir, 2021).

The artificial intelligence is widely present in our daily lives: facial recognition systems in smartphones, digital voice assistants, smart home devices, mobile banking, Google predictive search, Netflix recommendations, Google Maps, carpooling applications, banking mobile devices and more (Oprea, 2021). We agree with Oprea (2021) that the field of artificial intelligence is developing continuously and rapidly.

Background research

According to previous research, "artificial intelligence" and "smart tutoring system" are among the most common keywords in related bibliographic analyzes of AI in education (Baek and Doleck, 2020).

Other researchers have developed and provided a systematic overview of AI technologies in STEM education (Xu and Fan (2022). They have identified and detailed types of AI applications, teaching content, etc. practices, as well as teacher involvement, pedagogical strategies, teaching methods, contexts, and the impact of AI for STEM and STEAM education (Xu and Fan, 2022).

Some experts provided an overview of publications on the use of AI in higher education by keywords and topics such as author, institution, country and citation (Hinojo-Lucena et al., 2019).

The purpose of another study is to determine the trend of interaction of artificial intelligence (weak, hybrid, superintelligence) with humans in the areas of: forecasting, decision-making, development of artificial intelligence tools and development strategies, relations with society, valuation, evaluation, selection of new business models and artificial intelligence risk management. The methodology

includes benchmarking, comparative analysis of trends in the generation of artificial intelligence and its interactions (Richardson and Clesham, 2021).

Based on a large-scale technology adoption scenario, artificial intelligence (AI) is expected to have a disruptive impact on economies and societies. In recent years, there has been a breakthrough in basic research into the technologies underlying artificial intelligence. Artificial intelligence shows greater potential to become a general-purpose technology (Huang and Peissl, 2023).

Artificial intelligence (AI) is now being developed by large corporations and governments around the world are working hard on it. Artificial intelligence is not a futuristic concept; it is already here and being implemented in many industries (Mhlanga, 2022). The study of Yu and Nazir (2021) provides a detailed overview of the role of 5G and AI in the research and transformation of situational English teaching in higher education (Yu & Nazir, 2021).

The research of Ahmed & Ganapathy (2021) aims to focus on methods for creating intellectual content that improve learning management and enable the use of embedded artificial intelligence. Artificial intelligence is probably one of the most outstanding fields, and it can be used effectively. Azevedo & Almeida (2021) present the design and practice of this training specifically aimed at decision makers in medium-sized enterprises (SMEs). The proposed program with a multidisciplinary scope includes various thematic chapters (autonomy), as well as cross-cutting topics, towards the paradigm of Industry 4.0 and digital transformation (Azevedo and Almeida, 2021).

The aim of the work of Fedotova et al. (2020) is to assess the current changes in the structure of national economic systems resulting from the transition to Industry 4.0. (Fedotova et al., 2020).

The article presents the impact of artificial intelligence on the quality of diagnostic criteria of the pedagogical supervision system (Khaperskaya, & Minin, 2020). The authors have developed methods for providing automated educational supervision, describing the principle of operation of the developed methods from the technical and educational point of view and giving examples of their implementation. The article confirms that artificial intelligence can expand the field of pedagogical supervision in the digitization process, while maintaining the principles of traditional pedagogy (Khaperskaya & Minin, 2020).

The aim of the study of Karnouskos (2022) is to explore many potential problems of law and society by examining the interaction of law, robotics and society from different angles such as legal, social, economic, gender and ethical opinion (Karnouskos, 2022).

The moral hazard of employing algorithms that use international human rights law as a common standard for determining algorithmic accountability has been highlighted by Yam & Skorburg (2021).

Four types of algorithmic impact analysis with five human rights of candidates participating in the recruitment algorithm are effectively evaluated (Yam and Skorburg, 2021).

Interesting research results were presented by Kozlova et al. (2021). Business models of the economy of the future with the use of artificial intelligence of human resources have been proposed. A new model of working with analytics, a platform business model, has been developed (Kozlova et al., 2021).

As indicated by Pikkarainen and Tihinen (2023), the manufacturing industry is currently moving towards smart manufacturing systems through digitization. There are many technologies and professional skills that are recognized as crucial for embracing changes in the manufacturing industry, such as digital platforms and solutions, artificial intelligence (AI), diagnostics and data analytics (Pikkarainen and Tihinen, 2023).

Therefore, research by Pikkarainen & Tihinen (2023) focuses on educational solutions that drive digital transformation in the manufacturing industry.

The study of Ramírez (2021) provides an analysis of the areas, resources, and management options required to respond to the new environment of public higher education institutions in Mexico. These processes integrate the necessary elements, such as artificial intelligence, machine learning, digitization of processes or comprehensive leadership implementation (Ramirez, 2021).

Research shows that managing the Covid-19 crisis is difficult for startup training due to the need for specific and practical examples (Ratten, 2020). This means that augmented reality and artificial intelligence are needed to simulate the real environment. This will enable a more community-based approach to entrepreneurship research and practice (Ratten, 2020).

Smart digital aids for analog learning experiences and dynamic, transport-adaptive object-based learning textbooks for quantum cryptography are discussed in Sosnovsky et. al. (2020).

Researchers have developed an introductory course to teach basic ML concepts such as the basics of neural networks as well as the limitations and ethical issues of K-guideline 12 on artificial intelligence (Martins et al. 2023).

An analysis of AI music and its possible benefits in non-drug therapy is presented in Mata-Rivera et al. (2022).

In fact, AI is at the center of attention of many researchers and this trend is dynamically developing. Simultaneously a lot of questions are still without answers, in particular, the opinions of young people, and students of different specializations on the ethical and social aspects of AI and its impact and future perspective of using it in different areas of society, environment, economy, etc. Some research results were presented in Smyrnova-Trybulska, Przybyła-Kasperek, & Kommers (2023) and in Skalka, & Drlik (2022).

This article presents the extended results of research conducted by the authors.

Methodology

Research questions were defined based on literature review and the authors' own experience. Questions formulated in the present study are the following:

RQ1: What level of AI competence do computer science and education students have?

RQ2: What level of AI competence do students who have completed engineering technical studies (Bachelor's degree) have as well as those who are just after high school?

RQ3: What level of AI competence do students in their fifth year of study have as well as students in earlier years of study?

RQ4: What level of awareness of AI do education and computer science students have?

RQ5: What level of awareness of AI possibilities and applications do fifth year students have as well as students in their earlier years of study?

RQ6: Are there any dependencies between the level of students' AI competence, and the level of their appreciation of AI possibilities?

RQ7: Is there a difference between the level of fear of AI development among computer science students and education students?

RQ8: Is there a difference between the level of fear of AI development among computer science students and education students, because the increase in AI competence influences a calm attitude towards AI and a decrease in fear of AI development?

RQ9: Is there a difference between increased AI competence and the level of fear of AI development?

A model was created to present what relations are to be analysed and studied in this paper. Figure 1 shows the six conceptualized categories and the relations between them that will be verified.

Adequate hypotheses are posed. The hypotheses are verified based on the questionnaire responses using statistical inference specifically the Mann-Whitney and the Kruskal-Wallis tests. Of course, a comparison of statistical measures and graphs was also performed to confirm the differences in results and the following hypotheses.

H1: Computer science students have a higher level of AI competence than education students.

H2: Students who have completed engineering technical studies (Bachelor's degree) have a higher level of AI competence than students who are just after high school.

H3: Students in their fifth year of study have higher AI competence than students in earlier years of study.

H4: Computer science students are more aware of the possibilities and applications that AI brings than education students.
H5: Fifth-year students have a higher awareness of AI possibilities and applications than students in earlier years of study.
H6: Awareness of AI possibilities and applications increases proportionally to the level of AI competence. The higher the student's AI competence, the more they appreciate the possibilities of AI.
H7: Computer science students are more concerned and afraid of the development of AI than education students.
H8: Fifth year students have a lower level of concern and fear about AI development than students in their earlier years of study. This is due to greater experience and knowledge of these students.
H9: The increase in AI competence influences a calm attitude towards AI and a decrease in fear of AI development.

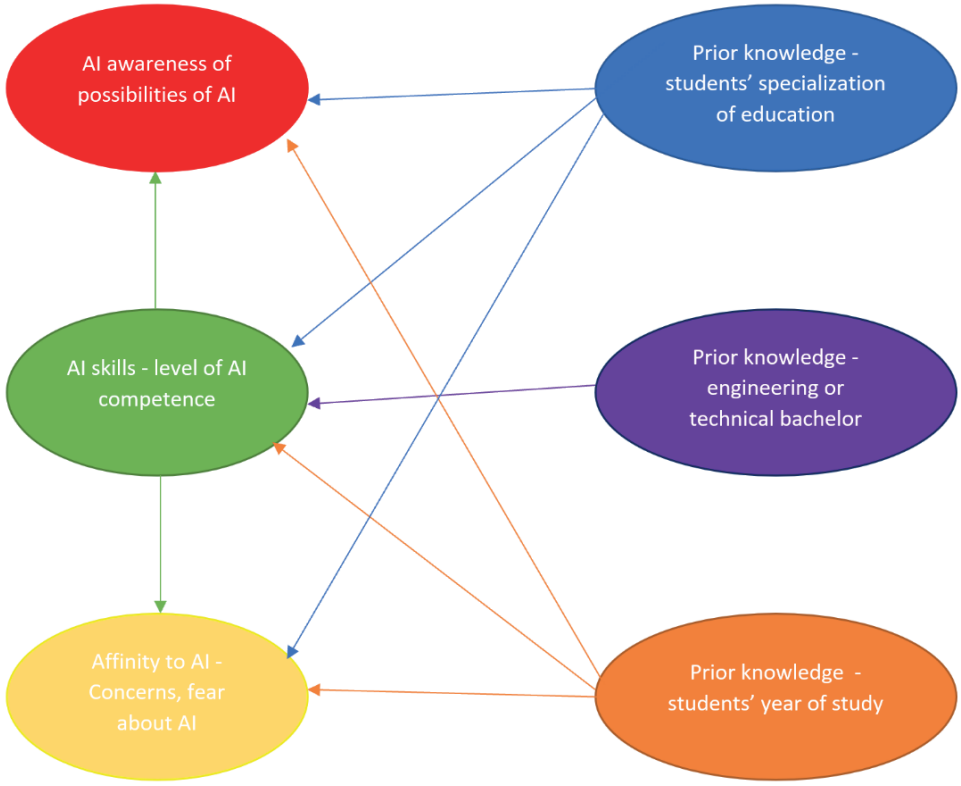

Figure 1. Six factors model and investigated relations

S o u r c e: Own work based on Asghar, Minichiello, & Iqbal, 2022.

This paper is a continuation of the conference paper (Smyrnova-Trybulska, et al., 2023) and provides a significant extension of it. It presents further analysis of risk perceptions regarding AI as well as analysis of the correlation between students' level of competence and answers to questions on various aspects, i.e. AI applications or AI risks.

The structure of the work is as follows. In Section 2, we present the assumptions of the questionnaire conducted as well as the sociological background of students. Section 3 presents the main results and analysis. This section is divided into sections on the various aspects studied: AI competence, AI possibilities and applications, AI possibilities and applications and self-assessment of AI literacy, potential risks of AI, correlation between feelings of anxiety toward AI and self-assessment of AI literacy. Section 4 contains discussions of the obtained results, the most important hypotheses that were successfully demonstrated are summarized here. The paper ends with conclusions.

Questionnaire, purpose and research questions

Our focus was on exploring students' attitudes toward AI issues, the degree of knowledge they have and their awareness of the potential use of AI issues in various aspects of life and the economy as well as their fears and anxieties about AI. Students from two different faculties, five different years of study and differing in age and gender, were asked to answer questions about their AI competences, perceptions of opportunities to use AI issues, and fears they have about AI development. The survey was conducted in December 2022 and January 2023. The students of two faculties – Faculty of Science and Technology, and Faculty of Arts and Educational Science of the University of Silesia - were asked to participate in the study. They were mainly students of two specializations – Computer Science and Education. A total of 103 responses were received. Respondents were randomly selected. Emails were sent to students at different years of studies and faculty asking them to fill out the survey. Taking part in the survey was voluntary.

Sociological background

In order to study the relationship between student characteristics and knowledge of AI or attitudes toward AI, the questionnaire included sociological questions. The sociological characteristics of questions and possible responses in the questionnaire are presented below:

- age – <19–21>, <22–25>, <25–30>, >30

- name of previous school, university – open question, (optional question)
- name of current school, university – open question
- gender – male, female
- course of the study – 1st, 2nd, 3rd, 4th, 5th
- study specialization – education, social, computer science, humanities, economics, technical but not AI

Descriptive statistics on the responses obtained related to the sociological background are presented in Table 1.

Table 1.
Descriptive statistics on responses to sociological questions

Age	Quantity/ Percentage	Name of previous school, university	Quantity/ Percentage	Name of current school, university	Quantity/ Percentage
<19–21>	33/32.04	Technical secondary school	31/30.10	University	103/100
<22–25>	55/53.40	General secondary school	33/32.04		
<26–30>	10/9.71	University	17/16.50		
>30	5/4.85	Technical University	12/11.65		
Gender	Quantity/ Percentage	Year of study	Quantity/ Percentage	Study specialisation	Quantity/ Percentage
Male	54/52.43	1st	18/17.48	Education	42/40.78
Female	49/47.57	2nd	19/18.45	Social	0/0
		3rd	35/33.98	Computer science	61/59.22
		4th	23/22.33	Humanities	0/0
		5th	8/7.77	Economics	0/0
				Technical but not AI	0/0

Based on the results obtained, it can be concluded that the majority of respondents are between 22 and 25 years old. They are mainly secondary school graduates – the vast majority of them received not technical but general education. All students are currently studying at the University of Silesia in Katowice. In terms of gender, it can be said that the sample is balanced – almost equal numbers of men and women were interviewed, only 5 more men than women were surveyed. The most numerous group of respondents is currently in their third year of study. Also, a large group of fourth-year students are present. Together, they account for more than half of the sample. First-year and second-year students make up about

36% of the total sample. The fifth-year students are the least represented. Students from the two specialties – education and computer science were interviewed, with computer science students accounting for 59.22% of the total sample.

Research questions

In our study, we had several research questions. First, we wanted to answer the question of what the level of AI competence among students is and whether social aspects influence this level. Further critical questions include the following: What is the awareness of the applicability of AI issues in different areas of life? Is there a significant correlation between this awareness and students' level of AI competence? What concerns do students have about AI development and about the future related to AI? Are these concerns significantly different in groups related to, for example, specialization, year of study, gender, age? Is there a significant correlation between the level of AI competence and concerns about AI?

All of the above questions are addressed and discussed in the next section.

Results and statistical tests

In this section, we will present statistical tests, analyses and their results on the perceptions of AI issues, opportunities that AI brings and concerns about AI expressed by the students who participated in the questionnaire. Each aspect is discussed separately in one of the following sections.

AI Competence

After the sociological background, the next coherent part of the questionnaire concerned students' self-assessment of their competence on various aspects of AI. The main purpose of this part was to find out whether respondents had encountered AI issues at university or in their personal lives, and at what do they rate their knowledge of specific AI issues. The questions in this part and possible responses included in the questionnaire are listed below:

1. Did you encounter AI – Yes, No
2. What do you think Artificial intelligence is? – robots, intelligent machines, machine learning, learning based on experience, learning based on data, other

3. How do you rate your level of AI competence? – seven-point qualitative scale, 1 the lowest level, 7 the highest level
4. How do you rate your level of competence in the area of AI supporting in programming languages (e.g. Python)?
5. How do you rate your level of competence in the area of ethical and social aspects of AI?
6. How do you rate your level of competence in the area of Data Preprocessing Techniques?
7. How do you rate your level of competence in the area of Knowledge Discovery?
8. How do you rate your level of competence in the area of Machine Learning?
9. How do you rate your level of competence in the area of Deep Learning?
10. How do you rate your level of competence in the area of Natural Language Processing?
11. How do you rate your level of competence in the area of Learning Analytics?
12. How do you rate your level of competence in the area of AI in cyber security?
13. How do you rate your level of competence in the area of Recommender systems?

As many as 98 respondents answered that they encountered AI issues, representing 95.15% of the sample. Five respondents answered that they had not encountered AI, which means that they are not aware of using AI issues on a daily basis through their smartphones or search engines. To the question "What do you think Artificial Intelligence is?", the largest number of respondents answered intelligent machines (31 responses), followed by learning based on experience (23 responses), machine learning (22 responses), robots (12 responses), all other possibilities were indicated by individual respondents. Bar charts of the responses obtained related to the assessment of AI competences are shown in Figure 2.

As can be seen from the results, students do not rate their knowledge and competences related to AI highly. For all questions presented in Figure 1, the most frequent answers are 1–3 which means low. It can be concluded that students rated their knowledge and competences in the following areas: Knowledge discovery and ethical and social aspects of AI. On the other hand, they rated their competences lowest in the areas of AI supporting programming languages, AI in cyber security and Learning analytics.

Statistical tests were performed in order to test the AI competence level obtained for groups defined by: study specialization, age, gender, year of study and previous school (each issue was considered separately). All results examined are for the ordinal variable. The Mann-Whitney test was used to detect differences in the two independent samples defined by field of study and gender. The results obtained are presented in Table 2: sum of ranks across groups and p-value. Significant results are shown in bold. If we take into account the groups defined by different specializations of studies, then we have a significant difference in results concerns competence in the area of AI supporting in programming languages (e.g. Python).

This confirms hypothesis H1. It is rather natural for computer science students to be more competent in this field than education students. What is surprising, however, is the lack of significant differences in other technical subjects such as machine learning or deep learning. This may indicate unsatisfactory competence of computer science students in this area. If we take into account the groups defined by gender there are statistically significant differences in the results obtained for two aspects studied: level of competence in area Deep Learning and level of competence in the area of AI in cyber security. Women indicated a higher degree of competence than men in both areas. But the third quartile of scores is rather low – below 4.

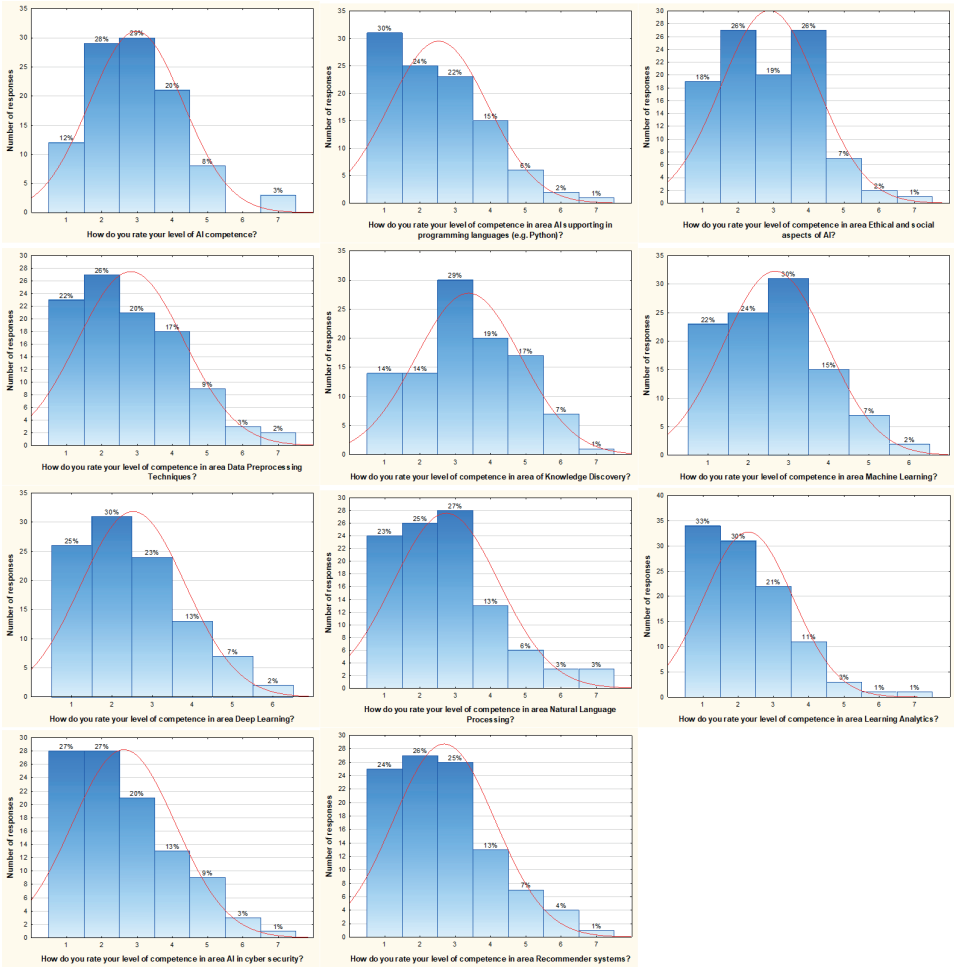

Figure 2. Bar charts of the responses obtained related to the assessment of AI competences

The Kruskal-Wallis tests were performed for groups defined by age, year of study and previous school (in each case the number of groups was greater than 2). The results obtained group size, group rank mean, p-value and test statistic value are presented in Table 3. Significant results are shown in bold. As can be seen, age, type of previous school and year of study have little influence on the evaluation of the AI competence in different fields. Significant differences were confirmed in the level of Knowledge Discovery competence by groups defined by the type of previous school. Based on the box-whiskers chart (Figure 3), it can be concluded that students who graduated from the technical universities have higher competence in this area than other students. This confirms hypothesis H2. Significant differences for groups defined by year of study were confirmed for competencies concerning: AI supporting in programming languages (e.g. Python), Data Preprocessing Techniques, Machine Learning and Recommender systems. Based on the box-whiskers charts (Figure 3), it can be concluded that students in the fifth year of study are distinguished by higher competences in this area compared to students in other years of study. This confirms hypothesis H3. This means that at the University of Silesia these issues are taught and students of the last year of study are familiar with them.

Table 2.
The Mann-Whitney test results of AI competence level for groups defined by study specialization and gender

Question	Groups defined by the study specialization: education and computer science			Groups defined by gender: male and female		
	Sum of the ranks for computer science	Sum of the ranks for education	p-value	Sum of the ranks for male	Sum of the ranks for female	p-value
3	3161	2195	0.944	2724	2632	0.581
4	3504.5	1851.5	**0.026**	2985	2371	0.244
5	3420	1936	0.097	2984	2372	0.246
6	3399	1957	0.129	2906.5	2449.5	0.518
7	3105.5	2250.5	0.658	2735.5	2620.5	0.634
8	3360	1996	0.208	2855.5	2500.5	0.756
9	2896	2460	0.064	2496.5	2859.5	**0.040**
10	2961	2395	0.158	2527.5	2828.5	0.064
11	3030.5	2325.5	0.344	2607	2749	0.185
12	2900.5	2455.5	0.069	2508	2848	**0.048**
13	3230.5	2125.5	0.697	2767.5	2588.5	0.792

Table 3.
The Kruskal-Wallis test results for AI competence and groups defined by age, year of study and previous school

Groups defined by age				
	<19–21>	<22–25>	<26–30>	>30
n	33	55	10	5
Question	Rank avg and results			
3	47	56	51	44
	H(4,103)=2.739; p-value=0.434			
4	45	56	56	44
	H(4,103)=3.491; p-value=0.322			
5	51	53	49	61
	H(4,103)=0.676; p-value=0.879			
6	49	57	37	54
	H(4,103)=4.511; p-value=0.211			
7	46	57	44	53
	H(4,103)=3.562; p-value=0.313			
8	50	55	43	47
	H(4,103)=2.024; p-value=0.568			
9	53	53	45	40
	H(4,103)=1.674; p-value=0.643			
10	52	54	40	52
	H(4,103)=1.967; p-value=0.579			
11	50	55	48	39
	H(4,103)=1.877; p-value=0.598			
12	54	54	40	45
	H(4,103)=2.253; p-value=0.522			
13	51	53	44	61
	H(4,103)=1.467; p-value=0.690			

Groups defined by previous school				
	Technical secondary school	General secondary school	University	Polytechnic
n	31	33	17	12
Question	Rank avg and results			
3	47	47	45	50
	H(3,93)=0.248; p-value=0.970			

4	44	43	51	60
		H(3,93)=4.460; p-value=0.216		
5	45	45	47	58
		H(3,93)=2.594; p-value=0.459		
6	47	43	46	61
		H(3,93)=3.986; p-value=0.263		
7	46	45	37	70
		H(3,93)=12.100; p-value=0.007		
8	46	44	43	61
		H(3,93)=4.293; p-value=0.232		
9	46	51	39	51
		H(3,93)=2.470; p-value=0.481		
10	48	50	44	40
		H(3,93)=1.512; p-value=0.679		
11	50	47	42	45
		H(3,93)=0.942; p-value=0.815		
12	48	53	37	42
		H(3,93)=4.847; p-value=0.183		
13	51	46	40	51
		H(3,93)=2.076; p-value=0.557		

	Groups defined by year of study				
	1st	2nd	3rd	4th	5th
n	18	19	35	23	8
Question			Rank avg and results		
3	51	58	47	47	74
		H(4,103)=7.154; p-value=0.128			
4	51	48	51	46	87
		H(4,103)=12.937; p-value=0.012			
5	65	46	50	47	58
		H(4,103)=5.644; p-value=0.227			
6	52	52	49	46	82
		H(4,103)=9.728; p-value=0.045			
7	43	54	52	52	65
		H(4,103)=3.434; p-value=0488			
8	59	51	49	42	78
		H(4,103)=10.266; p-value=0.036			

9	48	62	51	43	67
		H(4,103)=7.455; p-value=0.114			
10	45	60	51	48	64
		H(4,103)=4.723; p-value=0.317			
11	54	57	52	44	60
		H(4,103)=3.305; p-value=0.508			
12	54	64	52	41	52
		H(4,103)=6.686; p-value=0.153			
13	60	55	50	38	75
		H(4,103)=11.804; p-value=0.019			

Evaluation of perception of AI possibilities and applications in relation to study specializations, age, gender, year of study and previous schools

A subsequent section of the questionnaire included questions on perceptions of the applicability of AI issues in various areas of life and economy as well as the social and educational aspects of AI. The aim of this study was to analyse the attitudes and concerns about AI among students of different study specializations, age, gender, year of study and previous schools. The questions in this part and possible responses included in the questionnaire were defined using Likert scales to the 7-point scale listed below e.g.:

1. Can and should AI be more actively used, for example, in education to personalize teaching-learning?
2. Can social robots be helpful in the development of children including those with special needs?
3. Where can it be most useful and effective to use AI?
   a) For people
   b) For Education
   c) For Medicine
   d) For Transport
   e) For Business, Finance and Banking
   f) For Space and NASA
   g) For Economy and Management
   h) For IT (Information Technology)
   i) For public services
   j) Cybersecurity and safety

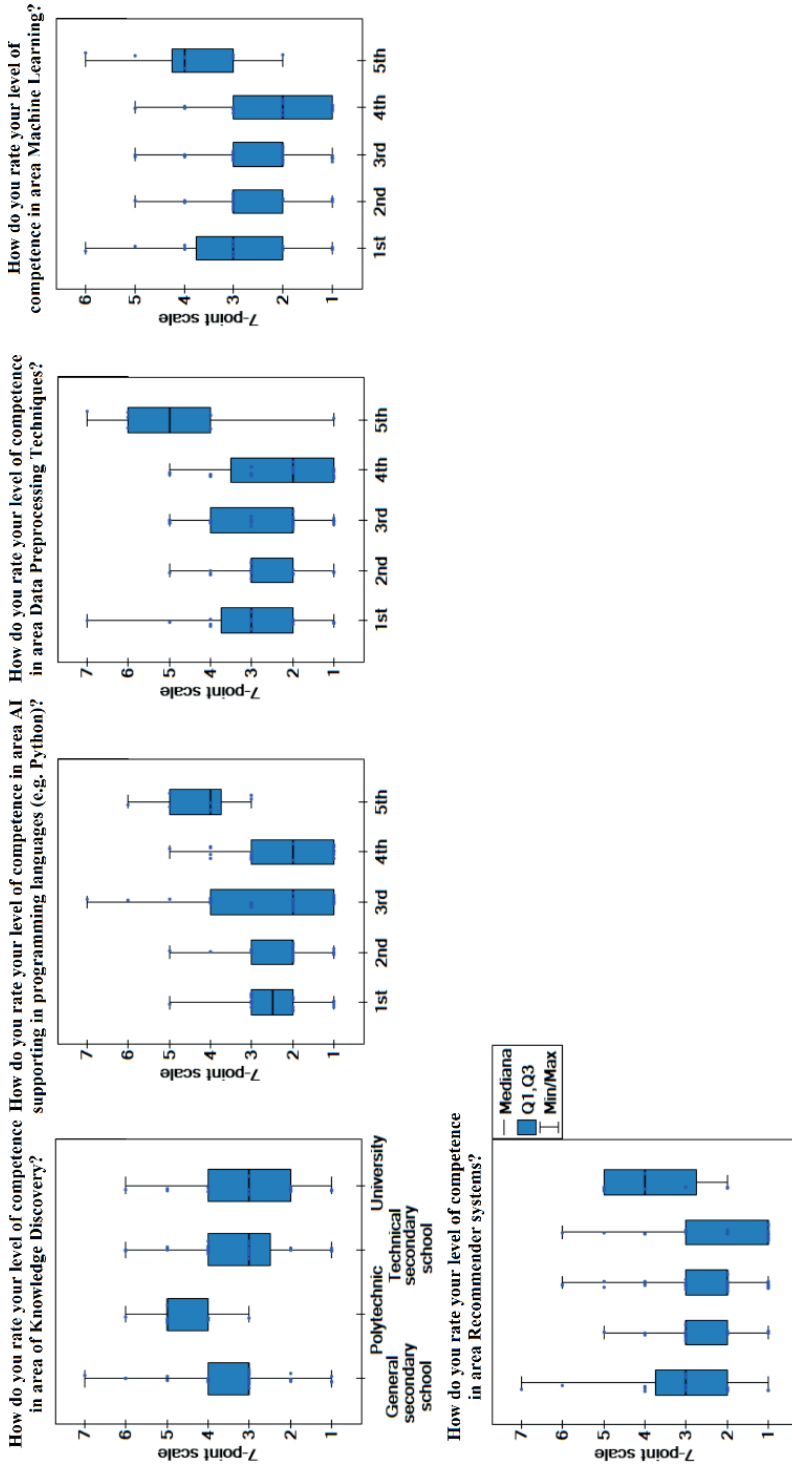

Figure 3. Comparison of the responses obtained for questions related to AI competence for which statistically significant differences are confirmed in Table 3

Bar charts of the obtained responses related to the assessment of AI competences are shown in Figure 4. As can be seen from the figures, respondents have no doubt that artificial intelligence can be useful in areas such as medicine, transport, business, finance and banking, space and NASA, information technology and cybersecurity. In all of these questions, the highest response – rate 7 – was indicated by about 35% to even 50% of respondents. By far the highest responses were given to the use of AI in space and NASA. However, in the case of AI applications for people, education or public services, respondents were not so strongly convinced of the answers for the other questions. In these cases, AI received support, but the results are rather spread around an intermediate intensity: responses of 4, 5, 6 were the most frequent. Respondents also gave moderate support for more active use of AI issues in education to personalize teaching-learning and the use of social robots in the development of children including those with special needs. Negative answers to these two questions were rather rare. But the most frequently indicated answers were average intensities 4, 5, 6.

Statistical tests were performed in order to test the significance of differences in the results obtained for groups defined by study specialization, age, gender, year of study and previous school (each issue was considered separately). All the results examined are for the ordinal variable. The Mann-Whitney test was used to detect differences in the two independent samples defined by field of study and gender. The results obtained are presented in Table 4: sum of ranks across groups and p-value. There are statistically significant differences in the results obtained for all aspects studied – questions 1, 2, 3a)–3j) – in the groups defined by study specialization. It can be seen that computer science students rate the possibility of using AI issues in all aspects studied higher and better than education students. This confirms hypothesis H4. Perhaps this is due to a greater awareness of the possibilities offered by AI. As far as groups defined by gender are concerned, practically in all questions the differences in ratings are significant – the only exceptions being the questions on: Can and should AI be used more actively in, for example, education to personalize teaching/learning? Where can the application of AI be most useful and effective: cyber security and safety? It was found that the majority of women study education, and the majority of men study computer science (only 7 women in computer science specialization took part in the questionnaire, the remaining 54 were men). Thus, the results obtained for groups defined by gender are probably also related to the specialization of students.

In the next stage of the study, the Kruskal-Wallis tests were performed for groups defined by age, year of study and previous school (in each case the number of groups was greater than 2). The results obtained group size, group rank mean, p-value and test statistic value are presented in Table 5. Significant results are shown in bold. As can be seen, age, type of previous school and year of study have little influence on the evaluation of the applicability of AI issues in different fields. Among the grouping conditions tested, it can be seen that the year of study

has the greatest influence. We notice a regularity that students of the first and the fifth year of study rate the applicability of AI for people, education, economy and management and computer science higher than students of the second, third or fourth year of study (see Figure 5). This confirms hypothesis H5. This may be related to the first fascination with AI issues in the first year of study, and the greatest knowledge about the possibilities of AI in the fifth year of study. Another trend is that master's students who have already completed a bachelor's degree at a university or technical university also rate the applicability of AI issues in the fields of medicine and transport higher than bachelor's students. This is probably related to these students' greater knowledge and experience with AI issues.

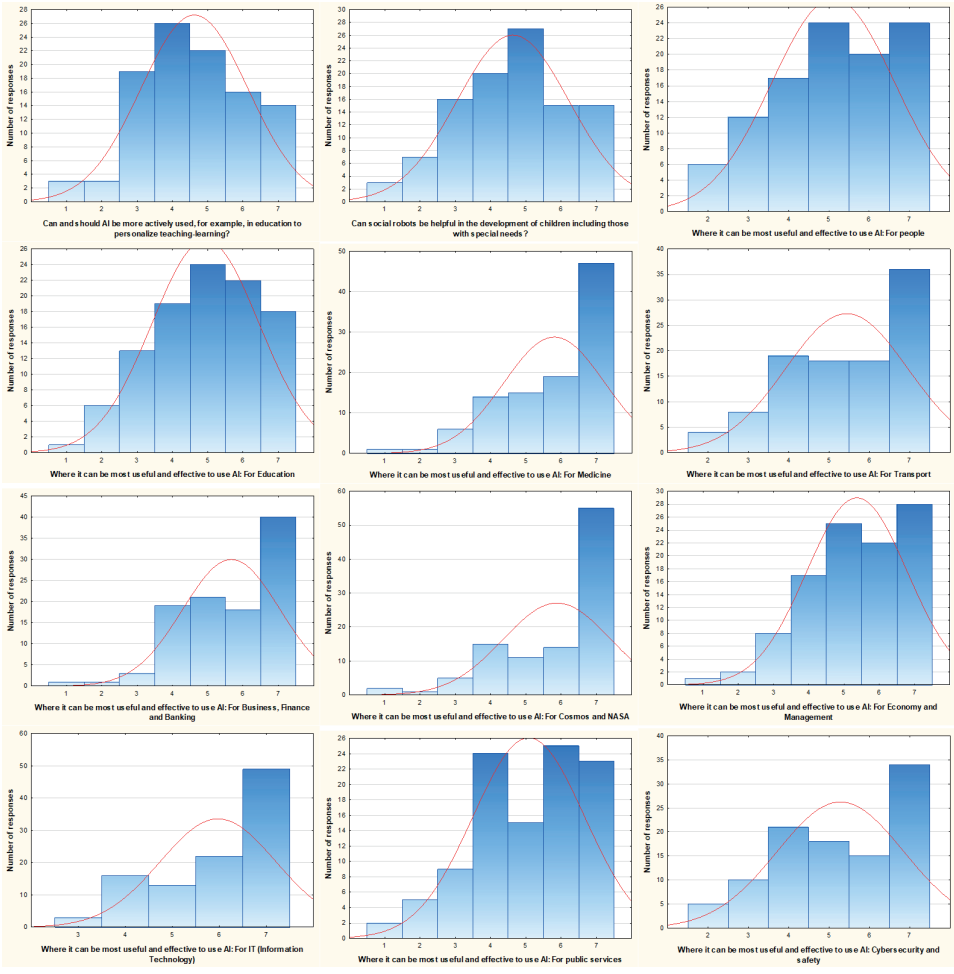

Figure 4. Bar charts of the responses obtained related to social, educational and development aspects of AI

Table 4.
The Mann-Whitney test results for AI possibilities and applications and groups defined by study specialization and gender

Question	Groups defined by the study specialization: education and computer science			Groups defined by gender: male and female		
	Sum of the ranks for computer science	Sum of the ranks for education	p-value	Sum of the ranks for male	Sum of the ranks for female	p-value
1	3462	1894	**0.048**	3049	2308	0.106
2	3525	1831	**0.016**	3113	2243	**0.041**
3a)	3661	1695	**0.001**	3254	2103	**0.003**
3b)	3515	1842	**0.019**	3101	2255	**0.049**
3c)	3555	1801	**0.007**	3217	2139	**0.004**
3d)	3692	1665	**0.000**	3333	2024	**0.000**
3e)	3626	1730	**0.002**	3150	2206	**0.019**
3f)	3494	1862	**0.019**	3101	2255	**0.035**
3g)	3531	1825	**0.014**	3110	2246	**0.041**
3h)	3509	1847	**0.016**	3104	2252	**0.037**
3i)	3498	1858	**0.026**	3066	2291	0.083
3j)	3544	1812	**0.010**	3146	2211	**0.026**

Table 5.
The Kruskal-Wallis test results for AI possibilities and groups defined by age, year of study and previous school

	Groups defined by age			
	<19–21>	<22–25>	<26–30>	>30
n	33	55	10	5
Question	Rank avg and results			
1	49	55	48	52
	H(4,103)=1.015; p-value=0.798			
2	45	52	75	54
	H(4,103)=7.750; p-value=0.052			
3a)	49	51	63	57
	H(4,103)=1.883; p-value=0.597			
3b)	48	52	67	53
	H(4,103)=3.295; p-value=0.348			
3c)	42	55	73	41
	H(4,103)=11.029; p-value=0.012			

3d)	46	53	64	55
		H(4,103)=3.076; p-value=0.380		
3e)	52	52	55	46
		H(4,103)=0.304; p-value=0.959		
3f)	44	54	64	55
		H(4,103)=5.536; p-value=0.137		
3g)	48	52	63	61
		H(4,103)=2.665; p-value=0.446		
3h)	48	54	63	34
		H(4,103)=4.377; p-value=0.224		
3i)	50	51	65	53
		H(4,103)=2.140; p-value=0.544		
3j)	52	51	61	51
		H(4,103)=1.185; p-value=0.757		

Groups defined by previous school				
	Technical secondary school	General secondary school	University	Technical university
n	31	33	17	12
Question		Rank avg and results		
1	52	41	47	52
		H(3,93)=3.229; p-value=0.358		
2	45	40	54	61
		H(3,93)=7.138; p-value=0.068		
3a)	47	39	58	56
		H(3,93)=7.293; p-value=0.063		
3b)	46	42	55	53
		H(3,93)=3.222; p-value=0.359		
3c)	47	38	56	59
		H(3,93)=8.543; p-value=0.036		
3d)	42	41	60	58
		H(3,93)=9.013; p-value=0.029		
3e)	44	40	56	60
		H(3,93)=7.599; p-value=0.055		
3f)	45	41	59	52
		H(3,93)=6.694; p-value=0.082		
3g)	45	40	62	48
		H(3,93)=7.557; p-value=0.056		

3h)	45	44	51	55
		H(3,93)=2.280; p-value=0.516		
3i)	46	43	57	44
		H(3,93)=3.490; p-value=0.322		
3j)	45	43	56	51
		H(3,93)=3.003; p-value=0.391		

	Groups defined by year of study				
	1st	2nd	3rd	4th	5th
n	18	19	35	23	8
Question			Rank avg and results		
1	61	48	48	50	63
		H(4,103)=3.826; p-value=0.431			
2	62	40	47	59	58
		H(4,103)=7.573; p-value=0.109			
3a)	66	35	51	52	64
		H(4,103)=11.871; p-value=0.018			
3b)	68	40	46	57	54
		H(4,103)=11.085; p-value=0.026			
3c)	57	39	49	61	59
		H(4,103)=7.930; p-value=0.094			
3d)	56	42	50	53	70
		H(4,103)=5.938; p-value=0.204			
3e)	60	49	43	54	71
		H(4,103)=8.586; p-value=0.072			
3f)	60	42	47	59	58
		H(4,103)=7.557; p-value=0.109			
3g)	67	45	43	56	63
		H(4,103)=10.952; p-value=0.027			
3h)	67	40	46	59	55
		H(4,103)=11.957; p-value=0.018			
3i)	59	41	50	55	61
		H(4,103)=5.015; p-value=0.286			
3j)	68	47	46	48	63
		H(4,103)=8.937; p-value=0.063			

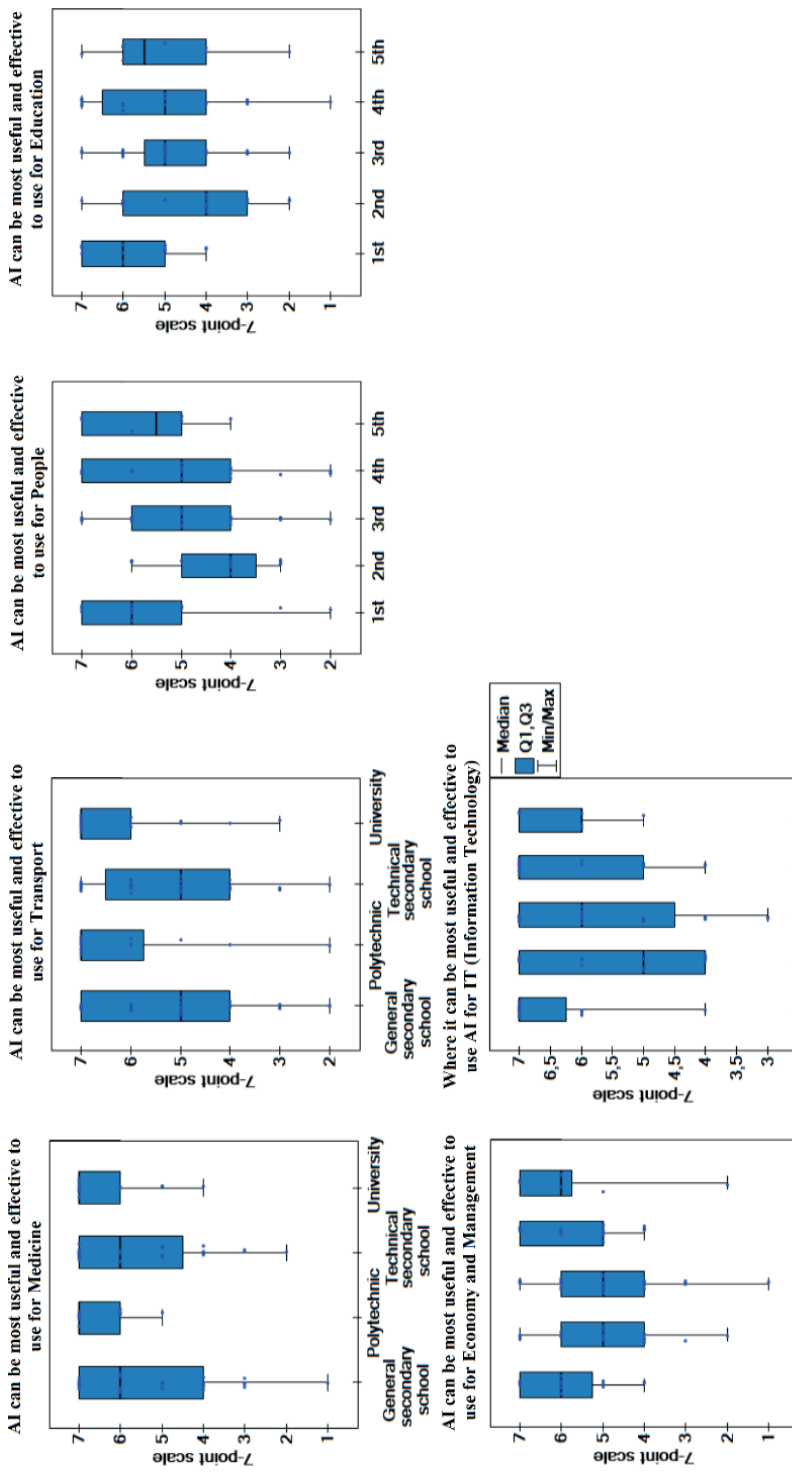

Figure 5. Comparison of the responses obtained for questions related to AI possibilities for which statistically significant differences are confirmed in Table 5

Correlation analysis between perception of AI possibilities and applications and self-assessment of AI literacy

In the previous section it has already been found that master's students evaluate the applicability of AI issues in practice higher than bachelor's students. A hypothesis arose that this was due to the higher level of competence of these students. An exhaustive study was conducted to see if there was indeed a link between the level of competence of students and their perception of the applicability of AI issues in various areas of life and the economy. The correlation between responses to questions on self-assessment of AI competence and the assessment of the applicability of AI issues in practice was investigated. Spearman's rank correlation coefficient was used for this purpose as we have ordinal categorical data. Table 6 shows the values of the correlation coefficient. Significant results with the level of significance, p-value smaller than 0.05 are shown in bold.

Table 6.
The values of Spearman's rank correlation coefficient between questions about applicability of AI issues and questions about self-assessment of AI competence

Questions**	Questions about self-assessment of AI competence								
	1*	2*	3*	4*	5*	6*	7*	8*	9*
1	**0.271**	**0.258**	**0.322**	**0.334**	**0.290**	**0.377**	0.168	0.091	0.136
2	0.054	0.054	0.173	0.032	0.070	0.179	–0.067	–0.102	–0.100
3a)	0.076	0.099	0.040	0.044	–0.007	0.147	–0.128	**–0.220**	–0.165
3b)	0.046	0.165	**0.246**	0.065	0.040	0.116	–0.053	–0.099	–0.010
3c)	0.007	0.103	0.149	0.049	0.114	0.099	–0.115	–0.114	–0.077
3d)	0.020	0.070	0.174	0.109	0.041	0.148	–0.133	–0.066	–0.047
3e)	0.030	–0.040	**0.215**	0.072	0.018	–0.002	**–0.229**	–0.108	**–0.228**
3f)	–0.183	–0.084	0.045	–0.096	0.001	–0.021	**–0.239**	–0.142	–0.115
3g)	0.000	0.019	0.050	0.020	–0.078	0.084	**–0.202**	–0.107	–0.154
3h)	–0.043	–0.017	0.105	–0.040	–0.023	0.015	–0.174	–0.078	–0.183
3i)	–0.071	0.019	0.031	–0.093	–0.175	0.040	**–0.230**	–0.165	–0.151
3j)	–0.064	–0.004	0.093	0.012	–0.101	0.093	**–0.209**	–0.193	**–0.211**

Designations: 1* – AI supporting in programming languages (e.g. Python); 2* – Ethical and social aspects of AI; 3* – Data Pre-processing Techniques; 4* – Knowledge Machine Learning; 5* – Deep Learning; 6* – Natural Language Processing; 7* – Learning Analytics; 8* – Cyber security; 9* – Recommender systems. 1 – Can and should AI be more actively used, for example, in education to personalize teaching-learning?; 2 – Can social robots be helpful in the development of children including those with special needs?; 3a) – Where it can be most useful and effective to use AI for People; 3b) – for Education; 3c) – for Medicine; 3d) – for Transport; 3e) – for Business, Finance and Banking; 3f) – for Space and NASA; 3g) – for Economy and Management; 3h) – for IT (Information Technology); 3i) – for public services; 3j) – for Cybersecurity and safety. ** Questions about applicability of AI issues.

As can be seen, the correlation between both aspects: competence of AI and applicability of AI issues is not very high. Only in sixteen cases it turned out to be significant. This confirms hypothesis H6. A significant correlation is between:

- Question 1 – Can and should AI be more actively used, for example, in education to personalize teaching-learning? and Questions 1*–6* – competence in programming languages, ethical and social aspects of AI, data Preprocessing Techniques, Knowledge Machine Learning, Deep Learning and Natural Language Processing. In all these cases, a significant positive correlation of medium to weak intensity was confirmed. This means that a higher range of competence influences a higher evaluation of the applicability of AI issues in education to personalize teaching-learning.
- Question 7* – Learning Analytics and Questions 3e)–3g) and 3i), 3j) – the possibility of using AI in Business, Finance and Banking, for Space and NASA, for Economy and Management, for public services and for Cybersecurity and safety. Negative correlations of weak intensity was found here. Thus, an increase in knowledge of Learning Analytics causes on average a decrease in belief that AI can be applied to these issues.
- Question 3* – competences in Data Preprocessing Techniques and Questions 3b) and 3e) – the possibility of using AI in Education and Business, Finance and Banking. Positive correlations of weak intensity was found here. This is very sensible, as financial and business data often require advanced data preprocessing, which takes sometimes up to 60%–70% of total analysis time. Students familiar with this subject are probably simply aware of it.
- Question 8* – competences in Cybersecurity and Question 3a) – the possibility of using AI for People. A negative correlation of weak intensity was found here. Thus, an increase in knowledge of Cyber security causes on average an increase in evaluating the applicability of AI for People. Perhaps this is related to students' awareness of the risks posed by the use of AI in cybersecurity.
- Question 9* – competences in Recommender systems and Questions 3e) and 3j) the possibility of using AI for Business, Finance and Banking and for Cybersecurity and safety. Negative correlations of weak intensity were found here. Thus, an increase in knowledge of Recommender systems causes on average a decrease in belief that AI can be applied to Business, Finance and Banking and for Cybersecurity and safety. To be honest, this is quite a strange result as in business, finance and banking recommendation systems are used with great success. Although, on the other hand, in cybersecurity recommendation systems are not very applicable.

Evaluation of potential risks in relation to study specializations, age, gender, year of study and previous schools

The next part of the survey is related to the potential risks associated with the development of artificial intelligence. The aim of this study was to analyse the attitudes and fears about AI among students of different study specializations, age, gender, year of study and previous schools. Also, the correlation between the level of knowledge of AI in a variety of contexts and students' concerns was studied. The questions in this part and possible responses included in the questionnaire were defined using Likert scales to the 7-point scale. Higher scores correspond to higher intensity of the problem. The questions are listed below.

What risks can AI bring:

1. Imposing a course of action depending on the analysis made by AI and its recommendations;
2. Increasing threat of interference in private life. Threats to fundamental rights and democracy;
3. Negative impact on the labour market;
4. Increasing role of robots, controlled by AI and in the future threats of robots going out of control;
5. Concurrency;
6. Transparency challenges;
7. Security risks;

Bar charts of the obtained responses related to the views on AI potential risks are shown in Figure 6.

As can be seen, respondents have the greatest fears in relation to increasing threat of interference of AI in private life – threats to fundamental rights and democracy. The largest number of respondents indicated a very high risk in this question. Similarly, it can denote the intensity of fear regarding security. Here again, a large number of respondents indicated the highest values. On the other hand, to the question concerning the role of robots, controlled by AI and possibility that in the future robots will go out of control respondents did not show such a significant concern. Practically, equal numbers of students indicated each value from the answer scale. For the remaining questions, rather, respondents mostly indicated the middle value on the scale, which means rather their neutrality towards the threat.

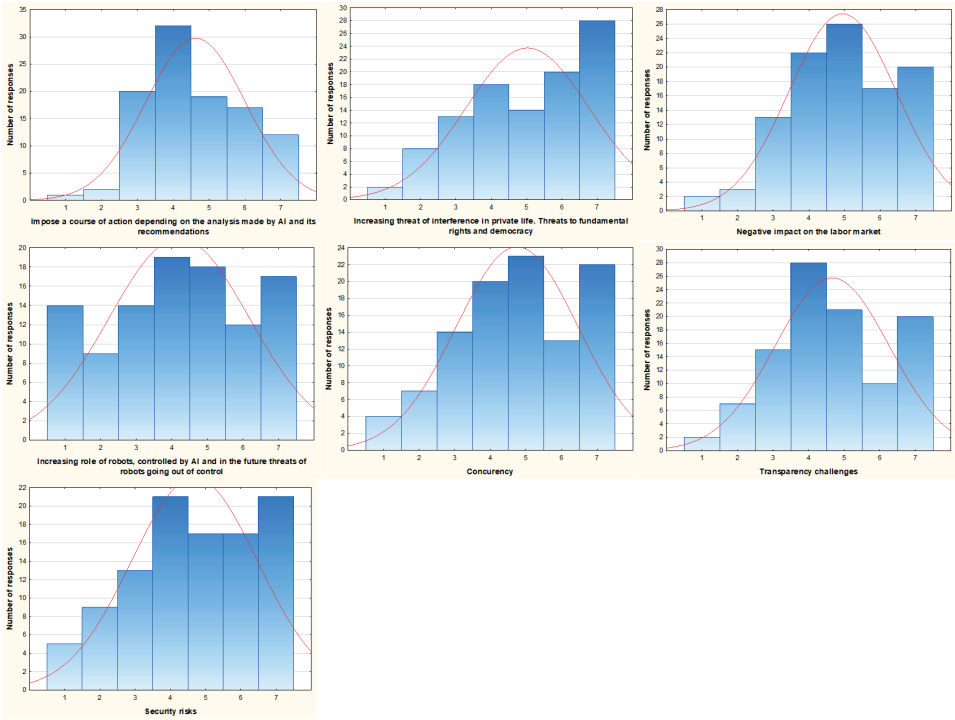

Figure 6. Bar charts of the responses obtained related to AI potential risks

Statistical tests were performed in order to test the significance of differences in the results – attitudes towards various threats – obtained for groups defined by study specialization, age, gender, year of study and previous school (each issue was considered separately). All the results examined are for the ordinal variable. The Mann-Whitney test was used to detect differences in the two independent samples defined by field of study and gender. The results obtained are presented in Table 7: sum of ranks across groups and p-value. There are statistically significant differences in the results obtained for two aspects studied; Imposing a course of action depending on the analysis made by AI and its recommendations; Increasing role of robots, controlled by AI and in the future threats of robots going out of control – questions 1 and 4 – in the groups defined by both study specialization and gender. Additionally, comparative box-whiskers charts for the responses to questions 1–7 grouped by specialization (Figure 7) and gender (Figure 8) were made. As can be observed, the values of the responses for the question 1 are much higher for computer science specialty students than for education specialty students. This means that computer science students are much more concerned about the threat of imposing a course of action depending on the analysis made by AI and its recommendations than education students. This confirms hypothesis H7. For question 4, the situation is quite opposite. Here, education students are more

concerned about the threat of increasing role of robots, controlled by AI and in the future threats of robots going out of control than computer science students. Similar conclusions can be drawn based on the box-whiskers charts presented in Figure 8. However, here it is the male students who show more concern about threat 1 and less concern about threat 4 than women. Probably this correspondence is due to the fact that significantly more women are studying in the specialty of education. There were only 7 women in computer science specialization who took part in the questionnaire, the remaining 54 were men. Thus, the results obtained for groups defined by gender are probably also related to the specialization of students. In reality, the probability of robots going out of control is low, and presumably the awareness of this is linked to the greater knowledge of AI issues that computer science specialty students have.

Table 7.
The Mann-Whitney test results for potential risks and groups defined by study specialization and gender

Question	Groups defined by the study specialization: education and computer science			Groups defined by gender: male and female		
	Sum of the ranks for computer science	Sum of the ranks for education	p-value	Sum of the ranks for male	Sum of the ranks for female	p-value
1	3604	1752	**0.004**	3278	2078	**0.002**
2	3249	2107	0.608	2883	2473	0.623
3	3237.5	2118.5	0.663	3003.5	2352.5	0.198
4	2683.5	2672.5	**0.001**	2348	3008	**0.002**
5	3045	2311	0.396	2801	2555	0.966
6	3254	2102	0.584	2894.5	2461.5	0.570
7	3030	2326	0.342	2689	2667	0.434

In the next stage of the study, the Kruskal-Wallis tests were performed to test the significance of differences in the results for groups defined by age, year of study and previous school (in each case the number of groups was greater than 2). The results obtained group size, group rank mean, p-value and test statistic value are presented in Table 8. Significant results are shown in bold. As can be seen, age and type of previous school have little influence on the AI-related anxiety. In contrast, the year of study has a significant impact on various types of AI related fears. A comparative box-whiskers charts for the responses to questions 1–7 grouped by year of study (Figure 9) were made. As can be observed, the greatest anxiety in relation to all investigated aspects – questions 1–7 – is felt by first and fourth-year students. In contrast, the lowest level of anxiety about the impact of AI is felt

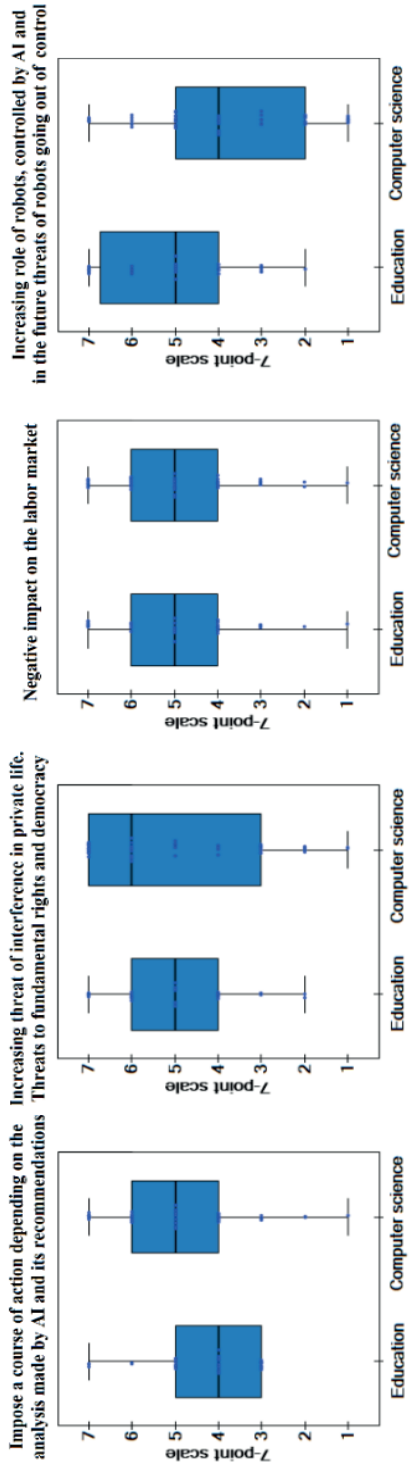

Figure 7. Comparison of the responses obtained for questions 1–7 in the groups defined by study specialization

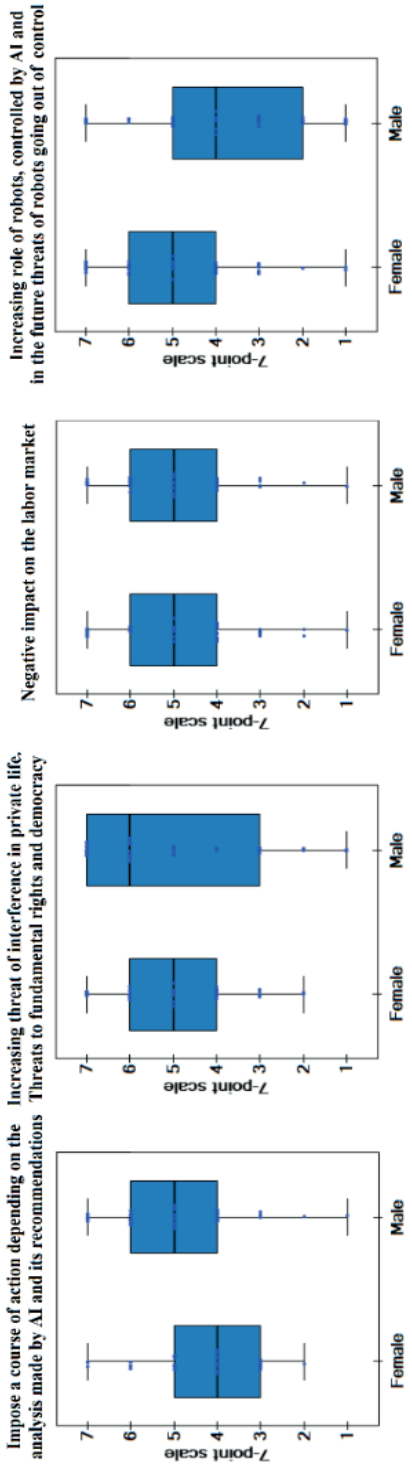

Figure 8. Comparison of the responses obtained for questions 1–7 in the groups defined by gender

by second and fifth-year students. This confirms hypothesis H8. The explanation we find for this phenomenon is that first-year students in both bachelor's and master's programs feel the biggest concern (the fourth year of study is the first year of master's studies). Considering question 1 where grouping in terms of previous school had a significant impact on the differences in results, it can be concluded that students who previously graduated from a technical university or technical secondary school consider this risk as more significant than students who previously graduated from a general secondary school or university. So, it can be concluded that for students with more technical knowledge, the issue of imposing a course of action depending on the analysis made by AI and its recommendations is more likely to occur.

Table 8.
The Kruskal-Wallis test results for potential risks and groups defined by age, year of study and previous school

	Groups defined by age			
	<19–21>	<22–25>	<26–30>	>30
n	33	55	10	5
Question		Rank avg and results		
1	43	55	64	57
		H(4,103)=5.367; p-value=0.147		
2	51	53	64	31
		H(4,103)=4.541; p-value=0.209		
3	46	56	57	40
		H(4,103)=3.325; p-value=0.344		
4	46	54	66	43
		H(4,103)=4.207; p-value=0.240		
5	47	56	50	45
		H(4,103)=2.456; p-value=0.483		
6	46	53	63	56
		H(4,103)=2.897; p-value=0.408		
7	45	56	59	40
		H(4,103)=4.266; p-value=0.234		

Groups defined by previous school				
	Technical secondary school	General secondary school	University	Polytechnic
n	31	33	17	12
Question	Rank avg and results			
1	52	37	50	59
	H(**3,93)=8.084; p-value=0.044**			
2	51	43	41	58
	H(3,93)=4.360; p-value=0.225			
3	54	41	44	51
	H(3,93)=3.995; p-value=0.262			
4	56	47	42	32
	H(3,93)=7.734; p-value=0.052			
5	54	41	48	45
	H(3,93)=3.732; p-value=0.292			
6	50	41	50	50
	H(3,93)=2.445; p-value=0.485			
7	53	44	40	50
	H(3,93)=3.377; p-value=0.337			

Groups defined by year of study					
	1st	2nd	3rd	4th	5th
n	18	19	35	23	8
Question	Rank avg and results				
1	60	32	53	61	50
	H(**4,103)=12.529; p-value=0.014**				
2	70	39	45	59	54
	H(**4,103)=13.553; p-value=0.009**				
3	63	34	52	62	41
	H(**4,103)=13.680; p-value=0.008**				
4	52	49	48	67	33
	H(**4,103)=10.478; p-value=0.033**				
5	67	41	46	64	37
	H(**4,103)=14.380; p-value=0.006**				
6	73	35	49	57	43
	H(**4,103)=16.910; p-value=0.002**				
7	52	38	55	60	49
	H(4,103)=6.316; p-value=0.177				

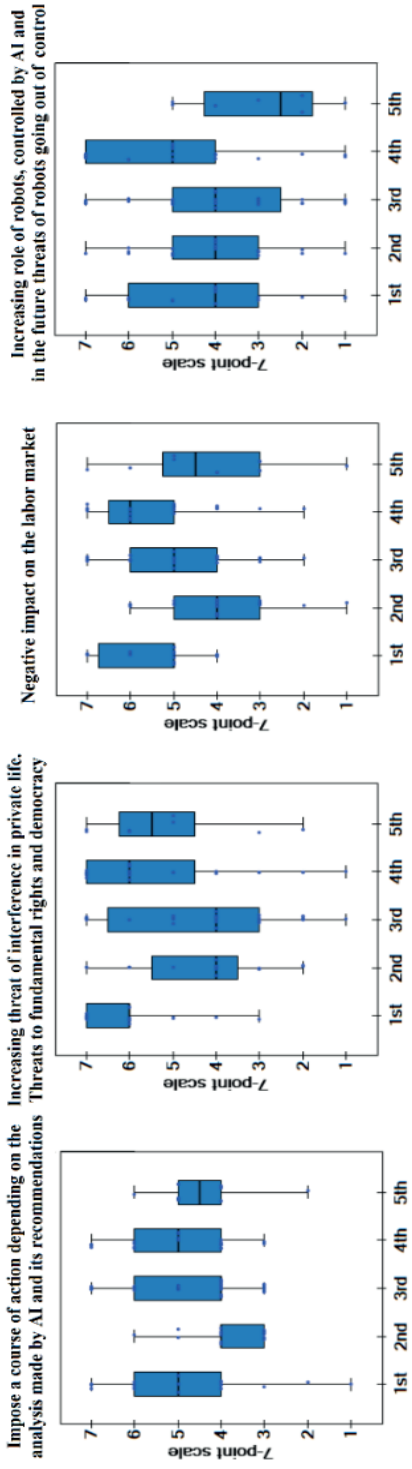

Figure 9. Comparison of the responses obtained for questions 1-7 in the groups defined by year of study

Correlation analysis between feelings of anxiety toward AI and self-assessment of AI literacy

After an analysis on the differences in feelings of anxiety toward AI by groups specified by study specialization and year of study, an assumption arose that fear toward AI is related to students' knowledge of AI. Therefore, the correlation between responses to questions on self-assessment of AI competence and the level of anxiety toward various AI threats was investigated. Spearman's rank correlation coefficient was used for this purpose as we have ordinal categorical data. Table 9 shows the values of the correlation coefficient. Significant results with the level of significance, p-value smaller than 0.05 are shown in bold.

Table 9.
The values of Spearman's rank correlation coefficient between questions about risk and questions about self-assessment of AI competence

Questions about potential risks	Questions about self-assessment of AI competence								
	1*	2*	3*	4*	5*	6*	7*	8*	9*
1	–0.002	–0.087	0.105	–0.024	0.058	–0.053	–0.100	0.036	–0.089
2	–0.111	–0.105	0.030	–0.141	0.007	0.002	–0.103	–0.121	–0.002
3	–0.125	–0.080	0.031	**–0.223**	–0.087	–0.106	–0.137	–0.054	–0.097
4	–0.048	–0.112	–0.124	–0.154	0.014	–0.095	0.016	0.093	0.077
5	–0.134	**–0.195**	–0.063	**–0.262**	–0.108	–0.097	–0.101	–0.007	–0.010
6	0.054	0.028	0.087	–0.041	0.013	0.096	–0.101	–0.071	0.069
7	0.014	–0.023	0.015	0.066	**0.181**	0.060	0.110	0.091	0.104

Designations: 1* – AI supporting in programming languages (e.g. Python); 2* – Ethical and social aspects of AI; 3* – Data Pre-processing Techniques; 4* – Knowledge Machine Learning; 5* – Deep Learning; 6* – Natural Language Processing; 7* – Learning Analytics; 8* – Cyber security; 9* – Recommender systems. 1 – Imposing a course of action depending on the analysis made by AI and its recommendations; 2 – Increasing threat of interference in private life. Threats to fundamental rights and democracy; 3 – Negative impact on the labour market; 4 – Increasing role of robots, controlled by AI and in the future threats of robots going out of control; 5 – Concurrency; 6 – Transparency challenges; 7 – Security risks.

As can be seen, the correlation between both aspects; competence of AI and anxiety towards AI is low. Only in four cases it turned out to be significant. This confirms hypothesis H9. A significant correlation is between:

- Question 2* – Knowledge about ethical and social aspects of AI and Question 5 – anxiety about Concurrency with AI. A negative correlation of weak intensity was found here. Thus, an increase in knowledge of ethical and social aspects of AI causes on average a decrease in concurrency anxiety.

- Question 4* – Knowledge Machine Learning and Question 3 – Negative impact on the labour market. A negative correlation of weak intensity was found here. Thus, an increase in knowledge of Machine Learning causes on average a decrease in a sense of fear about negative impact on the labour market.
- Question 4* – Knowledge Machine Learning and Question 5 – anxiety about Concurrency with AI. A negative correlation of weak intensity was found here. Thus, an increase in knowledge of Machine Learning causes on average a decrease in concurrency anxiety.
- Question 5* – Knowledge Deep Learning and Question 7 – Security risks. A positive correlation of weak intensity was found here. Thus, an increase in knowledge of Deep Learning causes on average an increase in concerns about security risks.

The rationale for the above found correlations may be as follows. Awareness of the social and ethical aspects of AI increases knowledge of regulations regarding AI, thereby reducing the fear that AI could compete with humans. Knowledge about machine learning models increases relevance in the job market and gives awareness of what aspects/tasks AI modules can really be applied to. Thus, it reduces the fear of lack of jobs as a consequence of AI occupying them and reduces the fear of competiting with AI. A good knowledge of deep learning issues gives an awareness of the capabilities of this tool and thus awareness how it can be used in the context of cybersecurity. Therefore, it increases concern about this issue.

Discussion

In the paper, nine different hypotheses were posed. Extensive statistical hypothesis testing and correlation analysis were carried out. The following hypotheses were able to be fully or partially proven:

I. Computer science students have a higher level of AI competence than education students. This hypothesis has only been proven for skills relating to programming languages supporting AI. In all other AI competences studied, no significant differences in competence levels in groups defined by faculty were observed.

II. Students who have completed engineering technical studies (Bachelor's degree) have a higher level of AI competence than, students who are just after high school. This hypothesis could only be proven for the skills concerning Knowledge Discovery. It was indicated that, in fact, students who graduated with a bachelor's degree from a technical university had higher competences in this area. In all other AI competences studied, no significant differences in competence levels were observed.

III. Students in their fifth year of study have higher AI competences than students in earlier years of study. This hypothesis has been fully proven. For four different AI competences (AI supporting in programming languages, Data Preprocessing Techniques, Machine Learning and Recommender systems) there are statistically significant differences in the level of competence in groups defined by the year of study, with the fifth-year students showing the highest level.

IV. Computer science students are more aware of the possibilities and applications that AI brings than education students. This hypothesis has been fully proven using the statistical tests. In all studied aspects of AI application there are statistically significant differences in the results, computer science students rated AI capabilities higher than education students.

VIII. Students in their fifth year of study have lower concerns, fear about AI development than students in earlier years of study. This is due to greater experience and knowledge of these students. This hypothesis has been fully proven. Virtually in all aspects studied, a statistically significant differences in results related to the AI concerns of students of different years of study was confirmed. The boxplot charts clearly show that it is the fifth-year students who show the lowest level of concern.

Certain regularities that seemed reasonable have not been demonstrated. The predicted correlations are not covered by the data. Hypotheses that could not be confirmed:

V. Fifth-year students have a higher awareness of AI possibilities and applications than students in earlier years of study. Although it was shown that there was a statistically significant difference in the ratings of the importance of AI in the four application areas studied. However, it was not only the fifth-year students who rated AI capabilities the highest. Often, it was the first-year students who assigned higher ratings. This is probably related to an initial fascination with AI issues more than knowledge of the subject.

VI. Awareness of AI possibilities and applications increases proportionally to the level of AI competence. The higher the students' AI competence, the more they appreciate the possibilities of AI. On the other hand, a statistically significant positive correlation was shown to exist in eight out of one hundred and eight relationships tested between AI competence and awareness of AI use. However, firstly these correlations are of weak intensity, secondly, also in eight cases a significant negative correlation was discovered (this applies to competences in Learning Analytics; Cyber security; Recommender systems). Therefore, this hypothesis cannot be confirmed.

VII. Computer science students have less concern, fear about the development of AI than education students. In two out of the seven hypotheses tested, we obtained a significant difference in the level of concern towards AI issues

between students of different faculties. However, in case of "increasing role of robots, controlled by AI and in the future threats of robots going out of control" computer science students had less concern, but in the case of "imposing a course of action depending on the analysis made by AI and its recommendations" they had more concern than education students.

IX. The increase in AI competence influences a calm attitude towards AI and a decrease in fear of AI development. In only three out of the sixty-three correlations tested statistically significant negative correlations were confirmed. Furthermore, the correlation is of weak intensity. The competences that influence a small but significant reduction in the level of concern are Ethical and social aspects of AI and Knowledge Machine Learning. However, in the overwhelming number of cases, an increase in competences does not affect the reduction of concerns towards AI.

The final model showing the confirmed relations between the studied concepts is presented in Figure 10.

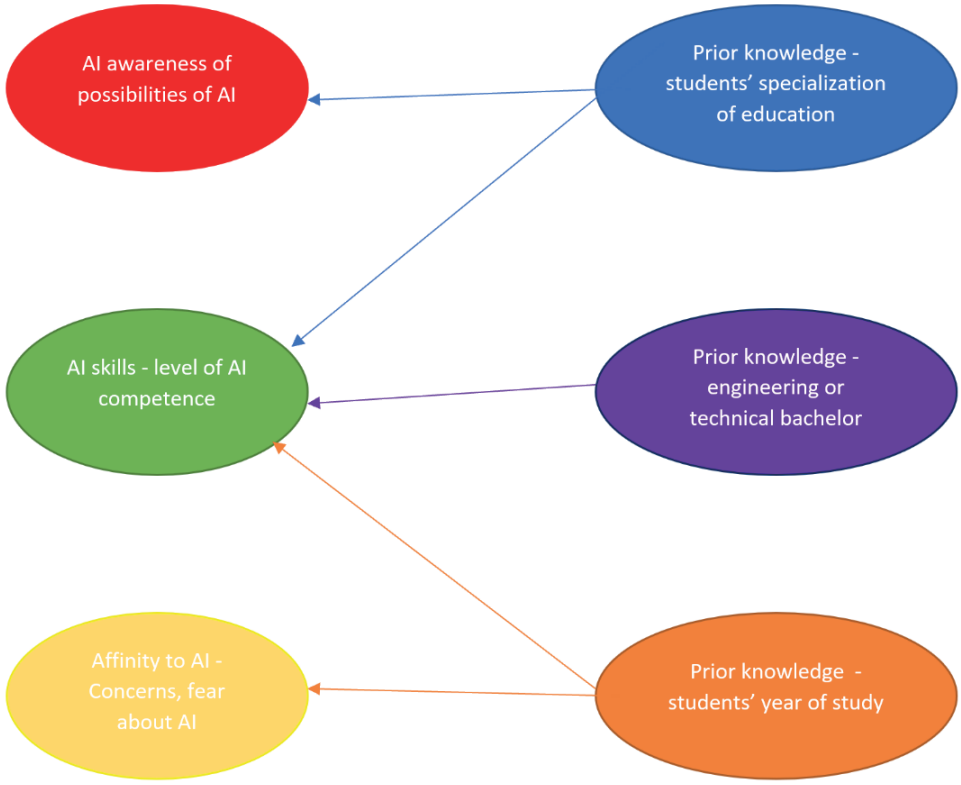

Figure 10. Six factors final model and investigated relations

Source: Own work based on Asghar, Minichiello, & Iqbal, 2022.

Based on the results, much attention should be paid to learning about AI issues for computer science and education students. The competence of students is low. It is worrying that there is no significant correlation between the extent of competence and awareness of AI applications and capabilities. Here there indeed remains a large field of work for university teachers. It is encouraging that students in their fifth year of study already have a greater awareness of the possibilities of using AI issues and have a positive attitude towards them. Thus, the greatest emphasis is placed on AI-related education in the fifth year of study. Arguably, it should be strengthened in the earlier years of study. However, students are mostly aware of AI's impact on the ethical aspects of life and are aware of the risks, so they will likely be able to recognize the school potential negative impacts of AI in their life. The natural conclusion is that if they can recognize it, they will also be able to respond to it. The main recommendations are to strengthen the education related to AI capabilities and competence in prematurely years of study.

Conclusions

In conclusion, it is possible to emphasize some of the findings regarding the attitudes of IT and pedagogy students to the educational, social and ethical aspects of AI implementation, as well as their competence in AI. Their self-assessment has shown an unsatisfactory level in the main areas of AI, while at the same time the students' attitude towards the prospect of using AI in some social areas was positive. Among the grouping conditions examined, it can be seen that the year of study has the greatest influence. We notice a regularity that students in the first and fifth year of studies rate the possibilities of using AI for people, education, economy and management and computer science higher than students in the second, third or fourth year of study. This may be related to an initial fascination with AI issues in the first year of study and the greatest knowledge about the possibilities of AI in the fifth year of study. Their interest in the topic is the motivation for the development of a platform and courses in the research area for students to deepen their knowledge and use it in their education and future professional career, which is what the FITPED-AI project serves, partly described in Skalka, & Drlik (2022), and Smyrnova-Trybulska, Skalka, & Drlik (2023). Other experiences and achievements may also be taken into account. The authors of the study (Larionov, et al., 2022) analyse digital trends in the development of higher education. The transition from a quantitative state of digitalization to a qualitative one is noted, associated with the introduction of artificial intelligence, blockchain, and work with large databases into education (Larionov, et al., 2022). The next study explores the prospects for improving the scientific and educational system

based on innovative methods of education using neural network technologies, the need for a transition to online education with integrated systems of natural and artificial intelligence (Akhmetshin et al., 2020). The researchers (Huang et al., 2023) described an interesting study, concerning applying AI-enabled personalized video recommendations to stimulate students' learning motivation and engagement during a systems programming course in a flipped classroom setting and some research results (Huang, Lu, & Yang, 2023). The Project FITPED-AI will create high-quality educational resources in a user-friendly online virtual environment to respect privacy and ethical standards. The chosen strategy of inclusion and diversity implemented in a virtual learning environment enables education for disabled users through created digital courses and resources. Any number of repetitions is allowed during learning, and educators are positively motivated to achieve partial goals. At the same time, the created educational content will be freely available via the Internet for those interested, regardless of cultural, social, geographical or economic barriers (Smyrnova-Trybulska, Skalka, & Drlik, 2023).

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Data Availability Statement

The datasets generated during the current study are available from the corresponding author on reasonable request. None of the data or materials for the experiments reported here is available, and none of the experiments was preregistered.

References

Ahmed, A. A. A. & Ganapathy, A. (2021). Creation of Automated Content with Embedded Artificial Intelligence: a Study on Learning Management System for Educational Entrepreneurship.

Academy of Entrepreneurship Journal, 27(3), 1–10. Print ISSN: 1087-9595; Online ISSN: 1528-2686.

Akhmetshin, E., Barmuta, K., Vasilev, V., Okagbue, H. & Ijezie, O. (2020). Principal Directions of Digital Transformation of Higher Education System in Sustainable Education (2020) E3S Web of Conferences, 208, art. no. 09042. https://doi.org/10.1051/e3sconf/202020809042.

Asghar, M., Minichiello, A. & Iqbal, A. (2022). Perceived Factors Contributing to the Subjective Wellbeing of Undergraduate Engineering Students: An Exploratory Study. Int. J. Environ. Res. Public Health 2022, 19, 16284. https://doi.org/10.3390/ijerph192316284.

Azevedo, A. & Almeida, A. H. (2021). Grasp the challenge of digital transition in smes – a training course geared towards decision-makers. *Education Sciences,* 11 (4). https://doi.org/10.3390/educsci11040151.

Baek, C. & Doleck, T. (2020). A bibliometric analysis of the papers published in the Journal of Artificial Intelligence in Education from 2015–2019. *International Journal of Learning Analytics and Artificial Intelligence for Education*, 2(1), 67–84. https://doi.org/10.3991/ijai.v2i1.14481.

Fedotova, G. V., Ushamirskaya, G. F., Sigidov, Y. I., Kuzmina, T. I. & Mandrik, N. V. (2020). Industry 4.0 as a new vector of growth and development of the knowledge economy. In Janusz Kacprzyk (Ed.) *Advances in Intelligent Systems and Computing*, 1100 AISC, (pp. 88–97). https://doi.org/10.1007/978-3-030-39319-9_9.

Hinojo-Lucena, F. J., Aznar-Díaz, I., Cáceres-Reche, M. P. & Romero-Rodríguez, J. M. (2019). Artificial intelligence in higher education: a bibliometric study on its impact in the scientific literature. *Education Sciences,* 9(1). https://doi.org/10.3390/educsci9010051.

Huang, Anna Y. Q., Lu, Owen H. T. & Yang, Stephen J. H., (2023). Effects of artificial Intelligence–Enabled personalized recommendations on learners' learning engagement, motivation, and outcomes in a flipped classroom. *Computers & Education,* 194, March 2023, 104684. https://doi.org/10.1016/j.compedu.2022.104684.

Huang, L. & Peissl, W. (2023). Artificial Intelligence – A New Knowledge and Decision-Making Paradigm?. In: Hennen, L., Hahn, J., Ladikas, M., Lindner, R., Peissl, W., van Est, R. (eds) *Technology Assessment in a Globalized World.* Springer, Cham. https://doi.org/10.1007/978-3-031-10617-0_9.

Karnouskos, S. (2022). Symbiosis with artificial intelligence via the prism of law, robots, and society. *Artificial Intelligence and Law,* 30, 93–115. https://doi.org/10.1007/s10506-021-09289-1.

Khaperskaya, A. & Minin, M. (2020). Artificial intelligence as an instrument of successful pedagogical monitoring and affect assessment for disabled people employment. CEUR Workshop Proceedings, 2770, *Proceedings of the 4th International Conference on Informatization of Education and E-learning Methodology: Digital Technologies in Education (IEELM-DTE 2020),* Krasnoyarsk, October 6–9, 2020, (pp. 220–227).

Kozlova, E. P., Morozova, G. A., Kuznetsov, V. P., Romanovskaya, E. V. & Andryashina, N. S. (2021). Interaction of Human and Smart Technologies in Modern Conditions. *Lecture Notes in Networks and Systems,* 155, (pp. 609–618). https://doi.org/10.1007/978-3-030-59126-7_68.

Larionov, V. G., Sheremetyeva, E. N. & Barinova, E. P. (2022). Digital Trends in Higher Education, Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti, (1), (pp. 322–329). https://doi.org/10.47367/0021-3497_2022_1_322.

Martins, R. M., von Wangenheim, C. G., Rauber, M. F. et al. (2023). Machine Learning for All! – Introducing Machine Learning in Middle and High School. *International Journal of Artificial Intelligence in Education*. https://doi.org/10.1007/s40593-022-00325-y.

Mata-Rivera, M. F., Zagal-Flores, R. & Barria-Huidobro, C. (Eds.) (2022). Telematics and Computing: 11th International Congress, WITCOM 2022, Cancún, México, November 7–11, 2022, Proceedings (*Communications in Computer and Information Science, 1659*) 1st ed. 2022, CCIS, 466 p.

Mhlanga, D. (2022). Human-Centered Artificial Intelligence: The Superlative Approach to Achieve Sustainable Development Goals in the Fourth Industrial Revolution Sustainability 2022, 14(13), 7804. https://doi.org/10.3390/su14137804.

Oprea, M. (2021). Integration of Artificial Intelligence in STEM Education Through IOT Projects Based on Machine Learning. *eLearning and Software for Education Conference*, (pp. 211–221). https://doi.org/10.12753/2066-026X-21-096.

Pikkarainen, A. & Tihinen, M. (2023). Education as a Promoter of Digital Transformation in the Manufacturing Industry. In: Kahraman, C., Haktanır, E. (eds) *Intelligent Systems in Digital Transformation. Lecture Notes in Networks and Systems*, vol 549. Springer, Cham. https://doi.org/10.1007/978-3-031-16598-6_8.

Ramírez, M. R. (2021). Digital transformation in the universities: Process in the time of covid 19 [Article@Transformación digital en las universidades: Proceso en épocas de covid 19] RISTI - Revista Iberica de Sistemas e Tecnologias de Informacao, 2021 (E42), pp. 573–582.

Ratten, V. (2020). Coronavirus (Covid-19) and the entrepreneurship education community. Journal of Enterprising Communities, 14 (5), (pp. 753–764). https://doi.org/10.1108/JEC-06-2020-0121.

Richardson, M. & Clesham, R. (2021) Rise of the machines? The evolving role of AI technologies in high-stakes assessment. London Review of Education. 19(1). art. no. 9. https://doi.org/10.14324/LRE.19.1.09.

Skalka, J. & Drlik, M. (2022). Proposal of Artificial Intelligence Educational Model Using Active Learning in a Virtual Learning Environment. In E. Smyrnova-Trybulska (ed.) *E-learning in the Transformation of Education in Digital Society. „E-learning" Series*. Vol. 14. Katowice-Cieszyn: STUDIO NOA for University of Silesia, (pp. 15–25) ISSN 2451-3644 (print edition), ISSN 2451-3652 (digital edition), ISBN 978-83-66055-31-5. https://doi.org/10.34916/el.2022.14.02.

Smyrnova-Trybulska, E., Drlik, M. & Skalka, J. (2023). Wymiana doświadczeń i najlepsze praktyki w nauczaniu AI. [Exchange of experiences and best practices in teaching AI.] *Gazeta Uniwersytecka, [University Newspaper]* 304, 28–29. https://gazeta.us.edu.pl/sites/gazeta.us.edu.pl/files/PDF/Gazeta_Uniwersytecka_nr_304%20(internet)%20(1).pdf.

Smyrnova-Trybulska, E., Przybyła-Kasperek, M. & Kommers, P. (2023). Educational, Social, and Ethical Aspects of AI in the Opinion of IT and Pedagogy Students – a Case Study In P. Iasias (Ed.), *Conference Proceedings E-Society*, 11–13 March, 2023, Lisbon IADIS Lisbon, (pp. 171–178), ISBN: 978-989-8704-47-4.

Sosnovsky, S., Brusilovsky, P., Baraniuk, R. & Lan, A. (2020). iTextbooks 2020 – *Proceedings of the 2nd International Workshop on Intelligent Textbooks 2020, co-located with 21st International Conference on Artificial Intelligence in Education, AIED 2020 (2020) CEUR Workshop Proceedings*, 2674, 104 p.

Xu, W. & Fan, O. (2022). The application of AI technologies in STEM education: a systematic review from 2011 to 2021. *International Journal of STEM Education,* 9, Article 59. https://doi.org/10.1186/s40594-022-00377-5.

Yam, J. & Skorburg, J. A. (2021). From human resources to human rights: Impact assessments for hiring algorithms. *Ethics and Information Technology* 23(4): 611–623. https://doi.org/10.1007/s10676-021-09599-7.

Yu, H. & Nazir, S. (2021). Role of 5g and Artificial Intelligence for Research and Transformation of English Situational Teaching in Higher Studies. *Mobile Information Systems*, 2021, art. no. 3773414. https://doi.org/10.1155/2021/3773414.

Factors Enhancing Students' Views on Artificial Intelligence

Małgorzata Przybyła-Kasperek, Eugenia Smyrnova-Trybulska, Piet Kommers

Czynniki warunkujące postrzeganie sztucznej inteligencji przez studentów

S t r e s z c z e n i e

Sztuczna inteligencja (AI) jest obecnie jednym z ważniejszych i współczesnych kierunków rozwoju nauki w kontekście interdyscyplinarnym. Podejście UE do sztucznej inteligencji koncentruje się na doskonałości i zaufaniu, mając na celu zwiększenie potencjału badawczego i przemysłowego przy jednoczesnym zapewnieniu bezpieczeństwa i praw podstawowych (Europejskie podejście do sztucznej inteligencji). Wzmocnienie wspierania doskonałości w dziedzinie sztucznej inteligencji wzmocni potencjał Europy w skali globalnej. Jednocześnie nie rozwiązano jeszcze wielu wyzwań i kwestii. Problemem poruszonym w artykule jest zbadanie i przeanalizowanie podejścia studentów informatyki i pedagogiki do edukacyjnych, społecznych i etycznych aspektów wdrażania sztucznej inteligencji. Celem jest odkrycie i analiza postaw studentów informatyki i pedagogiki wobec edukacyjnych, społecznych i etycznych aspektów wdrażania sztucznej inteligencji. O wypełnienie ankiety poproszono studentów dwóch wydziałów Uniwersytetu Śląskiego w Katowicach. Byli to głównie studenci dwóch specjalności – informatyki i pedagogiki. W badaniu wzięło udział 103 studentów. Do weryfikacji wykorzystano testy Kruskala-Wallisa. Głównymi badanymi zagadnieniami był poziom kompetencji studentów w zakresie AI, ich świadomość zastosowań AI w różnych dziedzinach życia i gospodarki oraz znaczenie dziedziny AI. Badanie obejmowało również poziom zaufania do AI oraz poziom lęku wobec AI. Zbadano różnego rodzaju zależności i powiązania między tymi aspektami. Hipotezy zostały w większości potwierdzone. Na koniec artykułu przedstawiono dyskusję i główne wnioski.

S ł o w a k l u c z o w e: Sztuczna inteligencja (AI), aspekty edukacyjne, społeczne i etyczne, studenci informatyki i pedagogiki, opinia, testy Kruskala-Wallisa

Małgorzata Przybyła-Kasperek, Eugenia Smyrnova-Trybulska, Piet Kommers

Factores que causando en la opinión de los estudiantes sobre la inteligencia artificial

R e s u m e n

La Inteligencia Artificial (IA) es actualmente una de las direcciones más importantes y contemporáneas del desarrollo de la ciencia en un contexto interdisciplinar. El planteamiento de la UE en materia de inteligencia artificial se centra en la excelencia y la confianza, con el objetivo de impulsar la investigación y la capacidad industrial, garantizando al mismo tiempo la seguridad y los derechos fundamentales (Un planteamiento europeo de la inteligencia artificial). Reforzar el fomento de la excelencia en IA fortalecerá el potencial de Europa para competir a nivel mundial. Simultáneamente, aún no se han resuelto muchos retos y problemas. El problema planteado en el artículo consiste en explorar y analizar la actitud de los estudiantes de informática y educación ante los aspectos educativos, sociales y éticos de la aplicación de la IA. El propósito es descubrir y analizar la actitud de los estudiantes de informática y pedagogía hacia los aspectos educativos, sociales y éticos de la implementación de la IA. Se pidió a los estudiantes de dos facultades de la Universidad de Silesia en Katowice (Polonia) que respondieran a una encuesta. Se trataba principalmente de estudiantes de dos especialidades: Informática y Pedagogía. Se encuestó a 103 estudiantes. Para la verificación

se utilizaron las pruebas de Kruskal-Wallis. Las principales cuestiones estudiadas fueron el nivel de competencia de los estudiantes en IA, su conocimiento de las aplicaciones de la IA en diversos ámbitos de la vida y la economía, y la importancia del campo de la IA. El estudio también incluyó el nivel de confianza hacia la IA y el nivel de ansiedad hacia la IA. Se investigaron varios tipos de dependencias y conexiones entre estos aspectos. Las hipótesis se confirmaron en su mayoría. Por último, el artículo presenta la discusión y las principales conclusiones.

P a l a b r a s c l a v e: Inteligencia Artificial (IA), aspectos educativos, sociales y éticos, estudiantes de informática y educación, opinión, pruebas de Kruskal-Wallis

Малгожата Пшибыла-Касперек, Евгения Смирнова-Трибульская, Пит Коммерс

Факторы, обуславливающие взгляды студентов на искусственный интеллект

А н н о т а ц и я

Искусственный интеллект (ИИ) в настоящее время является одним из наиболее важных и современных направлений развития науки в междисциплинарном контексте. Подход ЕС к искусственному интеллекту основан на совершенстве и доверии, направлен на повышение исследовательского и промышленного потенциала при обеспечении безопасности и основных прав (Европейский подход к искусственному интеллекту). Укрепление передового опыта в области искусственного интеллекта укрепит потенциал Европы в глобальной конкуренции. Одновременно с этим еще не решены многие вызовы и вопросы. Проблема, поднятая в статье, заключается в изучении и анализе отношения студентов факультетов компьютерных наук и наук об образовании к образовательным, социальным и этическим аспектам внедрения ИИ. Цель – выявить и проанализировать отношение студентов института компьютерных наук и наук об образовании (будущих педагогов) педагогики к образовательным, социальным и этическим аспектам внедрения ИИ. Студентам двух факультетов Силезского университета в Катовицах (Польша) было предложено ответить на вопросы анкеты. В основном это были студенты двух специальностей – компьютерных наук и педагогики. Всего было опрошено 103 студента. Для проверки использовались тесты Крускала-Уоллиса. Основными изучаемыми вопросами были уровень компетентности студентов в области ИИ, их осведомленность о применении ИИ в различных областях жизни и экономики, а также важность области ИИ. Исследование также включало уровень уверенности в отношении ИИ и уровень тревожности в отношении ИИ. Были исследованы различные виды зависимостей и связей между этими аспектами. Гипотезы в основном подтвердились. В конце статьи представлены обсуждение и основные выводы.

К л ю ч е в ы е с л о в а: Искусственный интеллект (ИИ), образовательные, социальные и этические аспекты, студенты факультетов информатики и наук об образовании, мнение, тесты Крускала-Уоллиса

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Jan Waligórski
AGH University of Krakow / EduVRLab / Poland
https://orcid.org/0000-0002-9399-9786

Aleksandra Cząstkiewicz
Maria Curie-Sklodowska University / Department of Philosophy and Sociology / Poland
https://orcid.org/0009-0002-9614-756X

Zofia Samsel
Université Paris Cité / Learning Planet Institute / France
https://orcid.org/0000-0001-6554-9051

Natalia Frys
Jagiellonian University / Department of Polish studies / Poland
https://orcid.org/0009-0002-8747-960X

Reimagining Online Academic Conferences: The Promise of Social Virtual Reality for the Return of Co-Presence

Abstract

New technologies and societal shifts are profoundly influencing communication and conducting meetings. Over the past few years, the number of online conferences has increased. The body of literature indicates that online events allow for cost and social inequalities reduction. Despite this, they also present challenges in non-verbal communication, and diminish the sense of co-presence, thus affecting networking. Current academic discussions on the advantages and limitations of organizing remote academic conferences are typically confined to those conducted via video-conferencing systems. The aim of this research is to explore the potential of virtual reality (VR) technology and social VR platforms as alternative methods for organizing online academic conferences. The authors present the course of one of the first academic conference conducted entirely in social VR (*Wirtualium 2.0*), along with the survey outcomes regarding the potential of this environment

for hosting academic conferences. Our findings indicate that, compared to video-conferencing systems, social VR platforms offer for most participants a higher sense of co-presence, facilitating networking and engagement in informal conversations. In this context, the identified limitations of social VR platforms encompass limited device accessibility, technical challenges, and impediments to efficient note-taking. Nonetheless, the majority of users consider social VR as suitable for hosting academic conferences. This suggests that even though academic events via social VR platforms encounter technical challenges and will not be the same as in-person conferences, they should exploit the potential of VR technology to achieve what is unattainable in a physical setting.

K e y w o r d s: Virtual Reality (VR), social virtual reality (social VR), co-presence, online academic conference, *Spatial*, networking

Academic conferences play an essential role in advancing science, primarily by providing opportunities for knowledge exchange (Mulders & Zender, 2021, p. 1; Edelheim et al., 2018, p. 12) and for establishing new connections, which can lead to new scientific collaborations (Edelheim et al., 2018, p. 13).

In recent years, there has been a marked increase in the frequency of academic conferences organized remotely (Roos et al., 2020, p. 5). The COVID-19 pandemic played a key role in accelerating this trend (Bray et al., 2022, p. 1). However, despite the possibility of resuming in-person conferences, many organizers have chosen to continue their events online due to the numerous benefits of remote events (Roos et al., 2020; Bray et al., 2022). The most commonly used tools for organizing remote conferences are *video-conferencing systems* (VCS), such as *MS Teams, Zoom, Google Meet, Skype, Webex*, and others (Chessa & Solari, 2021, p. 1). During these events, participants have the opportunity to present papers and participate in virtual poster sessions via the Internet (Roos et al., 2020, p. 5).

As online events become more and more popular, the academic debate about the advantages and limitations of organizing academic conferences remotely is intensifying (e.g., Bray et al., 2022; Roos et al., 2020; Lortie, 2020; Sá et al., 2019; Niner & Wassermann, 2021). Although more publications are addressing this subject, most focus only on video-conferencing systems (e.g., Roos et al., 2020; Bray et al., 2022; Lortie, 2020), neglecting less-known methods. Therefore, this article seeks to elucidate the potential of social virtual reality (social VR) platforms and virtual reality (VR) technology for organizing an academic conference, comparing them to video-conferencing systems. For this purpose, the authors present an evaluation of one of the first academic conferences held entirely in social VR (the Polish academic conference *Wirtualium 2.0*) and provide outcomes of the survey about participants' perspectives on social VR and its potential for organizing academic conferences.

Strengths and limitations of online academic conferences

One of the most commonly highlighted advantages of online conferences is their cost-efficiency for both organizers and attendees (Roos et al., 2020, p. 11; Bray et al., 2022, p. 4; Lortie, 2020, p. 2; Sá et al., 2019, p. 6). Conducting events remotely eliminates the need to rent venues and provide catering (Roos et al., 2020, p. 11). The reduced expenses often enable organizers to lower or even waive registration fees (Bray et al., 2022, p. 4), thereby enhancing conference accessibility. Moreover, participants in online conferences save on travel and accommodation costs (Sá et al., 2019, p. 8; Niner & Wassermann, 2021, p. 10). This proves beneficial for individuals unable to attend physical events due to geographical barriers or constraints such as financial limitations, health concerns, or family commitments (Sá et al., 2019, p. 8-10; Roos et al., 2020, p. 6). Additionally, the elimination of conference trips contributes to the reduction of carbon dioxide emissions, positively impacting the environment (Niner & Wassermann, 2021, p. 3). Furthermore, the absence of travel-associated exhaustion ensures that attendees can avoid jet lag, enhancing their well-being throughout the conference (Bray et al., 2022, p. 3).

The virtual format of events enables participation from a more diverse and global audience moving beyond the confines of the local academic community (Lortie, 2020, p. 6; Bray et al., 2022, p. 3). This has the potential to reduce inequalities stemming from factors such as gender or ethnic origin (Sá et al., 2019, p. 11; Bray et al., 2022, p. 1). Online academic conferences enable effortless recording and archiving of participants' presentations, enriching the open access collections of educational materials (Lortie, 2020, p. 6) and allowing for revisiting the shared materials later. However, organizing academic conferences remotely also carries the risk of technical problems or lack of access to suitable equipment for some participants (Roos et al., 2020, p. 12; Niner & Wassermann, 2021, p. 10).

On the one hand, the remote form of an academic conference enables participants to join from any location via the Internet, tailored to individual needs and available time (Niner & Wassermann, 2021, p. 8). On the other hand, the familiar environment and household duties can easily distract participants, making it difficult to actively participate in the event (Sá et al., 2019, p. 9).

Greater anonymity of participants in remote conferences compared to in-person conferences has dual consequences. It can facilitate communication for shy and introverted individuals (Raby & Madden, 2021, p. 4). On the other hand, a diminished sense of other participants' presence can hinder networking and informal interactions (Roos et al., 2020, p. 12) and decrease participant engagement (Raby & Madden, 2021, p. 6). Limiting networking and informal interactions is one of the biggest and most frequently cited disadvantages of academic conferences organized through video-conferencing systems (Roos et al., 2020, p. 12; Bray et al., 2022, p. 8; Holly & Wassermann, 2021, p. 6; Raby & Madden, 2021, p. 6; Sá et al., 2019, p. 8).

A significant problem that arises during online conferences is participants' issues with concentration. As Sá et al. write: "Too easy to be distracted by work, home, and all the other daily routines – unless you lock yourself in a closet" (2019, p. 9). Video-conferencing systems inherently pose limitations in the means of expression they offer (Raby & Madden, 2021, p. 4) There is a perceived lack in the availability of non-verbal communication or the ability to see the reactions of each of the attendees (Sá et al., 2019, p. 9). The issue of participants not turning on their cameras during a conference means it is indiscernible whether they are genuinely present during discussions (Bray et al., 2022, p. 8). Some video-conferencing systems often have built-in time restrictions, especially if organizers or delegates are using the free version of the software.

Numerous studies highlight the *zoom fatigue effect* (e.g., Bailenson, 2021; Nesher Shoshan & Wehrt, 2022; Fauville et al., 2021). The increased cognitive effort required to maintain concentration during a conference organized through video-conferencing systems results in a feeling of amplified fatigue after the event (Raby & Madden, 2021, p. 5).

The use of social VR and VR technology to conduct academic conferences

Social VR represents a new generation of multi-person platforms designed to facilitate user interaction within computer-generated 3D virtual environments using personalized avatars (digital representations of individuals). Distinguishing itself from previous collaborative virtual environment platforms, such as *Second Life* and *OpenSimulator*, social VR applications allow for the use of immersive head-mounted displays (HMD; McVeigh-Schultz et al., 2019, p. 1), which are the most common type of VR technology.

Typically, social VR platforms consist of collections of virtual worlds created by the users themselves (e.g., *VRChat, Spatial, Mozilla Hubs*). These emerging platforms can serve users both as places for activities related to daily human existence (e.g., meetings, work, learning, social games, travel), and as venues for hosting collective events (e.g., academic conferences, music festivals, community gatherings).

In recent years, social VR platforms have emerged as new venues for hosting academic conferences. In 2020, an academic conference conducted in German language, *VRARBB@Social VR*, was organized on the AltspaceVR platform (Mulders & Zender, 2021). In the same year, the *IEEEVR 2020 – Conference on Virtual Reality and 3D User Interfaces* took place on the *Mozilla Hubs* platform. During this event, a space was created for the collective viewing of paper presentations,

and a session of four posters was conducted (Le et al., 2020). In 2022, part of the subsequent edition of the *IEEEVR 2022 – Conference on Virtual Reality and 3D User Interfaces* took place on the *Virbela* platform. In 2022, the first edition of the Polish-language academic conference *Wirtualium* was hosted on the AltspaceVR platform, and in 2023 the second edition of this conference – *Wirtualium 2.0* – was held on the *Spatial* platform, detailed proceedings of which are elaborated in the subsequent section.

During conferences in social VR, users are in virtual rooms that typically resemble conference rooms from the physical world, where they can move freely via their avatars. This structure allows for informal discussions between participants in smaller groups, as was observed during the *VRARBB@Social VR* conference (Mulders & Zender, 2021, p. 3–4). Evaluative research conducted after this conference indicates that the structure of virtual rooms can influence participants' assessment of their suitability for interpersonal interaction (Mulders & Zender, 2021, p. 4). As Catlin Pidel and Philipp Ackermann have noted, „virtual reality conferencing affords more social interaction than video conferencing, such as the ability to organically break off into small groups, or interacting with virtual objects in the scene" (2020, p. 3).

Participant behaviors in space, like changes in interpersonal distances, are an inherent part of non-verbal communication, which, in contrast to VCS, can occur on social VR platforms (Li et al., 2021, p. 1). Proximal behaviors of users also relate to another non-verbal cue – the gaze, an important element of communication in social VR (Wei et al., 2022, p. 4). When social VR users utilize HMDs, movements of their physical body synchronize with the movements of their avatar visible in the virtual space. A directed gaze towards another person becomes visible in the virtual space through the avatar's movement. Similarly, HMD users can make a gesture, and for some devices with additional tracking systems, users' facial expressions can also be synchronized in this way (Wei et al., 2022, p. 4). Some social VR platforms (e.g., *Spatial*, *VRChat*) allow for other non-verbal messages, such as *emoji icons* appearing above the avatars' heads or markers enabling real-time sketching in space (Wei et al., 2022, p. 6). This contributes to the fact that communication in social VR, compared to VCS, „shows the most similarities to offline face-to-face, in terms of spatial behavior, hand behavior, and facial expressions" (Wei et al., 2022, p. 6).

Avatar-mediated communication in social VR offers rich non-verbal communication and provides users with a sense of partial anonymity. This can facilitate communication for shy and introverted individuals (Wei et al., 2022, p. 6). It also has the potential to reduce biases based on appearance, enhancing the comfort of women by decreasing the likelihood of them feeling judged purely based on appearance (Campbell et al., 2021, p. 15). It is hypothesized that this effect may similarly benefit men, however further research in this area is needed. Furthermore, users in social VR experience a higher sense of social presence compared to VCS (Wei et al., 2022, p. 6).

However, inclusivity cannot be found in all aspects of social VR. While, in theory, every user can create their own avatar representation, some creators (e.g., *Ready Player One*) have built-in limitations regarding available templates. This leads to underrepresentation of certain groups, such as individuals with disabilities or obesity. Further changes are necessary to make social VR accessible for all interested individuals.

A significant limitation for social VR is the availability of HMDs. Consequently, some social VR platforms (such as *VRChat, Spatial, Virbela, Mozilla Hubs*) also allow users to use other devices: computers, laptops, tablets, or phones. In the evaluation questionnaire after the academic conference *IEEEVR 2020*, 5 out of 26 respondents declared that they used HMDs (Le et al., 2020, p. 490). In the subsequent edition, *IEEEVR 2021*, "most people accessed *Virbela* from a desktop, while 16.3% reported experimenting with HMDs and small percentage (4,6%) used a VR headset all the time" (Moreira et al., 2022, p. 1918). In the evaluative study after the *VRARBB@Social VR* conference, 76% of respondents declared that they used HMDs during the conference (Mulders & Zender, 2021, p. 1).

Using social VR only with desktop devices can limit the possibilities for user interaction in the virtual environment and non-verbal communication. Although desktop users can freely move their avatar around virtual rooms and turn towards other users, they are not able to freely communicate non-verbal messages in real-time, as users with HMDs. Some social VR platforms (e.g., *VRChat, Spatial*) allow desktop users to activate avatar animations (e.g., applauding, thumbs up, smiling) to express non-verbal messages. The results of Chessa & Solari's (2021, p. 11) study, conducted in the context of university classes, indicate that even users without HMDs in social VR (in this case on the *Mozilla Hubs* platform) might feel a stronger sense of presence compared to VCS.

On the one hand, HMDs limit the influx of distractions from the physical world, which can lead to increased focus on communication contents (Le et al., 2020, p. 492). On the other hand, a prolonged use of HMDs can lead to discomfort and fatigue (Mulders & Zender, 2021, p. 5; Wei et al., 2022, p. 6), which is a significant drawback of this technology.

Another advantage of social VR platforms include possible interactions with 3D objects (Mulders & Zender, 2021, p. 5; Wei et al., 2022, p. 6), which, for instance, can augment presentations prepared by speakers and provide opportunities for organizing innovative entertainment (e.g., social games) or networking activities during conferences (Moreira et al., 2022, p. 1910–1911).

It is worth noting that users rate social VR platforms as more challenging to use than VCS (Wei et al., 2022, p. 6). Similar to other conferencing tools, significant issues with social VR platforms arise from internet connection quality and software errors (Mulders & Zender, 2021, p. 5; Le et al., 2020, p. 486).

Wirtualium 2.0 – academic conference on the *Spatial* platform

The aim of this section is to describe the proceedings of the academic conference, *Wirtualium 2.0*, which took place on May 26–27, 2023. It was organized by several Polish academic student groups, including *Sekcja Filozofii Techniki KNSF* from Jagiellonian University, and both *Koło Naukowe Architektów Informacji* and *Koło Naukowe Kognitywistyki* from Maria Curie-Sklodowska University. Additionally, *Academia Electronica* was involved in the organization. To the best of the authors' knowledge, this conference was the first academic conference in the world to be held on the *Spatial* platform and one of the first academic conferences entirely conducted in social VR. The previous edition of the conference, titled *Wirtualium 1.0*, took place on June 4th, 2022, on the AltspaceVR platform. To the authors' knowledge, it was the first academic conference in Poland organized entirely on social VR platform.

The conference theme revolved around interdisciplinary research in virtual reality. The language of the conference was Polish. Participation was free of charge for both speakers and attendees. During the conference, there were 23 speakers' presentations, 4 expert lectures, and 1 discussion panel. 196 people registered for the conference using the attendee registration form. At its peak, the conference was attended by 75 people – during the opening lecture. We do not have statistics on the number of unique users who participated throughout the conference, but we estimate that a total attendance ranged from 90 to 100 individuals.

The conference was organized using the *Spatial* platform – a social VR platform established in 2016, accessible via web browsers, mobile applications, and HMDs (*Meta Quest 1*, *Meta Quest 2*). *Spatial* features an integrated avatar creator (which allows for customization of the users' digital representations) and is synchronized with the *Ready Player Me* tool, enabling users to use the same avatar across multiple social VR platforms. The key features of the *Spatial* platform in the context of holding an academic conference include: a built-in text chat, an extensive system for animating non-verbal avatar messages for users of the browser version and mobile application (e.g., clapping animation, thumbs up, dancing, emojis appearing over the avatar), a screen-sharing system in the browser version, a user management system (e.g., the ability to send users to the audience, block and ban users), as well as a virtual space editor and space templates. *Spatial* also allows for sharing a webcam video over an avatar and real-time translation, however, these features were not employed during the *Wirtualium 2.0* conference.

The conference was held in the virtual auditoriums of *Academia Electronica* (AE). AE is a Polish academic and educational center operating in virtual reality, founded by Sidey Myoo in 2007 on the *Second Life* platform (see Ostrowicki, 2022). Since 2021, AE has also been operating on social VR platforms: until March

2023, on *AltspaceVR* and, since early 2023 on *Spatial*. AE is the venue for regular academic classes for Polish university students and other academic events.

During the conference, the keynote speakers gave their presentations, and the expert discussion panel was held in the *Digital Beam* auditorium (see Figure 1a), which features a clear division between the stage and the audience. Additionally, a hanging chair for the lecturer was placed on the stage. On the back of the stage, there was a large screen where presentations were displayed. A major limitation of the *Spatial* platform is that it only allows 50 users to be in one room simultaneously while maintaining communication among them. For this reason, in the *Agora* auditorium, a live broadcast from the Digital Beam auditorium was relayed onto an auxiliary screen. The speakers' presentations took place in two parallel panels in the *Fireworks* auditorium (see Figure 1b) and the *TV Room* auditorium (see Figure 1c). Both of these auditoriums maintained a clear division between the audience space and the speaker's stage, with a screen set up on the back of the stage to display presentations. One of the experts, Maciej Pronkiewicz, utilized a template and editor available on the *Spatial* platform to prepare his own space (see Figure 1d), where his presentation combined with a discussion segment took place.

After each expert lecture, during the expert panel discussion, and at the end of the speakers' panels, conference participants had the opportunity to discuss and ask questions using a text or voice chat. Consequently, they were deeply engaged in discussions, often utilizing the time allocated by the organizers for this purpose (sometimes also the time scheduled for breaks).

The organizers provided guidelines on how to use the *Spatial* platform and facilitated instructional sessions for interested attendees before the conference. Apart from a few isolated incidents, the attendees experienced no issues navigating through the spaces where the conference was held. They transitioned seamlessly between auditoriums using teleports. Some users encountered difficulties sitting on some virtual chairs, potentially due to a non-intuitive interface. A few speakers did not ascend to the stage while presenting. Several times during the conference, the presentation display on the screen was interrupted and had to be restarted by the speaker, possibly due to software errors or issues with the speaker's internet connection. During some presentations, the audio quality was subpar, likely resulting from the presenter's inadequate internet connectivity.

The conference participants were encouraged by the organizers to use network nomenclature, for instance, addressing each other by network names and omitting official courtesy phrases. The participants partially adhered to these guidelines. In the future, we aim to examine whether this shift can enhance interpersonal communication during academic conferences.

To facilitate networking among users, the organizers invited conference participants to a virtual campfire after the official proceedings on both the first and second days (see Figure 1e). Those who joined the gathering expressed strong ap-

preciation for this idea in conversations with the organizers. Nonetheless, further research in this area is necessary.

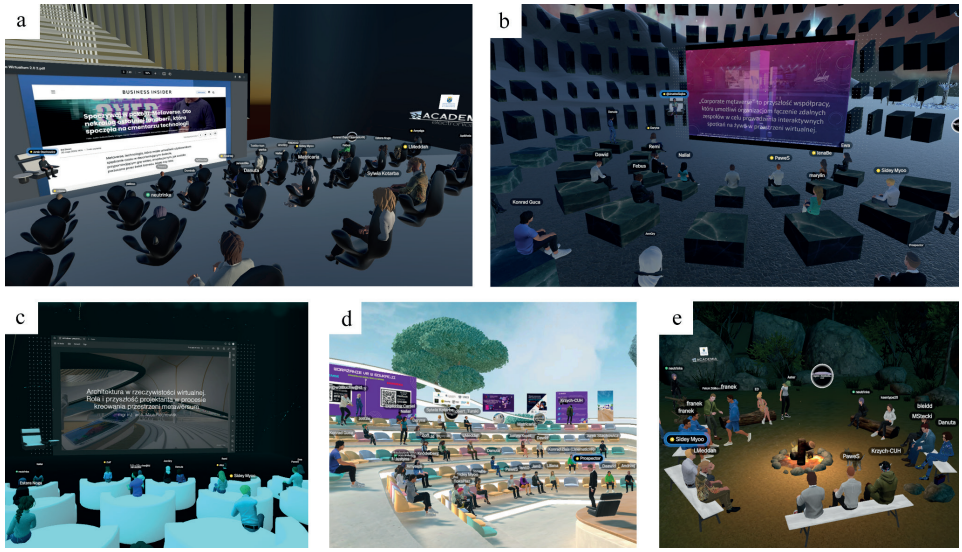

Figure 1. Photographic documentation from the academic conference *Wirtualium 2.0*: a) *Digital Beam* auditorium, b) *Fireworks* auditorium, c) *TV Room* auditorium, d) auditorium designed by the expert, e) integration by the campfire

S o u r c e: Own work.

Evaluation

In this section, we present the findings of a survey that examined the perspectives of *Wirtualium 2.0* conference participants regarding the potential of utilizing social VR for organizing academic conferences. The survey questionnaire addresses the following research questions (RQ):

- RQ1: What devices were used by the conference participants?
- RQ2: Do conference participants think that social VR is a suitable venue for organizing an academic conference?
- RQ3: Do conference participants think that, during a conference in social VR, the sense of presence of others is more strongly felt compared to VCS?
- RQ4: Do conference participants think that there are fewer distractions during conferences in social VR compared to VCS?
- RQ5: Do conference participants think that there are fewer networking issues during conferences in social VR than on VCS?

- RQ6: Do conference participants think that attending a conference in social VR is technically simpler than attending one via VCS?

The subsequent section of the article will delve into the methods and evaluation outcomes. In the survey questionnaire, the authors opted to refrain from employing specialized terminology. The term *social virtual reality* was replaced with *3D virtual environment* (VE), *video-conferencing system* was substituted with *video communication tools* and *head-mounted display* was replaced with *VR headset*. To avoid potential misunderstandings, the examples of platforms belonging to each respective category were provided.

Upon further reflection, we recognize potential ambiguity associated with the term *3D virtual environment*. This designation can encompass a broader range of platforms and might not exclusively pertain to social VR, which is the primary object of our analysis. In our case, it most likely did not affect the results, as for 86% of the respondents, Wirtualium 2.0 (conducted in social VR) was the only academic conference they attended in a 3D virtual environment. Among the remaining respondents (N=8) who also attended other academic conferences in 3D virtual environments: 5 indicated events in social VR, 2 did not specify the platform, and 1 mentioned both social VR and other platforms. Nonetheless, in the future, we suggest refraining from such replacement.

Method

The responses were collected using *Google Forms*, and completion took approximately 5 to 10 minutes. The study was conducted in Polish. Participation was voluntary and anonymous. Information about the opportunity to participate was provided to *Wirtualium 2.0* attendees via a post-conference email. The questionnaire consisted of 21 questions divided into 5 sections, including both close-ended and open-ended questions. The questions covered both demographic information and aspects directly related to the investigated subject matter. Categories in open-ended questions were formulated inductively.

Limitations

The respondents were participants of a conference addressing the VR topic. Since the conference was attended largely by individuals with a vested interest in VR technology or by those who use this technology in their professional work, this might have influenced their responses. The authors of the research were involved in the organization of the *Wirtualium 2.0* conference, which creates a risk of bias in the interpretation and analysis of the results.

Results

In the survey, 43 respondents (N=43) provided responses out of an estimated 90-100 unique conference attendees. At its peak, the conference was attended by 75 individuals during the opening keynote lecture. The precise data on unique participants throughout the conference are unavailable. Questions in section I. were used to verify the minimum inclusion criterion, which was participation in the *Wirtualium 2.0* conference. Due to the non-fulfillment of this condition, responses from one participant were excluded from the analysis. Most of the respondents included in the study (N=42) were women (67.7%, compared to 33.3% men). The average age in the group was 34 years, with ages ranging from 20 to 66 years.

Among the respondents, the majority declared they possessed higher education (N=31, 73.8%) (see Figure 2). Only one individual had a secondary education. 23.8% of the respondents (N=10) reported an active student status within Bachelor's or Integrated Master's programs, with an equivalent percentage holding a Master's or Master of Engineering degree (N=10). Those with PhD or post-PhD qualifications constituted 19% (N=8) of all respondents, while Master's students (N=6) and PhD candidates (N=5) accounted for 14.3% and 11.9%, respectively. Graduates of Bachelor's and Engineering programs constituted 4.8% (N=2) of all respondents.

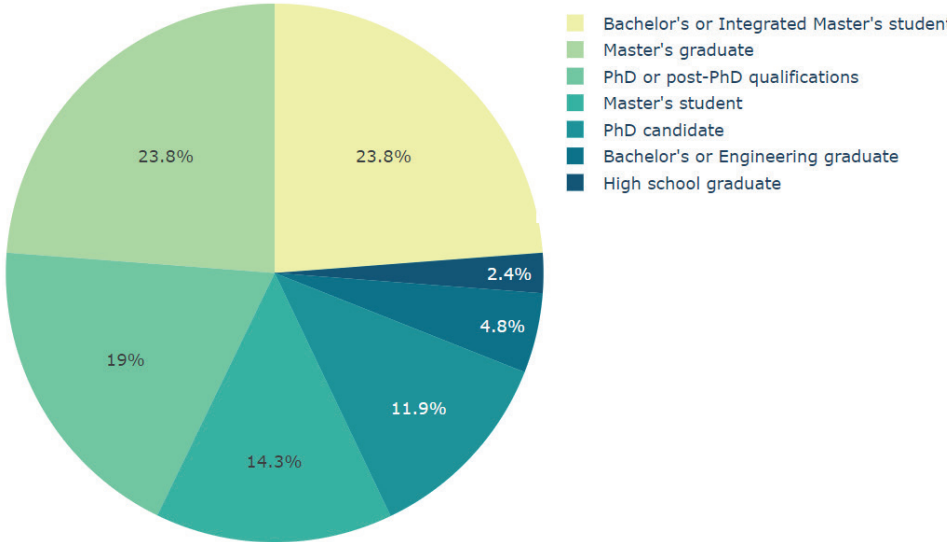

Figure 2. The pie graph illustrates the level of education of the respondents

S o u r c e: Own work.

For 81% of the respondents, *Wirtualium 2.0* was their first academic conference experience within a VE (N=34). The remaining 19% (N=8) declared having prior

experience with other VE-based academic conferences. In the open-ended question, a majority of them (N=4) pointed to the previous edition of the *Wirtualium* conference.

RQ 1. Devices Regarding the equipment utilized for conference participation, nearly all respondents (97.6%, N=41) reported (in a closed-ended question) using a laptop or desktop computer (hereinafter referred to as *desktop users*) for at least a part of the event. For 82.9% of them (N=34), this was the sole device employed for participation in the event.

Only one participant used exclusively VR headset for this purpose, while no participants used only a mobile device (tablet or smartphone). Three desktop users, constituting 7.3% of the surveyed individuals, also used VR headsets. The same percentage of desktop users (N=3) also employed mobile devices. One respondent combined the usage of all available options (laptop or desktop computer, VR headset and mobile devices) (Figure 3).

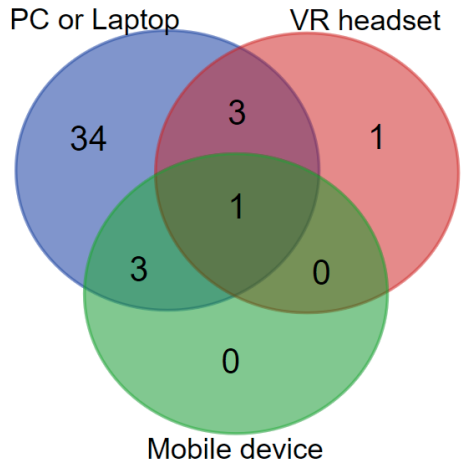

Figure 3. The Venn diagram illustrates the distribution of equipment used by respondents to attend the conference (https://bioinformatics.psb.ugent.be/webtools/Venn/)

S o u r c e: Own work (with the tool https://bioinformatics.psb.ugent.be/webtools/Venn/).

Among the reasons for not using VR technology during the conference, as reported in a semi-open multiple-choice question, the default options presented in the questionnaire content were dominated by the lack of access to such equipment (N=32, 86.5% of 37 respondents answering this question). Additionally, 8.1% (N=3) selected "*Want to avoid the discomfort of using a VR headset*" and one respondent chose the answer "*Difficulties associated with using a VR headset*". In the open-ended section of the question, respondents indicated technical issues (N=2), difficulty in taking notes (N=1), incompatibility of the *Spatial* application

with a specific VR headset model (N=1), and the need to perform other tasks during the conference (N=1). A total of 88.1% (N=37) of the participants included in the analysis provided responses to this question. As only one individual exclusively used a VR headset during the conference, there is no possibility to compare the influence of the employed hardware on user responses.

RQ 2. Academic social VR In response to the question of whether a VE, such as the *Spatial* platform, is a suitable venue for organizing an academic conference, 38.1% of respondents answered "Strongly yes" (N=16), 42.9% "Rather yes" (N=18), 9.5% "Rather no" (N=4), 4.8% "Strongly no" (N=2), and 4.8% "I don't know" (N=2).

The majority of respondents (88.1%) answered "Strongly yes" (N=26) or "Rather yes" (N=11) to the question of whether they would be willing to participate in future academic conferences organized in VE-based platforms, such as *Spatial*. Two individuals selected the response "Rather no" (4.8%), while three individuals chose "I don't know" (7.1%). No one chose the response "Strongly no" (Figure 4).

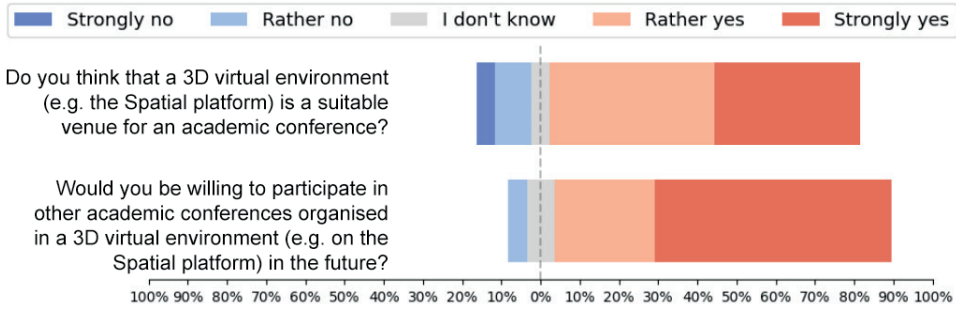

Figure 4. The graph illustrates respondents' answers to the five-point Likert-scale questions concerning their attitude towards attendance in academic conferences in a 3D virtual environment

S o u r c e: Own work.

The respondents were asked (in an open-ended question) to specify the major advantages of participating in an academic conference organized in a VE (e.g., on the *Spatial* platform). Among the collected responses (N=41), the most frequently indicated advantage was the avatar-mediated communication (N=11). According to the examined individuals, avatar-mediated communication facilitated informal interactions among conference participants, provided support for shy individuals, and did not require sharing a webcam. As one individual stated: "*When presenting a paper, my avatar represents me, which is much more convenient than having to adjust my real environment to the conference conditions, such as making sure no household members enter the camera's frame during the conference. Additionally, this type of conference gives me more time to practice my presentation before the panels begin, as I don't have to spend a lot of time getting ready, doing makeup, or*

choosing the right outfit". The respondents pointed out the benefit of gaining new experience (N=10) related to "*engaging with new technologies*" and participating in an experimental form of conference organization within the VE. The next most commonly cited advantages were: stronger sense of presence of other conference attendees (N=7) and experience of spatiality (N=7) compared to VCS. The sense of presence reported by respondents was generally associated with the feeling of being situated within a shared avatar-mediated virtual space. When discussing the advantage of spatial experience, surveyed individuals most frequently indicated the freedom to move around virtual rooms and spatiality of perception. Further advantages highlighted by the respondents pertained to the visual attractiveness of the VE (N=6) as well as convenience and availability associated with a remote form of conference organization (N=6). Furthermore, two individuals mentioned the possibility of using VR headset (N=2) and chat feature (N=2).

In the subsequent open-ended question, the respondents were asked to specify the primary limitations of participating in an academic conference organized in a VE such as the *Spatial* platform. Among the collected responses (N=37), the majority of individuals indicated potential or actual ensuing technical issues (N=19). Amid them, Internet connection-related issues were the most frequently mentioned (N=9). Another drawback highlighted by the respondents was the limited visibility of presentations (N=8). They also elaborated on the inability to switch to a full-screen presentation view, and challenges associated with properly configuring and zooming the screen view. Some mentioned that avatars of other conference attendees occasionally obstructed the screen. A subsequent disadvantage pointed out by the respondents pertained to personally experienced or observed issues with navigating the virtual space using avatars (N=7). As one person commented, "*I think that if someone is not often in virtual environments, they might find it difficult to navigate in the digital world – to operate keys, move freely, and add reactions. However, this is more a matter of habituation or practice rather than a genuine drawback"*. The respondents also reported that VEs require more advanced hardware compared to VCS (N=5). Some mentioned that due to the lack of a compatible VR headset, they could not fully leverage the conference's potential (N=3).

In a subsequent question respondents were asked to choose which type of platform they considered as a better venue for hosting an academic conference. Given the comparative nature of this question, an additional criterion for inclusion in the analysis was set: apart from participating in *Wirtualium 2.0*, respondents must have declared in the questionnaire that they had taken part in any conference via VCS. This inclusion criterion was also applied to all subsequent questions, hence out of 42 responses, 36 were considered for this set of questions.

When choosing a better venue for organizing an academic conference, the largest number of respondents (44.4%, N=16) declared an advantage of VE-based platforms over VCS. In contrast, 33.3% of participants (N=12) indicated an advan-

tage of VCS over VEs. Another 8.3% (N=3) saw no difference between the two, and 13.9% (N=5) selected "*I don't know*".

RQ 3. Co-presence The subsequent set of questions compared experiences of attending academic conferences on VE-based platforms (such as *Spatial, AltspaceVR, Virbela*) with those on VCS platforms (such as *Google Meet, MS Teams, Zoom*).

According to 69.4% of surveyed individuals (N=25), during an academic conference organized in a VE, the presence of other participants is more strongly felt. A notably smaller proportion of respondents saw an advantage in this regard with VCS (16.7%, N=6) or stated that there was no difference between the two previously mentioned options (13.9%, N=5).

In a subsequent question, respondents were asked about the type of platform on which they felt a stronger sense of co-presence in one place during an academic conference. The majority of respondents (72.2%, N=26) chose VEs. Some individuals stated no difference (22.2%, N=8) while the fewest indicated an advantage of VCS in this aspect (5.6%, N=2) (Figure 5).

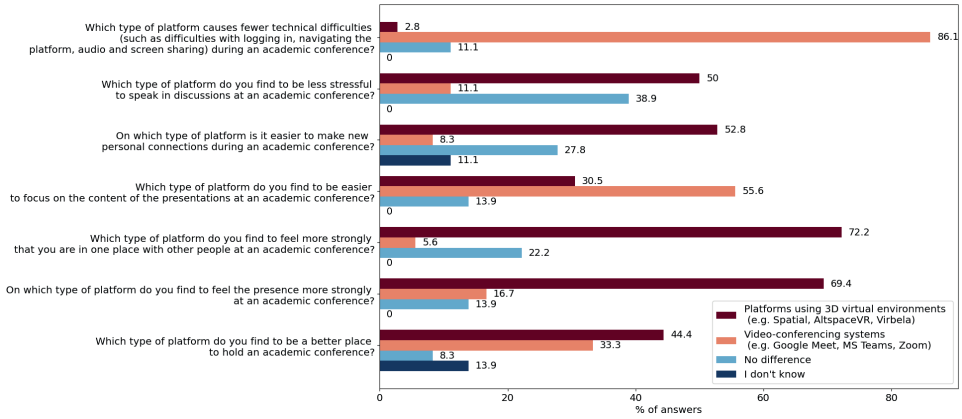

Figure 5. The graph illustrates respondents' answers related to the level of co-presence, attention, ease of establishing new connections, and possibility of technical issues depending on the type of academic conferences (platforms using 3D virtual environments or video communication apps)

S o u r c e: Own work.

RQ 4. Ease of focus For the majority of respondents (55.6%, N=20), it is easier to focus on the content of papers presented during academic conferences when using VCS. 11 surveyed individuals (30.5%) indicated a superiority of VE-based platforms in response to this question, while 5 respondents (13.9%) saw no difference between VCS and VE-based platforms.

RQ 5. Networking A considerable portion of respondents (52.8%, N=19) reported that they think it is easier to establish new connections during an academic

conference in a VE. There were 10 surveyed individuals who did not perceive a difference between VE-based platforms and VCS in this case (27.8%). 4 individuals selected the answer "I don't know" (11.1%), while 3 individuals indicated an advantage for VCS (8.3%). In a subsequent question, half of respondents (50%) stated that taking part in discussions during an academic conference is less stressful on VE-based platforms (N=16). Meanwhile, 14 surveyed individuals observed no difference (38.9%) and 4 participants (11.1%) indicated a preference for VCS in this case.

RQ 6. Technical issues When assessing technical issues (such as difficulties with logging in, navigating the platform, audio and screen sharing) during an academic conference, the vast majority of surveyed individuals (86.1%, N=31) specified that they deem VCS to present fewer such difficulties. 1 participant (2.8%) stated the advantage of VE-based platforms in this matter, whereas 4 individuals (11.1%) claimed no difference between those two types of platforms.

Discussion

Only one in ten respondents (11.9%) used an HMD during the conference (**RQ1**), marking the lowest utilization rate compared to reports from other academic conferences in social VR (refer to section 3 for details). The vast majority of respondents (86.5%) reported lack of access to appropriate devices as the reason for not using HMDs. This result may also be influenced by the fact that, at this time, the *Spatial* platform was solely compatible with HMDs *Meta Quest 1* and *Meta Quest 2*. Further research on this issue is necessary, as in the future it may partially exclude Polish researchers from participating in social VR conferences.

In open-ended questions, a new issue was identified, which is the inability to take notes and use them while wearing an HMD (this arises due to the lack of access to appropriate software and the inability to take notes in a physical notebook due to the HMDs' limitation on visibility of the physical environment). This issue was also highlighted during the *Wirtualium 2.0* conference, in the keynote lecture by Jerzy Stachowicz.

Numerous studies indicate differences in the perception of presence, immersion, and emotional responses between users of the same applications using HMDs and flat-screen computers (e.g., Pallavicini et al., 2019; MacQuarrie & Steed, 2017; Kim et al., 2014). Due to the small number of respondents using only HMDs during the conference (N=1), it is not possible to analyze this difference in our case. However, based on available research, it can be hypothesized that increasing the availability of HMDs is crucial for harnessing the full potential of social VR platforms.

The respondents generally rated the potential of social VR for organizing academic conferences very positively (**RQ2**). However, there exists a significant limitation concerning generalizability. To the best of authors' knowledge, there

have been no studies evaluating opinions about academic conferences held in social VR that do not focus on VR-related topics.

Conferences in social VR have the potential to emulate certain aspects of the experience of physical conferences. This may be indicated by the return of the sense of presence, which was markedly diminished in standard online conferences (conducted via VCS), but constitutes a key element of the overall conference experience. Our study demonstrated that a significant part of respondents (72%) perceived academic conferences organized on social VR platforms as providing them with greater social and spatial presence compared to VCS (**RQ3**), which may predispose this format to provide a better experience, especially when in-person meetings are not possible.

It is worth noting that for the majority of respondents participating in the study, *Wirtualium 2.0* was the only academic event conducted within a VE that they had attended. The fascination with the possibilities and the relative novelty of the conference format could have influenced their experience and consequently the results, thus, further research is needed in this regard.

The obtained results align with other studies suggesting that virtual reality provides users with a sense of being there and being around others (Li et al., 2019; Maloney, 2020). However, what seems most significant, given the current limitations on access to HMDs, is that these results indicate a stronger sense of presence in social VR (compared to VCS) even when HMDs are not being used (Chessa & Solari, 2021, p. 11).

This may reflect the quality of relations established during the event, which was noticed and reported by participants as an advantage of social VR. A prevalent finding in open-ended question was the reduction in networking inconveniences and a decrease in attendees' stress level during engagement in discussions compared to VCS (**RQ5**). Similarly, in closed-ended questions, for the majority of surveyed individuals conferences in social VR offered a better opportunity to forge new acquaintanceships, and for half of them - this conference format is more favorable to unrestricted expression compared to VCS. In addition to the mentioned attributes of social VR platforms, it is noteworthy that avatar-mediated communication not only enhances the sense of presence, but also facilitates communication for individuals who are shy or affected by prevailing stereotypes (Baker et al., 2019; Baker et al., 2021). One respondent noted that "*virtual avatars encourage shortening distance and engaging in direct, informal communication*".

Additionally, social VR platforms allow for the formation of smaller groups suitable for conducting discussions and informal interpersonal exchanges (Mulders & Zender, 2021, p. 3–4). Possessing an avatar's body, users can also enrich the networking process through non-verbal communication (e.g., utilizing various gestures, presenting specific body posture), including proximal communication which constitutes the key factor for communication in social VR. This is linked to the inherent characteristic of social VR, namely spatiality (refer to section 3 for details).

The results of our survey indicate that for the majority of participants, maintaining focus on presentation content is easier when the event is conducted through VCS as opposed to events in social VR (**RQ4**). These data are in contrast with other research suggesting that VR enhances focus during virtual events (Li et al., 2019; Le et al., 2020). One possible explanation for this effect could be linked to the high perceived immersion in the VE (e.g., Cadet & Chainay, 2020; Baker et al., 2021; Smith & Neff, 2018), as well as the elimination of disruptive stimuli from external surroundings (Li et al., 2019) that can positively influence focus. Many of these studies primarily explored the potential of virtual reality experienced using HMDs. On the other hand, in our study, nine out of ten participants attended the conference using only computers or mobile devices, which compared to HMDs, might provide a lower level of immersion (Pallavicini et al., 2019). However, some research also suggests that even without HMDs, individuals can achieve a high level of perceived immersion, and consequently, concentration in VR (Zhang et al., 2021). Further research is needed to resolve this issue.

The reason for concentration problems as indicated in the open-ended question among the respondents was the excessive activity of some conference participants. One respondent pointed out that such behavior might "*disturb others and draw attention to oneself*." A similar issue might also arise during in-person conferences, for instance, when someone enters the room late or slams the door. The literature also points out the following sources of concentration problems: technical issues, frustration, and stress caused by insufficient skills in handling devices, overstimulation, or the novelty of environments (Williamson et al., 2021; Moreira et al., 2022). As VR technology continues to develop, research on optimal design practices seems crucial for enhancing effectiveness and focus in social VR. Further studies are essential to explore this issue.

The majority of participants found academic conferences conducted through VCS to be less technically challenging than those held on social VR platforms (**RQ6**). The technical challenges highlighted in the open-ended responses were primarily related to the quality of the internet connection, such as poor sound, loss of connection, or delays in loading virtual rooms. Additionally, the respondents mentioned the need to dedicate extra time for learning how to use the new tool and the accompanying stress of "*fearing something might go wrong*" as additional drawbacks.

To proactively mitigate technical issues, we conducted pre-conference instructional meetings for speakers and provided a platform user guide for all participants, ensuring they could navigate the social VR environment and validate equipment, connectivity, and software setup beforehand. We presume that these solutions could have reduced the number of technical problems that occurred during the event.

In addition to these steps, we propose further improvements. A dedicated technical support chat can offer real-time assistance during the conference. Interactive in-platform tutorials aid users in adapting to the interface and functionalities.

Appointing virtual moderators or support staff for real-time assistance guides participants through technical challenges. We believe these enhancements can help reduce technical difficulties. Therefore, we recommend that future organizers of social VR conferences consider these ideas.

It also seems worthwhile to point out the graphical aspect of social VR. On the one hand, its appealing visual representation adds value. However, in countries like Poland, where there is significant digital exclusion and issues with access to stable internet connections are prevalent (Bartol et al., 2021), the high hardware requirements needed to load such visually advanced spaces may pose a limitation. Consequently, for certain groups of interested individuals the participation in the event might be complicated or even impossible.

Summary

The conducted analyses support the recommendation of social VR, especially the *Spatial* platform, as a venue for organizing online academic conferences. Compared to VCS, there are indications that participants in social VR might often experience a stronger sense of others' presence, more comfortable discussions, and convenient networking conditions. However, further research is still needed, especially regarding conferences that would not be related to the topic of new technologies.

Said aspects constitute a pivotal element of participation in academic conferences, which is significantly curtailed on VCS. Nonetheless, it is imperative to bear in mind the limitations associated with organizing events in social VR, such as the need for access to HMDs, higher hardware requirements, and the necessity of acquiring new technical skills.

Presumably, with the development of the HMD technology and its increased accessibility, social VR conferences, while retaining the benefits of online events, will be able to overcome the limitations stemming from mediated communication. On the other hand, conferences in social VR will always differ from their physical counterparts. Hence, according to the authors, more significant than attempting to emulate in-person conferences under virtual conditions is the utilization of novel opportunities afforded by virtual reality.

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References

Bailenson, J. N. (2021). Nonverbal overload: A theoretical argument for the causes of Zoom fatigue. *Technology, Mind, and Behavior, 2(1).* https://doi.org/10.1037/tmb0000030.

Baker, S., Waycott, J., Carrasco, R., Kelly, R. M., Jones, A. J., Lilley, J., Dow, B., Batchelor, F., Hoang, T. & Vetere, F. (2021). Avatar-mediated communication in social VR: an in-depth exploration of older adult interaction in an emerging communication platform. Proceedings from the *2021 CHI conference on human factors in computing systems*, 1–13. https://doi.org/10.1145/3411764.3445752.

Baker, S., Vetere, F., Kelly, R., Waycott, J., Carrasco, R., Hoang, T., Batchelor, F., Ozanne, E., Dow, B. & Warburton, J. (2019). Interrogating Social Virtual Reality as a Communication Medium for Older Adults. *Proceedings of the ACM on Human-Computer Interaction*. 3. 1–24. https://doi.org/10.1145/3359251.

Bartol, A., Herbst, J. & Pierścińska, A. (2021). Wykluczenie społeczno-cyfrowe w Polsce. Stan zjawiska, trendy, rekomendacje. *Fundacja Stocznia*. Retrieved from https://fundacja.orange.pl/strefa-wiedzy/post/wykluczenie-spoleczno-cyfrowe-w-polsce-2021 (accessed 05.08.2023).

Bray, H. J., Stone, J., Litchfield, L., Britt, K. L., Hopper, J. L. & Ingman, W. V. (2022). Together alone: Going online during covid-19 is changing scientific conferences. *Challenges*, *13*(1), 7. https://doi.org/10.3390/challe13010007.

Cadet, L. B. & Chainay, H. (2020). Memory of virtual experiences: Role of immersion, emotion and sense of presence. *International Journal of Human-Computer Studies,* 144, 1906–1922. https://doi.org/10.1016/j.ijhcs.2020.102506.

Campbell, A. G., Holz, T., Cosgrove, J., Harlick, M. & O'Sullivan, T. (2020). Uses of virtual reality for communication in financial services: A case study on comparing different telepresence interfaces: Virtual reality compared to video conferencing. *Advances in Information and Communication: Proceedings of the 2019 Future of Information and Communication Conference (FICC), Volume 1*, 463–481. https://doi.org/10.1007/978-3-030-12388-8_33.

Chessa, M. & Solari, F. (2021). The sense of being there during online classes: analysis of usability and presence in web-conferencing systems and virtual reality social platforms. *Behaviour & Information Technology*, *40*(12), 1237–1249. https://doi.org/10.1080/0144929x.2021.1957017.

Fauville, G., Luo, M., Queiroz, A. C., Bailenson, J. N. & Hancock, J. (2021). Zoom exhaustion & fatigue scale. *Computers in Human Behavior Reports, 4,* 100–119. https://doi.org/10.1016/j.chbr.2021.100119.

Edelheim, J. R., Thomas, K., Åberg, K. G. & Phi, G. (2018). What do conferences do? What is academics' intangible return on investment (ROI) from attending an academic tourism conference?. *Journal of Teaching in Travel & Tourism*, 18(1), 94–107. https://doi.org/10.1080/15313220.2017.1407517.

Kim, K., Rosenthal, M. Z., Zielinski, D. J. & Brady, R. (2014). Effects of virtual environment platforms on emotional responses. *Computer methods and programs in biomedicine*, *113*(3), 882–893 https://doi.org/10.1016/j.cmpb.2013.12.024.

Le, D. A., Maclntyre, B. & Outlaw, J. (2020). Enhancing the experience of virtual conferences in social virtual environments. Proceedings from the *2020 IEEE Conference on Virtual Reality and 3D User Interfaces: Abstracts and Workshops (VRW)*, 485–494. https://doi.org/10.1109/vrw50115.2020.00101.

Li, J., Kong, Y., Röggla, T., De Simone, F., Ananthanarayan, S., De Ridder, H., Abdallah, A. & Cesar, P. (2019). Measuring and understanding photo sharing experiences in social virtual reality. Proceedings from the *2019 CHI Conference on Human Factors in Computing Systems*, 1–14. https://doi.org/10.1145/3290605.3300897.

Li, J., Vinayagamoorthy, V., Williamson, J., Shamma, D. A. & Cesar, P. (2021). Social VR: A new medium for remote communication and collaboration. Proceedings from the *2021 CHI Conference on Human Factors in Computing Systems*, 1–6. https://doi.org/10.1145/3411763.3441346.

Lortie, C. J. (2020). Online conferences for better learning. *Ecology and Evolution, 10(22)*, 12442–12449. https://doi.org/10.1002/ece3.6923.

MacQuarrie, A. & Steed, A. (2017). Cinematic virtual reality: Evaluating the effect of display type on the viewing experience for panoramic video. *2017 IEEE Virtual Reality (VR)*, 45–54. https://doi.org/10.1109/vr.2017.7892230.

Maloney, Divine & Freeman, Guo & Wohn, Donghee. (2020). "Talking without a Voice": Understanding Non-verbal Communication in Social Virtual Reality. *Proceedings of the ACM on Human-Computer Interaction*. 4. 1–25. https://doi.org/10.1145/3415246.

McVeigh-Schultz, J., Kolesnichenko, A. & Isbister, K. (2019). Shaping pro-social interaction in VR: an emerging design framework. Proceedings from the *2019 CHI conference on human factors in computing systems*, 1–12. https://doi.org/10.1145/3290605.3300794.

Mulders, M. & Zender, R. (2021). An academic conference in virtual reality? - evaluation of a Social VR conference. Proceedings from the *2021 7th International Conference of the Immersive Learning Research Network (iLRN)*, 1–6. https://doi.org/10.23919/ilrn52045.2021.9459319.

Moreira, C., Simões, F. P., Lee, M. J., Zorzal, E. R., Lindeman, R. W., Pereira, J. M., Johnsen, K. & Jorge, J. (2022). Toward VR in VR: Assessing Engagement and Social Interaction in a Virtual Conference. *IEEE Access*, 11, 1906–1922. https://doi.org/10.1109/access.2022.3233312.

Nesher Shoshan, H. & Wehrt, W. (2022). Understanding "Zoom fatigue": A mixed-method approach. *Applied Psychology, 71(3)*, 827–852. https://doi.org/10.1111/apps.12360.

Niner, H. J. & Wassermann, S. N. (2021). Better for whom? Leveling the injustices of international conferences by moving online. *Frontiers in Marine Science, 8,* 638025. https://doi.org/10.1111/apps.12360.

Ostrowicki, M. (2022). The Academia Electronica-Vision, Experiment, Future. *Analiza i Egzystencja: czasopismo filozoficzne*, (58), 111–124. https://doi.org/10.18276/aie.2022.58-06.

Pallavicini, F., Pepe, A. & Minissi, M. E. (2019). Gaming in virtual reality: What changes in terms of usability, emotional response and sense of presence compared to non-immersive video games?. *Simulation & Gaming*, *50*(2), 136–159. https://doi.org/10.1177/1046878119831420.

Pidel, C. & Ackermann, P. (2020). Collaboration in virtual and augmented reality: a systematic overview. Proceedings from the *Augmented Reality, Virtual Reality, and Computer Graphics: 7th International Conference, AVR 2020, Lecce, Italy, September 7–10, 2020, Proceedings, Part I 7*, 141–156. https://doi.org/10.1007/978-3-030-58465-8_10.

Raby, C. L. & Madden, J. R. (2021). Moving academic conferences online: Understanding patterns of delegate engagement. *Ecology and Evolution*, *11*(8), 3607–3615. https://doi.org/10.1002/ece3.7251.

Roos, G., Oláh, J., Ingle, R., Kobayashi, R. & Feldt, M. (2020). Online conferences–Towards a new (virtual) reality. *Computational and Theoretical Chemistry*, *1189*, 112975. https://doi.org/10.1016/j.comptc.2020.112975.

Sá, M. J., Ferreira, C. M. & Serpa, S. (2019). Virtual and face-to-face academic conferences: comparison and potentials. *Journal of Educational and Social Research*, 9(2), 35–47. https://doi.org/10.2478/jesr-2019-0011.

Smith, H. J. & Neff, M. (2018). Communication behavior in embodied virtual reality. Proceedings from the *2018 CHI conference on human factors in computing systems*, 1–12. https://doi.org/10.1145/3173574.3173863.

Wei, X., Jin, X. & Fan, M. (2022). Communication in immersive social virtual reality: A systematic review of 10 years' studies. *arXiv preprint arXiv:2210.01365*. https://doi.org/10.48550/arXiv.2210.01365.

Williamson, J., Li, J., Vinayagamoorthy, V., Shamma, D. A. & Cesar, P. (2021). Proxemics and social interactions in an instrumented virtual reality workshop. Proceedings from the *2021 CHI conference on human factors in computing systems*, 1–13. https://doi.org/10.1145/3411764.3445729.

Zhang, Q., Ban, J. S., Kim, M., Byun, H. W. & Kim, C. H. (2021). Low-asymmetry interface for multiuser VR experiences with both HMD and Non-HMD users. *Sensors*, 21(2), 397. https://doi.org/10.3390/s21020397.

Jan Waligórski, Aleksandra Cząstkiewicz, Zofia Samsel, Natalia Frys

Nowa wizja konferencji akademickich online. Potencjał społecznej wirtualnej rzeczywistości do powrotu współobecności

Streszczenie

Nowe technologie i zmiany społeczne głęboko wpływają na sposób komunikacji i przeprowadzania spotkań. W ciągu ostatnich kilku lat liczba konferencji online wzrosła. W literaturze wskazuje się, że wydarzenia online pozwalają na redukcję kosztów oraz nierówności społecznych. Pomimo tego mogą one istotnie ograniczać komunikację niewerbalną i zmniejszać poczucie współobecności, utrudniając tym samym nawiązywanie nowych kontaktów zawodowych. Bieżące dyskusje akademickie dotyczące zalet i ograniczeń zdalnych konferencji akademickich, zwykle koncentrują się na tych prowadzonych za pomocą systemów wideokonferencyjnych. Naszym celem jest zbadanie potencjału technologii wirtualnej rzeczywistości (VR) oraz platform społecznościowych VR jako alternatywnych narzędzi do organizacji akademickich konferencji online. Autorzy prezentują przebieg jednej z pierwszych konferencji akademickich (*Wirtualium 2.0*), która została przeprowadzona w całości w społecznościowej VR, wraz z wynikami ankiety badającej opinie jej uczestników na temat potencjału tej platformy do organizowania akademickich konferencji. Nasze wyniki sugerują, że w platformy społecznościowe VR, w porównaniu z systemami wideokonferencyjnymi, oferują dla większości uczestników wyższe poczucie współobecności, ułatwiają nawiązywanie kontaktów i prowadzenie nieformalnych rozmów. Zidentyfikowane ograniczenia platform społecznościowych VR w tym kontekście to: ograniczony dostęp do urządzeń, trudności techniczne oraz utrudnione sporządzanie notatek. Większość respondentów uważa społecznościowy VR za odpowiednie miejsce do organizacji konferencji akademickich. Chociaż wydarzenia akademickie na platformach społecznościowych VR wiążą się z trudnościami technicznymi i nigdy nie będą oferowały takich samych doświadczeń jak konferencje stacjonarne, to ich organizatorzy powinni przede wszystkim skupić się na wykorzystaniu potencjału technologii VR, aby osiągnąć to, co jest nieosiągalne w fizycznym środowisku.

S ł o w a k l u c z o w e: wirtualna rzeczywistość (VR), społecznościowa wirtualna rzeczywistość (social VR), współobecność, konferencja akademicka online, *Spatial*, networking

Jan Waligórski, Aleksandra Cząstkiewicz, Zofia Samsel, Natalia Frys

Nueva visión de las conferencias académicas en línea. El potencial de la realidad virtual social para el regreso a la co-presencia

R e s u m e n

Las nuevas tecnologías y los cambios sociales están influyendo profundamente la comunicación y la conducta de reuniones. En los últimos años, el número de conferencias en línea ha aumentado. La literatura existente indica que los eventos en línea permiten la reducción de costos y desigualdades sociales. Sin embargo, también presentan desafíos en la comunicación no verbal y disminuyen la sensación de copresencia, afectando así el networking, es decir el establecimiento de nuevos contactos. Las discusiones académicas actuales sobre las ventajas y limitaciones de conferencias académicas remotas generalmente se limitan a aquellas realizadas a través de sistemas de videoconferencia. El objetivo de esta investigación es explorar el potencial de la tecnología de realidad virtual (VR) y las plataformas de VR social como métodos alternativos para organizar conferencias académicas en línea. Los autores presentan el transcurso de una de las primeras conferencias académicas realizadas íntegramente en VR social (*Wirtualium 2.0*), junto con los resultados de encuestas sobre el potencial de este entorno para albergar conferencias académicas. Nuestros hallazgos indican que, en comparación con los sistemas de videoconferencia, las plataformas de VR social ofrecen para la mayoría de los participantes una mayor sensación de copresencia, facilitando el networking y el entusiasmo en conversaciones informales. En este contexto, las limitaciones identificadas de las plataformas de VR social abarcan acceso limitado a dispositivos, desafíos técnicos e impedimentos para tomar notas de manera eficiente. Sin embargo, la mayoría de los usuarios consideran que el VR social es adecuado para albergar conferencias académicas. Esto sugiere que, aunque los eventos académicos a través de plataformas de VR social se enfrenten a desafíos técnicos y no sean lo mismo que las conferencias presenciales, se debería explotar el potencial de la tecnología VR para lograr lo que es inalcanzable en un entorno físico.

P a l a b r a s c l a v e: Realidad Virtual (VR), Social Realidad Virtual (social VR), Copresencia, Conferencia académica en línea, *Spatial*, networking

Ян Валигорский, Александра Часткевич, Зофия Самсель, Наталия Фрыс

Новое видение онлайн-академических конференций. Потенциал социальной виртуальной реальности для возвращения к совместному присутствию

А н н о т а ц и я

Новые технологии и социальные изменения глубоко влияют на коммуникации и проведение встреч. За последние несколько лет количество онлайн-конференций увеличилось. Литературные источники указывают, что онлайн-мероприятия позволяют снижать затраты

и социальные неравенства. Тем не менее, они также представляют собой вызовы в области невербальной коммуникации и уменьшают чувство совместного присутствия, что влияет на сетевое взаимодействие. Текущие академические обсуждения преимуществ и ограничений организации дистанционных академических конференций обычно ограничиваются теми, которые проводятся с использованием систем видеоконференций. Цель этого исследования – изучить потенциал технологии виртуальной реальности (VR) и социальных платформ VR как альтернативных методов организации онлайн-академических конференций. Авторы представляют ход одной из первых академических конференций, полностью проведенной в социальной VR (*Wirtualium 2.0*), а также результаты опроса относительно потенциала этой среды для проведения академических конференций. Наши выводы указывают, что по сравнению с системами видеоконференций, социальные платформы VR предоставляют большинству участников более высокое чувство совместного присутствия, способствуя сетевому взаимодействию и участию в неформальных беседах. В этом контексте выявленные ограничения социальных платформ VR включают в себя ограниченный доступ к устройствам, технические проблемы и трудности в эффективной записи. Тем не менее, большинство пользователей считают социальную VR подходящей для проведения академических конференций. Это предполагает, что, несмотря на технические проблемы и отличия от очных конференций, стоит использовать потенциал технологии VR для достижения того, что невозможно в физической среде.

Ключевые слова: Виртуальная реальность (VR), Социальная виртуальная реальность (социальная VR), ко-присутствие, Онлайн-академическая конференция, *Spatial*, нетворкинг

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Małgorzata Przybyła-Kasperek
University of Silesia in Katowice, Institute of Computer Science, Poland
https://orcid.org/0000-0003-0616-9694

Kornel Chromiński
University of Silesia in Katowice, Institute of Computer Science, Poland
https://orcid.org/0000-0001-9875-5812

Eugenia Smyrnova-Trybulska
University of Silesia in Katowice, Faculty of Arts and Educational Science, Poland
https://orcid.org/0000-0003-1227-014X

Nataliia Morze
Borys Grinchenko Kyiv University, Faculty of Information Technologies and Mathematics
https://orcid.org/0000-0003-3477-9254

Ainur Bazarbayeva
Kazakh National Women's Teacher Training University, Institute of Physics, Mathematics and Digital Technologies, Kazakhstan
https://orcid.org/0000-0002-8810-196X

Importance, Popularity and Elements of Educational Platforms – A Study of the Opinions of Students from Poland, Ukraine and Kazakhstan

Abstract

This article presents a comparative international research study analyzing the opinions of students from Poland, Ukraine, and Kazakhstan regarding the importance, popularity, and elements of educational platforms in the field of computer science. The study employed the Kruskal-Wallis test for statistical analysis. The research questions addressed are as follows: RQ1: Which educational platforms, in general, and which specific platforms, are most popular among students from Poland, Ukraine and Kazakhstan and which specific platforms? RQ2: What topics are most frequently searched for on educational platforms, and what motivates students

from Poland, Ukraine and Kazakhstan to engage in learning through educational platforms? RQ3: How do students from Poland, Ukraine and Kazakhstan evaluate the usefulness of different types of content posted on educational platforms, and do they use various platforms to share their code? RQ4: How do students from Poland, Ukraine and Kazakhstan evaluate the elements of courses on educational platforms that they consider most important or useful. RQ5: How do students from Poland, Ukraine and Kazakhstan evaluate the value of courses offered on educational platforms? Five hypotheses are proposed: The country of origin does not affect the frequency of use of educational platforms. The country of origin affects the topics of courses that students are interested in on educational platforms. The country of origin does not affect the motivation to take courses on educational platforms. The country of origin does not affect the evaluation of elements of the courses on educational platforms that students find most important or useful. The country of origin affects the evaluation of value of courses provided on educational platforms. The most popular topics on these platforms are programming and computer networks, with students from Kazakhstan also displaying a keen interest in subjects related to artificial intelligence and computer graphics. Additionally, this study analyzes the conditions of learning and teaching in specialized modules at each university, including teacher requirements, curricula, and the potential for practical implementation of new knowledge by students. Furthermore, the study examines course elements that are most essential to students, such as video recordings of lectures, tutorials/instructional videos, practical tasks, and solutions to tasks. The article concludes with a discussion and summary of the findings.

K e y w o r d s: Educational platforms, Student opinion, Tutorials, Practical task, Questionnaire, Kruskal-Wallis test

Introduction

The continuous success of Massive Open Online Courses (MOOCs) is driving an increasing number of institutions to adopt this method of delivering distance education. In 2014, there were over 400 universities engaged in providing MOOCs (Miranda, Isaias & Pifano, 2015), offering more than 2,400 courses. Online education has gained significant prominence in the 21st century, particularly following the COVID-19 pandemic. One of the major trends in higher education is the widespread adoption of Massive Open Online Courses (MOOCs), now a common feature in many universities worldwide (Nguyen, 2022). Despite the potential benefits of MOOCs in expanding educational choices and enhancing learning, the persistent issue of low completion rates remains (Wang, Cao, Xu, & Li, 2022).

While Coursera, Udacity, and edX continue to be the dominant MOOC providers, there are approximately 50 MOOC platforms, each offering unique courses and learning approaches. Given this diverse array of providers, this paper aims to develop a model for assessing the quality of MOOC platforms (Miranda, Isaias, & Pifano, 2015).

Literature review

The aim of the research was to develop and test an introductory computer science course for a middle school titled "Fundamentals of Computational Thinking Development (FACT)". This course was designed to prepare and inspire middle school students for future engagement in algorithmic problem solving. Furthermore, FACT was piloted as a seven-week course on Stanford's OpenEdX MOOC platform for blended classroom learning (Grover, Pea, & Cooper, 2015). The research assessed changes in students' perceptions of computer science as a discipline. The r esults, obtained through mixed-method analysis, indicated that students in both the pilot and the main studies (1) demonstrated significant progress in their algorithmic thinking skills, (2) were able to transfer their learning from Scratch to a text-based programming context, and (3) exhibited substantial improvements in their understanding of computer science as a discipline (Grover, Pea, & Cooper, 2015). The authors stressed that students' previous computer experience, as measured by entrance tests, and their math abilities were strong predictors of learning outcomes.

Miranda, Isaias, and Pifano (2015) proposed a model for assessing the quality of MOOC activities, based on six categories: openness, mass, content, communication tools, evaluation methods and participants. These categories reflect fundamental aspects of MOOC platforms and were derived from an extensive literature review of MOOCs, supported by an analysis of specific courses offered on five MOOC platforms: edX, Coursera, Udacity, FutureLearn and MiriadaX (Miranda, Isaias, & Pifano, 2015). Veletsianos and Shepherdson (2016) conducted a systematic analysis and synthesis of the empirical MOOC literature published between 2013 and 2015.

In their study, Zhu, Sari, & Lee (2020) explored various research methods, topics, and trends in MOOC empirical research, with a focus on student-related themes, design, and instructor-related aspects. Among student-focused topics, student retention, learning experience, and engagement were frequently discussed. The majority of MOOC authors were affiliated with institutions in the US, China, and Spain (Zhu, Sari, & Lee, 2020). In a review of sensory learning MOOCs, Limone, Pati, and Loprior (2022) examined empirical MOOC studies published

between 2008 and 2021. They conducted a comprehensive search across databases including PubMed, Scopus, Web of Science, and Google Scholar. The review aimed to enhance understanding of sensory acquisition and its future implications for research.

Nguyen (2022) emphasized that learners in MOOCs typically interact with pre-designed materials and often engage in self-directed learning. Understanding learner satisfaction with such courses is crucial for improving their learning experiences and performance. Nguyen's study employed a mixed-methods approach, combining a survey design with semi-structured interviews involving 120 students of a Vietnamese private university enrolled in academic writing courses on Coursera, one of the world's leading MOOC platforms (Nguyen, 2022). The study identified moderate correlations between students' satisfaction and their perceived usefulness of Coursera courses. Pedagogically, the study highlighted the need for teacher feedback, faster support from course designers, and user-friendly plagiarism checking tools to enhance learners' satisfaction with MOOCs.

Wang, Cao, Xu, and Li (2022) conducted a systematic review of articles on learning engagement in MOOCs published between 2015 and 2022. Their review revealed that engagement in learning can be measured through various methods, including diary, text, image, interview, and survey data analysis. They categorized the factors influencing engagement as intrinsic (e.g. satisfaction with learning) or extrinsic (e.g. curriculum design). The authors emphasized the importance of Course Instructors providing technical support ("scaffolding") to enhance self-directed learning and increase student engagement in MOOCs (Wang, Cao, Xu, & Li, 2022).

Zhu, Sari, and Lee (2018) conducted a systematic review of research methods and topics in empirical MOOC literature published between October 2014 and November 2016. Their study explored key areas of MOOC research, with an emphasis on student retention and motivation as most frequently cited, followed by student experience, satisfaction, assessment and instructional design (Zhu, Sari, & Lee, 2018).

With the growing number of people learning on Massive Open Online Courses (MOOCs), self-directed learning (SDL) skills are essential for their success. An analysis of how to support self-directed learning in MOOCs in the context of motivation, learning strategies and instruction was carried out by Zhu, Bonk, & Berri (2022). Their study aimed to investigate student motivation to enroll in MOOCs and their SDL strategies, as well as the instructional elements supporting SDL from the students' perspective. Among their findings, the authors identified that the instructional elements such as self-assessment, discussion forums, feedback from instructors, flexibility, clearly defined learning goals, authentic content and small training units were instrumental in supporting SDL. The implications of the study are discussed in the article (Zhu, Bonk, & Berri, 2022). The data obtained from the research – semi-structured interviews with 15 students from three MOOC

courses were analyzed using thematic analysis. The researchers found that motivation for enrolling in MOOCs included intrinsic motivation (e.g. curiosity, deepening personal knowledge and personal interest) and extrinsic motivation (e.g. supporting formal education and career development). The learning strategies used by MOOC students are Task Strategies, Self-Control, and Self-Management Strategies. Task strategies included taking notes, reading texts or subtitles, watching videos, and doing further research. Self-monitoring strategies included self-assessment, self-reflection, progress indicators, final projects, and authentic tasks (Zhu, Bonk, & Berri, 2022).

Some of the important issues have been the essential study interests of MOOC scholars in recent years. Papadimitriou (2023) discussed critical research questions related to MOOC effectiveness, including dropout rates, completion rates, loneliness, and the potential of Adaptive and Intelligent MOOCs. The study examined the learner characteristics used for adaptation and the methods and techniques employed to improve traditional MOOCs.

The research conducted by Smyrnova-Trybulska et al., in 2015–2022 focused on assessing the digital competences of pre-service and in-service teachers who completed the MOOC "Contemporary ICT Tools and Innovative Methods of Creative Education". The study examined various theoretical and practical aspects (Smyrnova-Trybulska et al., 2016), social and educational dimensions (Smyrnova-Trybulska et al., 2015) as well as methodological aspects of developing MOOCs (Smyrnova-Trybulska et al., 2017). Following the Preliminary Analysis of the Development and Implementation of the MOOC Project (Smyrnova-Trybulska, Sekret, & Morze, 2021), the most recent study (2022) provides a brief description of the MOOC, outlines the course requirements and analyzes the learning outcomes through the students' self-evaluation and feedback. The MOOC was developed in both Polish and English as part of the project "MOOCs for Sciences of Education" and hosted on the Polish MOOC platform Navoica (www.navoica.pl) within the framework of a competition, initiated by of Ministry of Education and Science of Poland and National Centre for Research and Development (NCBR – Narodowe Centrum Badań i Rozwoju) under the theme "Direction to the MOOC". The conclusions drawn from the focussed assessment of the MOOC and the overall recommendations for enhancing MOOC effectiveness in formal education and improving learning outcomes were derived from research and are presented accordingly (Smyrnova-Trybulska, Sekret, Morze, & McKay, 2022). Despite significant progress, there remain research questions that still need to be answered. This article contributes new research results obtained from an international comparative study conducted in Poland, Ukraine, and Kazakhstan to the research area.

Methodology

The research presented in this paper was conducted through a questionnaire survey simultaneously administered at three universities in three different countries: Poland, Ukraine and Kazakhstan. It is important to note that the higher education systems and mentalities in Poland, Kazakhstan, and Ukraine are influenced by historical, cultural, and socio-economic factors. All three countries were part of the Socialist Bloc, and the Soviet Bloc, that was the coalition of communist states of Central and Eastern Europe, and they gained independence in the early 1990s after the dissolution of the USSR. This shared history has left a significant impact on their political, economic, and social structures. These countries have a three-tier higher education system – Bachelor's, Master's, and Doctorate – following the Bologna Process standards. All three countries are increasingly recognizing the importance of globalization and are working to internationalize their higher education systems. In Poland, the education system is aligned with the European Higher Education Area standards. Kazakhstan, like Ukraine, has a Soviet legacy that has influenced its educational system.

The survey was conducted anonymously and on a voluntary basis. The questionnaire, available via Google Form online, was distributed to students majoring in computer science. It encompassed a range of questions regarding educational platforms. The questionnaire questions were divided into four thematic groups: sociological characteristics, frequency of use of educational platforms, the most interesting topics of the courses, assessment of the usefulness of various contents within the courses and the use of code-sharing platforms. Such division appear thematically coherent and provide a comprehensive analysis of the topic. The answers to most of the questions were provided on a 5-point scale, which allows for a wide interpretation. The collected data were analyzed using various statistical methods, in particular the Kruskal-Wallis test, along with various statistical metrics and charts, with a special emphasis on box-plot graphs. Depending on the research question addressed, datas were collected in appropriate groups and their characteristics were compared. The primary objective of this study was to examine differences in students' attitudes, frequency of use, and assessment of the usefulness of courses offered on educational platforms. The study also investigated the topics of courses on educational platforms that were of greatest interest to students from different countries. To achieve this, multiple statistical metrics were computed, and the results were visually represented using column graphs and box-plot graphs. Furthermore, several statistical tests were conducted to validate the five main hypotheses, which are detailed below. These hypotheses pertain to the frequency of educational platform usage, the preferred course topics, motivations for taking courses on educational platforms, evaluations of course elements, and assessments of the value of courses offered on educational platforms.

Questionnaire, purpose and research questions

Our research aimed to explore students' attitudes toward a variety of educational platforms, identify the platforms most frequently utilized, and ascertain which elements provided on these platforms were most valuable to students. The survey was conducted in June 2023 and involved students majoring in computer science from the University of Silesia in Katowice, Poland (Faculty of Science and Technology), Borys Grinchenko Kyiv University, Ukraine, and West Kazakhstan Agrarian-Technical University named after Zhangir Khan. The selected universities have much in common. All three universities offer a wide range of programs in various fields. They all have a strong focus on research and innovation. The West Kazakhstan Agrarian-Technical University has a specific focus on agrarian and technical fields, setting it apart from universities with a broader range of programs. Also, the West Kazakhstan Agrarian-Technical University is noted as being among the youngest universities in the country, while the other two have a longer history. It should be noted that there are multidimensional differences between students from the analyzed universities, such as differences of situation of students, governmental support, economic and war stability. However, in this research we did not analyze these factors. Such analysis and the impact of various parameters on the students' perceptions of MOOC will be conducted in future work. A total of 158 responses were collected, with respondents selected randomly. Students at various stages of their studies were invited to participate in the survey through email invitations, and their participation was entirely voluntary. Selected research results were presented in the Comparative International Research In Area Of Educational Platform And MOOCs In Opinion Of IT Students Using Data Mining Analysing (Chromiński, Przybyła-Kasperek, Smyrnova-Trybulska, Bazarbayeva, Morze, 2023).

Sociological metrics

In order to study the relationship between student characteristics and attitude towards educational platforms, the questionnaire included sociological questions. The sociological characteristics questions and possible responses in the questionnaire are presented below:

- gender – male, female
- degree of study – Engineer's Degree, Master's Degree
- age – <19–20>, <21–22>, <23–24>, <25–26>, <27–28>, <29–30>, >30

Descriptive statistics on the responses obtained related to the sociological metrics are presented in Table 1.

Table 1.
Descriptive statistics on responses to sociological questions

Gender	Quantity/ Percentage	Degree of study	Quantity/ Percentage	Age	Quantity/ Percentage
Male	117/74.05	Engineer's Degree	114/72.15	<19–20>	18/11.39
Female	41/25.95	Master's Degree	44/27.85	<21–22>	70/44.30
				<23–24>	33/20.89
				<25–26>	8/5.06
				<27–28>	4/2.53
				<29–30>	5/3.16
				>30	20/12.66

S o u r c e: Own work.

Based on the results obtained, it can be concluded that the majority of respondents were male engineering students. The largest group consisted of individuals aged 21 to 24 years old, constituting 65% of the respondents. Concerning the participation of students from different countries, the largest group was from Poland – 81 students responding to the questionnaire. Additionally, 40 students from Kazakhstan and 37 students from Ukraine participated and answered the survey questions.

In Poland, Kazakhstan and Ukraine students often start their higher education with a Bachelor's degree, typically around 19–20 years old in Poland, the age of 18–19 in Kazakhstan and around 17–18 years old in Ukraine; after completing secondary education. So there are some differences, however, small and it is unlikely that they have much impact on the distribution of age of questionnaire participants. Therefore, it seems that due to the similarity in terms of age of study and many aspects resulting from the historical homogeneity of the education background in Central and Eastern European countries, groups of students from Poland, Kazakhstan and Ukraine seem to be quite homogeneous.

Research questions and hypotheses

The research conducted can be categorized into three main areas.

The first group examined the frequency of the use of educational platforms in general and identified the most popular platforms. Our next group of questions focused on what topics are most frequently searched for on educational platforms, and explored the motivation behind students' engagement in educational platforms. The last group of questions concerned evaluating the usefulness of different types of content posted on educational platforms and investigated whether students use a variety of platforms to share their code.

The research questions (RQ1–RQ5) are as follows:

RQ1: Which educational platforms, in general, and which specific platforms, are most popular among students from Poland, Ukraine and Kazakhstan?

RQ2: What topics are most frequently searched for on educational platforms, and what motivates students from Poland, Ukraine and Kazakhstan to engage in learning through educational platforms?

RQ3: How do students from Poland, Ukraine and Kazakhstan evaluate the usefulness of different types of content posted on educational platforms, and do they use various platforms to share their code?

RQ4: How do students from Poland, Ukraine and Kazakhstan evaluate the elements of courses on educational platforms that they consider most important or useful.

RQ5: How do students from Poland, Ukraine and Kazakhstan evaluate the value of courses offered on educational platforms.

Hypotheses determined based on RQ1–RQ5 are as follows:

H1: The country of origin does not affect the frequency of use of educational platforms.

H2: The country of origin affects the topics of courses that students are interested in on educational platforms.

H3: The country of origin does not affect the motivation to take courses on educational platforms.

H4: The country of origin does not affect the evaluation of elements of the courses on educational platforms that students find most important or useful.

H5: The country of origin affects the evaluation of value of courses provided on educational platforms.

Results and statistical tests

In this section, we will present statistical tests, analyses and their outcomes related to the usage of educational platforms, categorized into three themes corresponding to the topics listed above.

Frequency of use and the most popular educational platforms

In this part of the questionnaire, we explored the popularity of educational platforms and identified which ones are most frequently used by students. The main questions and their potential responses were as follows:

1. How often do you use educational platforms to learn about programming/IT issues? – Three or more times a week, Once a week, Once every two weeks, Once a month, Once every six months, Once a year, Never.
2. Indicate how often you use educational platforms to learn about programming/IT issues.
   a) Udemy
   b) Codecademy
   c) Coursera
   d) edX
   e) Khan Academy
   f) FreeCodeCamp
   g) Treehouse
   h) Udacity
   i) Navoica
   j) Prometheus
   k) Cognitive Class

For the second question, the respondents provided their frequency of use on a 5-point scale, with 1 indicating "I do not use" and 5 indicating "I use very often."

Descriptive statistics regarding the responses obtained for the first question are presented in Table 2. The first column provides aggregated results for all countries, and the subsequent three columns show down the results by country.

Table 2.
Descriptive statistics on responses to the question related to frequency of usage educational platforms

Frequency of usage	Total Quantity/ Percentage	Poland Quantity/ Percentage	Kazakhstan Quantity/ Percentage	Ukraine Quantity/ Percentage
Never	5/3.16	2/2.47	2/5	1/2.70
Once a year	2/1.27	1/1.23	0/0	1/2.70
Once every six months	9/5.70	5/6.17	4/10	0/0
Once a month	21/13.29	11/13.58	4/10	6/16.22
Once every two weeks	18/11.39	9/11.11	4/10	5/13.51
Once a week	49/31.01	24/29.63	11/27.5	14/37.84
Three or more times a week	54/34.18	29/35.80	15/37.5	10/27.03

S o u r c e: Own work.

The first conclusion drawn from the results is that students in computer science use educational platforms quite frequently – there are only a few students who do not use these platforms at all or use them only once a year. It is evident that the distributions of results in Poland, Kazakhstan and Ukraine are very similar.

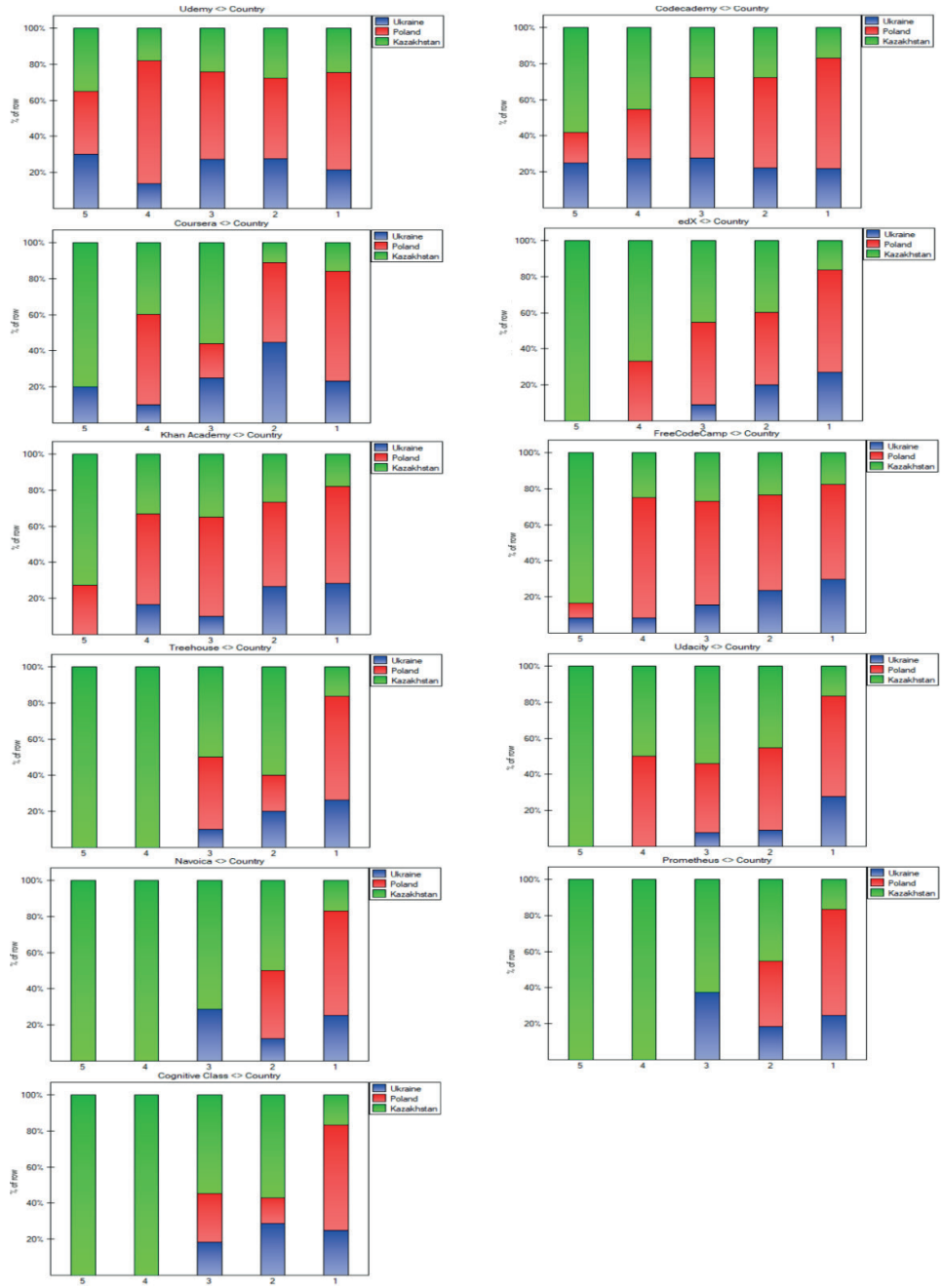

*Figure 1. C*harts of the responses obtained related to the question how often you use educational platforms to learn about programming/IT issues, with 1 indicating "I do not use" and 5 indicating "I use very often"

S o u r c e: Own work.

This leads to a hypothesis that the country of origin does not significantly affect the frequency of educational platform use. The statistical significance of this hypothesis was assessed using The Kruskal-Wallis tests for groups defined by country. The result $H(2,158) = 0.19$ and *p-value* equal to 0.91 were obtained. Therefore, it confirmed the first hypothesis H1, stating that the country of origin has no effect on the frequency of educational platform usage. Similarly, the Kruskal-Wallis test was performed to verify whether age has an impact on the frequency of students' use of educational platforms. Once again, no statistically significant differences were found in the frequency of platform use among groups of students categorized by age.

Figure 1 presents a column chart illustrating the responses to the second question about the frequency of use of each educational platform, categorized by the country in which the respondents study. It is evident that the most popular educational platform is Udemy, as indicated by the highest columns across all countries for the answer 5 – "I use very often." Codecademy and FreeCodeCamp follow closely in terms of frequency of use, occupying the second position. Khan Academy ranks third in terms of popularity, while other educational platforms are used less frequently.

Remarkably, there is no significant difference in the distribution of the frequency of use for each platform among students from the analyzed countries. The same platforms appear to be the most popular in Poland, Ukraine, and Kazakhstan. To verify this observation, the Kruskal-Wallis test was conducted to assess whether there were significant differences in the average frequency of use of individual platforms by country. The test confirmed that there is no significant difference in the case of the Udemy platform. However, for the other platforms, it indicated significant differences in the averages. A further analysis of the box-plot graphs revealed that the results from students in Kazakhstan had an influence on this outcome, as a small group of students often selected the highest answer, 5, which accounts for the observed differences.

Topics most frequently utilized on educational platforms, and motivation for using educational platforms

In this part of the questionnaire, we explored the topics of the courses that are most commonly used on educational platforms, and the motivations that led students to take a course on these educational platforms. The main questions and potential responses were as follows:

3. Select the topics of the courses you use on educational platforms.
   a) Programming
   b) Artificial intelligence
   c) Computer networks
   d) Computer graphics

e) Databases
f) Mathematics
g) Biometrics
h) Computer architecture

4. What was your motivation for starting the course?
   a) Willingness to learn about new technologies/issues
   b) Supplementing the topics taught as part of the studies
   c) A lack of understanding of the topics covered in the studies and the need for self-study
   d) Labor market need, employer suggestion

   Responses to all questions were rated using 5-point scale, where 1 indicated "I do not use" or "Absolutely disagree," and 5 indicated "I use very often" or "Absolutely agree.".

Figure 2 presents a column chart illustrating the responses to the question regarding the topics of courses that students use on educational platforms, categorized by the country in which the respondents study. It is evident that programming is the most popular topic on educational platforms. In the second place are students interested in computer networks and databases. Artificial intelligence takes the third place in terms of students' interest. Other courses have gained moderate interest, with biometrics topics receiving the least interest from students.

The Kruskal-Wallis test was performed to verify whether there are significant differences in the average interest level of students from different countries in particular topics. The results, including group size, p-values, and test statistic values, are presented in Table 3. All obtained results are statistically significant. Thus, hypothesis H2, which posits that the country of origin does affect the topics of courses that students are interested in on educational platforms, is confirmed. In addition, Figure 3 includes box-plot graphs prepared for each topic and country separately. It is noticeable that students from Kazakhstan exhibit particularly higher interest in the topics offered on educational platforms, a trend that is consistent across all topics. When comparing Polish and Ukrainian students, it is Polish students who show more interest in the topics related to computer networks and mathematics. Conversely, Ukrainian students display more interest in topics related to computer graphics and databases.

Such differences in students' interest in particular topics are probably due to the specificity of specializations offered at various universities at which students study. A detailed discussion of the various study profiles is provided in the Discussions section, but we will now present the basic profiles. At the considered university in Poland, the emphasis is putted mainly on software and engineering applications as well as computer graphics. The main area of interest of the considered university in Kazakhstan is artificial intelligence and information systems and technologies. However, the main area of interest of the considered university in Ukraine is computer engineering, programming, mathematics and cybersecurity.

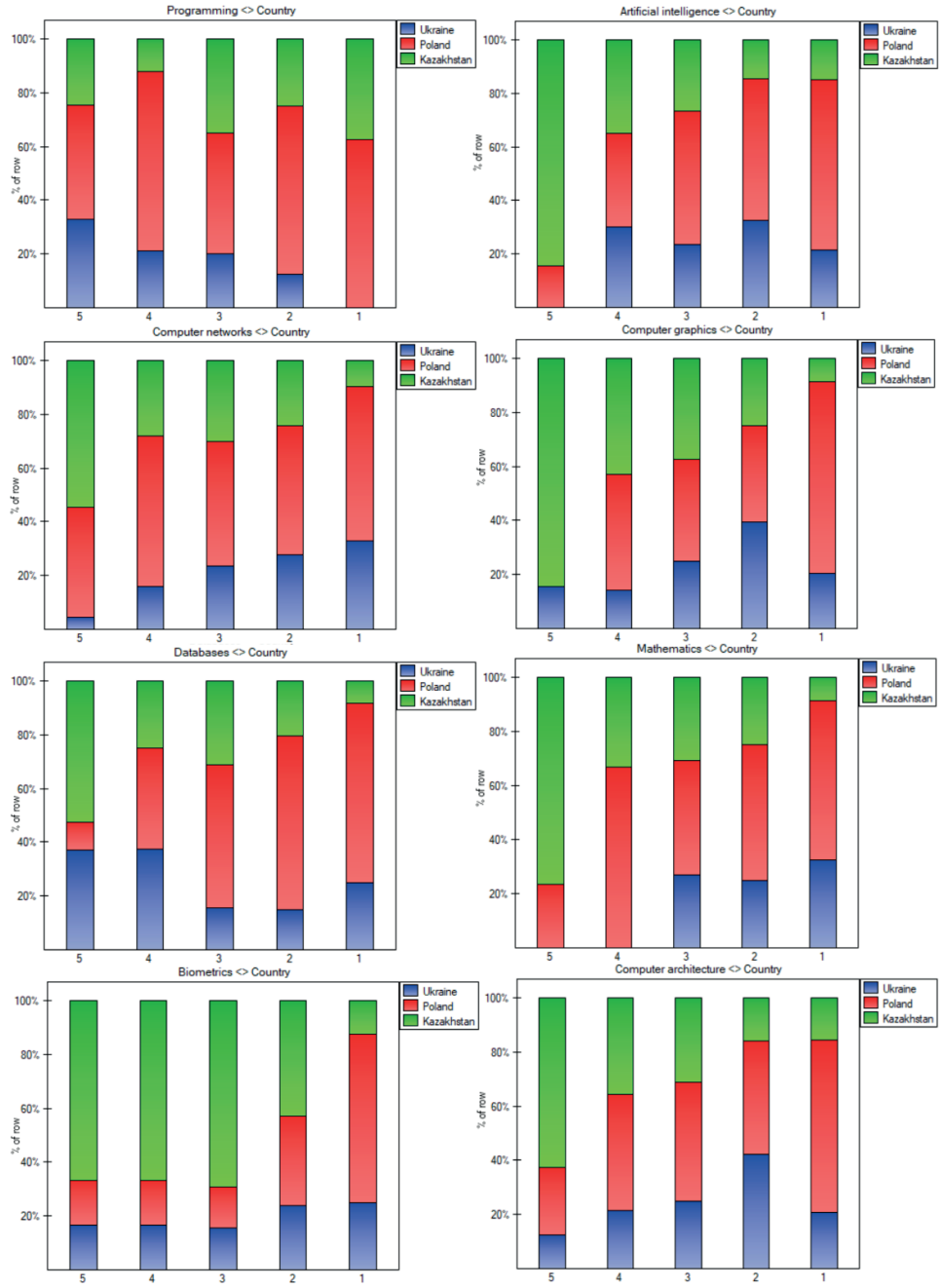

Figure 2. Charts of the responses obtained related to the question about topics of the courses used by students on educational platforms, with 5 indicating “I use very often”, 1 indicating “I do not use”

S o u r c e: Own work.

Table 3.
The Kruskal-Wallis test results for the responses obtained related to the question about topics of the courses used by students on educational platforms

Topic	Kazakhstan	Poland	Ukraine
n	40	81	37
Programming	H(2,158)=6.111; p-value=0.047		
Artificial intelligence	H(2,158)=18.204; p-value=0.0001		
Computer networks	H(2,158)=16.946; p-value=0.0002		
Computer graphics	H(2,158)=37.125; p-value=0.0001		
Databases	H(2,158)=17.786; p-value=0.0001		
Mathematics	H(2,158)=28.968; p-value=0.0001		
Biometrics	H(2,158)=37.182; p-value=0.0001		
Computer architecture	H(2,158)=14.841; p-value=0.0006		

S o u r c e: Own work.

The next aspect investigated concerned students' motivation when taking a course on educational platforms. Figure 4 presents a column chart illustrating the responses to the question about the motivation for starting a course on educational platforms, categorized by the country in which the respondents study. As observed, the primary motivation for students in all countries was the desire to learn about new technologies and issues. Moreover, students from Poland were frequently motivated by the need to address specific issues or difficulties that arose during their studies. In contrast, for students from Kazakhstan and Ukraine, supplementing their academic material was not as significant a motivation for taking courses on educational platforms. Surprisingly, the motivation related to labor market needs was relatively average for students. It appears that Kazakh students had the highest motivation when it came to supplementing their knowledge required for their jobs.

The Kruskal-Wallis test was performed to verify whether there are significant differences in the average assessment of motivation for taking courses on educational platforms between countries. The test confirmed that there is no significant difference in almost all tested aspects. Only for the motivation of willingness to learn about new technologies/issues statistically significant difference in averages was confirmed with values $H(2,158) = 8.063$, *p-value* = 0.0177. In this case, Ukrainian students demonstrated the highest motivation for taking courses with a desire to expand their knowledge, as can be seen in Figure 5, which includes box-plot graphs for each motivation and country separately. Thus, hypothesis H3, which posits that the country of origin, in general, does not affect the motivation to take courses on educational platforms, is confirmed.

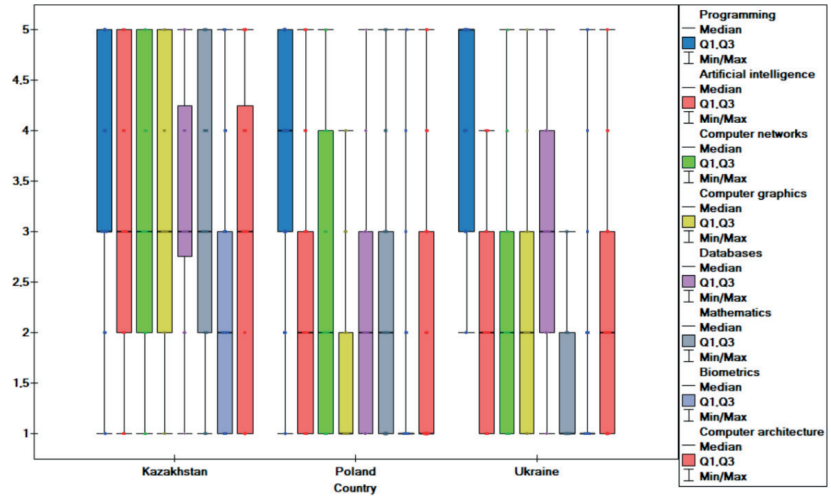

Figure 3. Box-plot graphs of the responses obtained related to the question about topics of the courses used by students on educational platforms, with 5 indicating "I use very often", 1 indicating " I do not use"

S o u r c e: Own work.

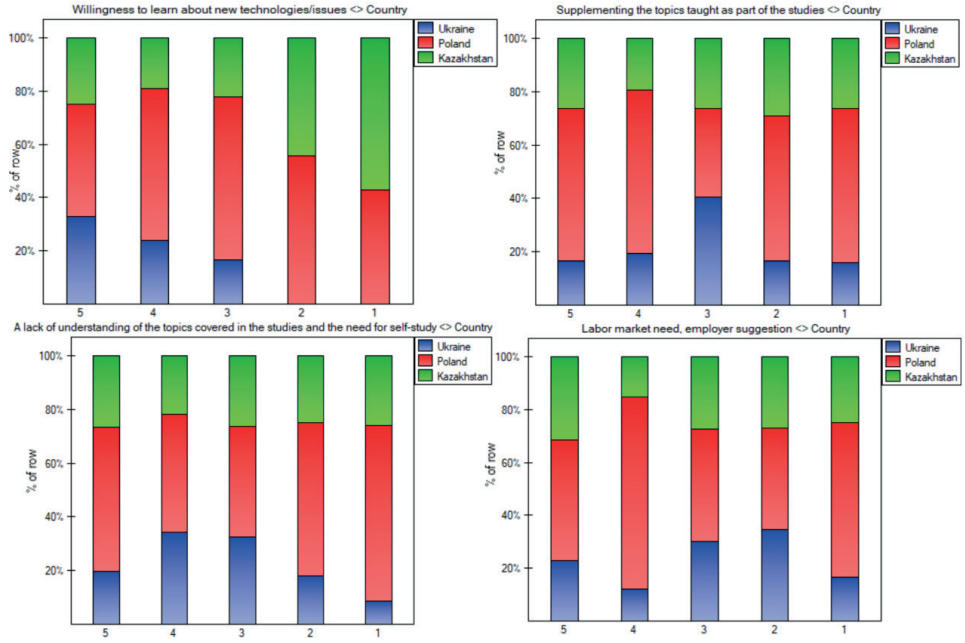

Figure 4. Charts of the responses obtained related to the question about the motivation for starting the course on educational platforms, with 5 indicating "Absolutely agree", 1 indicating "Absolutely disagree"

S o u r c e: Own work.

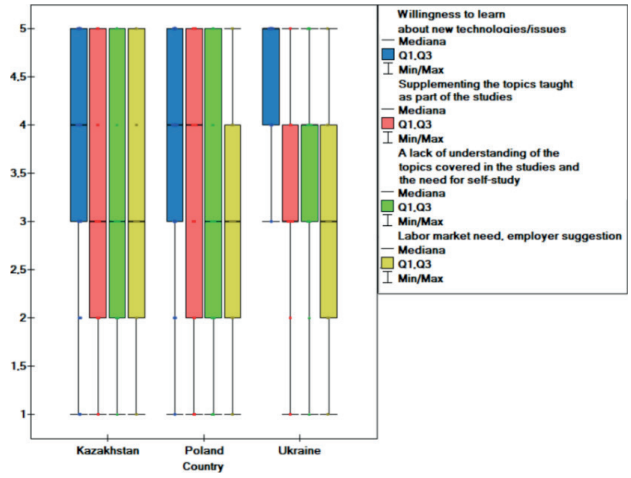

Figure 5. Box-plot graphs of the responses obtained related to the question about topics of the courses used by students on educational platforms

S o u r c e: Own work.

Usefulness of different types of content posted on educational platforms and usage of a variety of platforms to share students' code

In the last part of the questionnaire, we focused on the content of courses that students find most useful on educational platforms. Additionally, we inquired whether students themselves use these platforms to share their code. The primary questions and possible responses were as follows:

5. What elements of the course on educational platforms do you find most important/useful
   a) Theoretical description to the topic
   b) Video recordings of lectures
   c) Tutorials/Instructional videos
   d) Practical tasks
   e) Solutions to tasks
   f) Control tests
6. Do you think the courses offered on educational platforms are valuable?
7. Do you use code sharing platforms/tools – specifically Git systems (GitHub, GitLab, Bitbucket, etc.) – as part of expanding your knowledge?
8. Do you use code sharing platforms/tools – specifically Stack Overflow systems – as part of expanding your knowledge?

   For all these questions, the possible responses were defined using a 5-point scale, where 1 signifies "Not useful" or "I do not use" or "Absolutely disagree," and 5 denotes "Very useful" or "I use very often" or "Absolutely agree."

Figure 6 presents a column chart illustrating the responses to the question about the elements of the course on educational platforms that students find most important and useful, categorized by the country in which the respondents study. It is evident that students from all analyzed countries highly value course content such as Tutorials/Instructional Videos, Practical tasks, and Solutions to tasks. Additionally, Figure 7 highlights that these elements hold particular importance for students from Poland and Ukraine. Video recordings of lectures were also considered quite significant by students. Conversely, the elements of courses on educational platforms that students find the least important are Theoretical descriptions of the topic and Control tests.

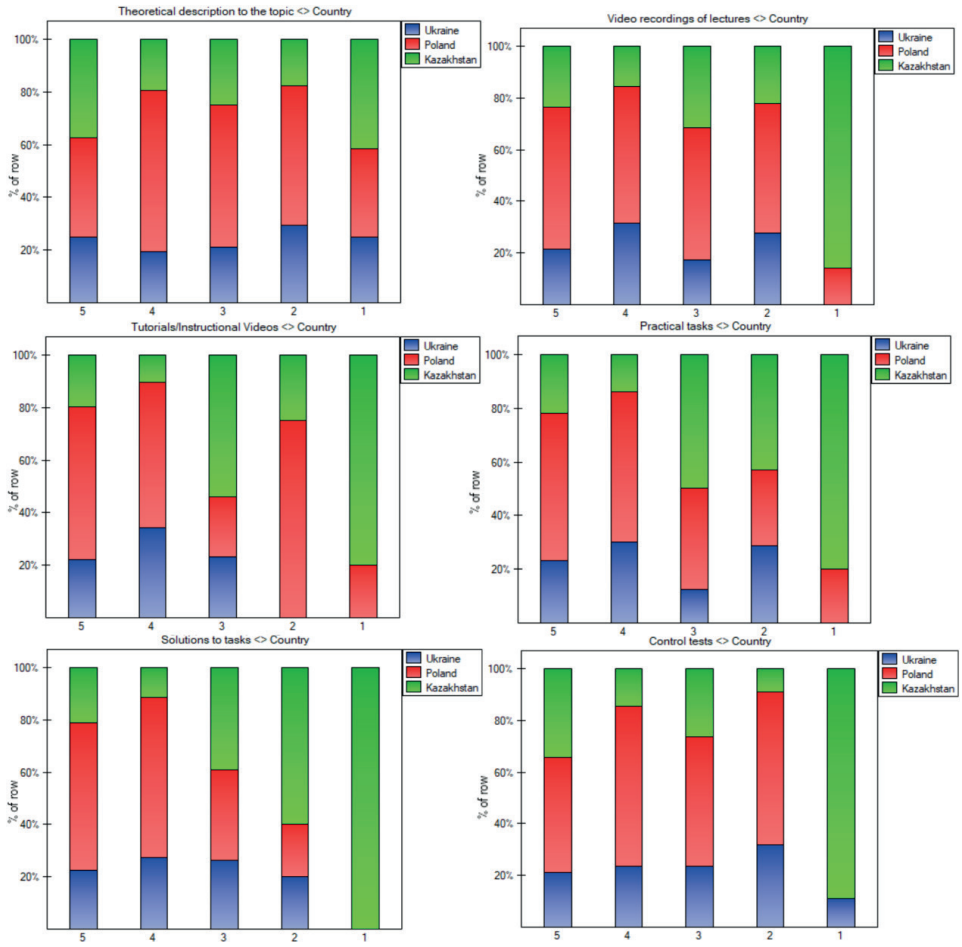

Figure 6. Charts of the responses obtained related to the elements of the course at educational platforms that students find most important/useful, with 5 indicating "Very useful", 1 indicating "Not useful"

S o u r c e: Own work.

The Kruskal-Wallis test was performed to verify whether there are significant differences in the average evaluation of elements of the course on educational platforms that students find most important and useful. The test confirmed that there is no significant difference in almost all the tested aspects. This confirmed hypothesis H4, suggesting that the country from which the student originates, in general, does not affect the evaluation of elements of the course on educational platforms that students find most important and useful. However, for the elements such as Tutorials/Instructional Videos and Solutions to tasks, a statistically significant difference in averages was confirmed with values $H(2,158) = 8.365$ *p-value* = 0.0153 and $H(2,158) = 8.183$ *p-value* = 0.0167, respectively. Polish students rated these elements as the most relevant, while students from Kazakhstan gave them lower ratings.

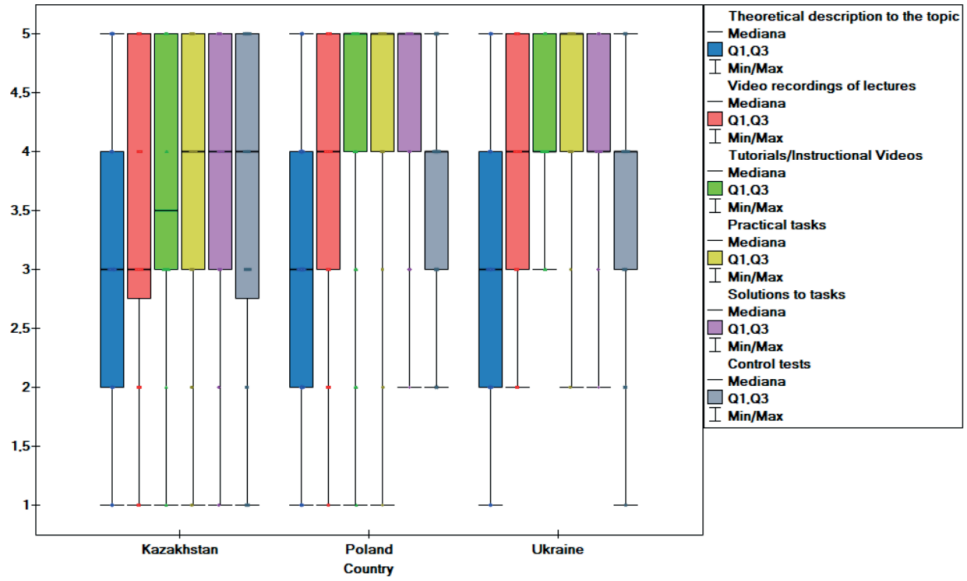

Figure 7. Box-plot graphs of the responses obtained related to the question about elements of the course on educational platforms that students find most important/useful

S o u r c e: Own work.

A question was also posed whether students find the courses posted on educational platforms valuable. Figure 8 presents a column chart illustrating the answers to this question, and the box-plot graphs display the responses obtained, categorized by the country in which the respondents study. As observed, Ukrainian students rate the value of courses available on educational platforms the highest. Students from Poland, who also rate the value of such courses highly, come in second place. The lowest importance or valence of courses is given by students from Kazakhstan.

The Kruskal-Wallis test confirms significant differences in the average evaluation of the value of courses provided on educational platforms, with results $H(2,158) = 12.223$ *p-value* = 0.0022. Thus, hypothesis H5 is confirmed, suggesting that the country of origin does affect the evaluation of the value of courses provided on educational platforms. Such differential student evaluation of the value of courses may result from their expectations towards the courses and attitudes. This specific attitude may be related to comparing courses conducted at individual universities with courses conducted using educational platforms. A detailed analysis of the specificity of all the considered universities is presented in the Discussions section, but it is definitely the level of knowledge and specificity of the classes that are offered at each university that determines the level of students' expectations towards courses on educational platforms.

The final stage of the research investigated whether students also share their work, specifically their program code, on platforms. Figure 9 presents a column chart illustrating the answers to the question of whether students use code sharing platforms/tools, and Figure 10 provides the box-plot graphs for the obtained results. It is evident that students use platforms like Git systems (GitHub, GitLab, Bitbucket, etc.) or Stack Overflow systems as part of expanding their knowledge. The only exception is students from Kazakhstan, who are less likely to use Stack Overflow systems. The Kruskal-Wallis test confirms significant differences in the usage of code sharing platforms/tools like Stack Overflow systems as part of expanding knowledge among students from the studied countries, with results $H(2,158) = 17.696$ *p-value* = 0.0001.

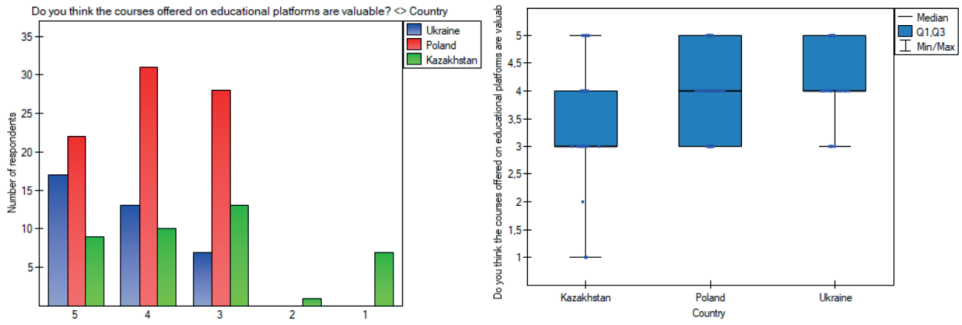

*Figure 8. C*harts and box-plot graphs of the responses obtained related to the question about whether students find the courses posted on educational platforms valuable

S o u r c e: Own work.

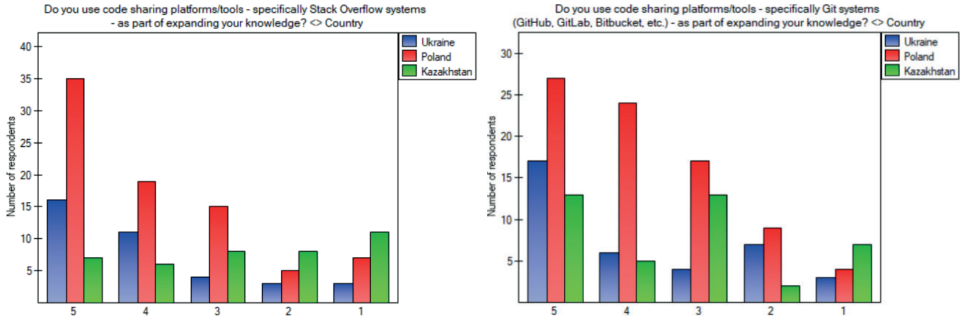

Figure 9. Charts of the responses obtained related to whether students used code sharing platforms/tools, with 5 indicating "I use very often", 1 indicating "I do not use"

S o u r c e: Own work.

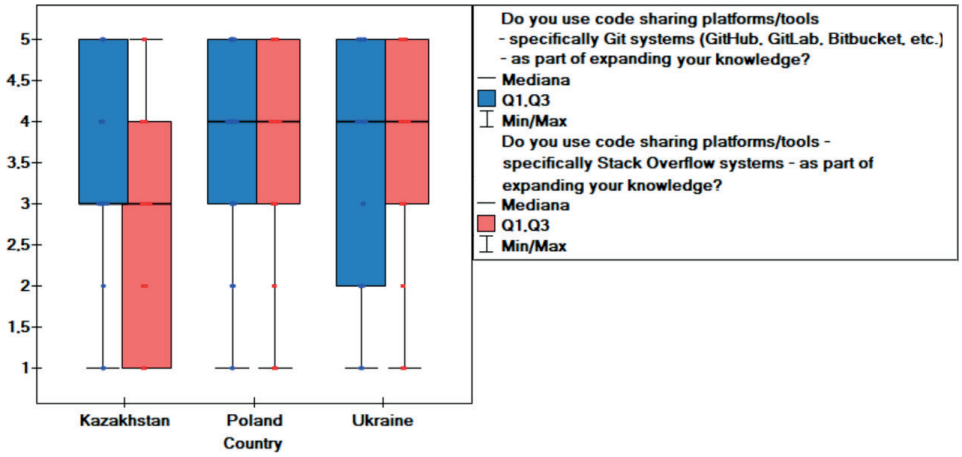

Figure 10. Box-plot graphs of the responses obtained related to whether students used code-sharing platforms/tools

S o u r c e: Own work.

Discussions

At the University of Silesia in Katowice, in the field of computer science, there is a strong emphasis placed on issues such as programming, including web applications programming and computer networks. This emphasis is also reflected in the most popular courses among Polish students on educational platforms. As Figure 3 shows, programming courses are the most popular among Polish students

on educational platforms, with computer networks being the second most popular. The specialities offered in the field of computer science are as follows:

Software engineering – students acquire knowledge and skills in all aspects of software development, with a special emphasis placed on programming, modern application development methodologies, and user interface design.

Information systems engineering – the program covers the design of information systems, with an emphasis on practical aspects such as databases, desktop application programming, web application development, mobile application development, and cloud computing. The curriculum is aligned with current trends in software development and labour market requirements.

Web and hybrid application graphics – students gain expertise in designing graphical interfaces for web applications, with a focus on front-end design for web and mobile applications, back-end programming for mobile apps, interactive and real-time graphics design, and the application of geometric modelling methods and multi-resolution image analysis.

Computer game programming – graduates of the specialty are capable of designing and implementing computer games and multimedia applications using advanced techniques and tools, in line with the latest industry trends.

Web application design – this program introduces students to modern methods of building interactive web applications that run in web browsers and other environments. Students learn front-end application design (HTML, JavaScript, Bootstrap, JQuery) and back-end application development (MVC, PHP, JEE), as well as technologies for building, testing, and maintaining web applications across various operating systems.

Computer networks and mobile devices – the speciality focuses on designing and configuring modern internet networks, including the selection of communication protocols and hardware and software configuration. Practical knowledge is gained through hands-on experience with CISCO equipment.

Data processing technologies – the educational content covers a wide range of data processing methods and technologies, with a particular emphasis on designing, implementing, and analyzing information systems that support data processing in business, engineering, and scientific applications.

In Kazakhstan, both the West Kazakhstan Agrarian-Technical University named after Zhangir Khan and the Kazakh National Women's Teacher Training University, located in Uralsk and Almaty, respectively, train computer science specialists for various fields of activity. Due to the widespread use of AI in many areas of life, there is a significant interest among students in artificial intelligence, which is reflected in the diagrams above and is also evident in research projects and student startups. The educational programs in the field of computer science in Kazakhstan include:

Information Systems and Technologies – this program covers programming, web programming, database administration, information systems, computer net-

works, and information security. It offers learning trajectories and elective subjects that allow students to specialize in their chosen field and function professionally after graduation.

In 2023, the Ministry of Higher Education and Science of the Republic of Kazakhstan implemented the "Coursera in Kazakh Language" programme, providing free access to Coursera platform courses in English and Kazakh to over 20,000 students from 25 regional universities in Kazakhstan, including the Kazakh National Women's Teacher Training University. As a result, more than 22,000 courses were made available.

Borys Grinchenko Kyiv University got access to more than 5,200 free courses and 2,200 managed projects from the world's leading universities thanks to Coursera's cooperation with the Ministry of Education and Science of Ukraine. Also, the BGKU elaborated a digital campus (https://digital.kubg.edu.ua), which includes a lot of useful e-services for students and academic teachers, which successfully support the didactic and scientific work at the university.

Borys Grinchenko Kyiv University educates students in the following educational programs for bachelors: Informatics, Computer Engineering, Security of Information and Communication Systems and prepares the following specialists:

In the field of information and analytical systems, there are: developer of computer systems, system administrator, a specialist in computer modelling, forecasting and optimization of processes in various industries, a specialist in design and implementation of modern databases, designer of computer systems, analyst of computer systems.

In the field of Security of information and communication systems it offers: cyber security specialist, cyber security analyst, cyber security project manager, cyber security engineer;

In Computer Engineering, there are: Programming Engineer, Network Engineer, Hardware Development Engineer, Software Tester, Data Analyst, Web Developer, Technical Support Engineer.

Students in these bachelor's programmes study the following subjects: technology of creating software products, programming, system programming, computer architecture, parallel and distributed computer systems, computer networks, applied modelling and programming, design of embedded systems, robotics, computer graphics and animation, programming: decision-making management systems, computer game development technologies, information analysis and processing technologies, databases and information systems, algorithms and data structures.

In addition, the university implements the following master's programs: information and analytical systems, security of information and communication systems, where students have the opportunity to study the following subjects: computer modelling of systems, information and analytical systems, analysis and processing of big data, computer URBAN monitoring systems, digital technologies of communications and management, IT project management, data analytics, computer

modelling of systems, software engineering, processing and analysis of big data, artificial intelligence, information-analytical systems.

Electronic training courses hosted in LMS Moodle have been developed and implemented for all academic disciplines at the University of Grinchenko. Since distance learning has been systematically introduced at the university for more than 10 years, and the developed e-learning courses are evaluated and certified, students are used to using their own Moodle system with training courses. This can be explained by a low interest of students from Ukraine in using MOOC materials posted on open platforms. University students have enough e-course material for learning, created by the university's teachers themselves, which is highly appreciated by students. In addition, the university does not encourage the use of open platforms and learning on them, since according to the internal regulation of the organization of the educational process, students are not credited with the certificates they received while studying at MOOC.

Conclusions

In conclusion, the findings of this research have provided valuable insights into the impact of the country of origin and the university where the student is studying on various aspects of students' engagement with educational platforms. It has been demonstrated that the country of origin does play a significant role in shaping students' preferences and behaviours within the educational context.

Firstly, the notion that the country of origin does not affect the frequency of use of educational platforms has been refuted.

Secondly, the research supports the hypothesis that the country of origin does influence the topics of courses that students are interested in on educational platforms. This highlights the importance of considering cultural and societal factors in tailoring educational content to meet the diverse preferences and needs of students from different regions.

In terms of motivatio to take courses, the hypothesis suggesting that the country of origin does not affect motivation has been contradicted.

Interestingly, while the country of origin may not significantly impact the evaluation of specific elements within courses, such as content or delivery methods, the research suggests that it does influence the overall perceived value of courses on educational platforms. This underscores the importance of considering cultural perspectives in designing and delivering courses to ensure they are perceived as valuable and relevant across different regions.

In essence, this study highlights the multifaceted influence of the country of origin on students' interactions with educational platforms. Acknowledging and

understanding these influences is crucial for educators and platform developers to create more inclusive and effective educational environments that cater to the diverse needs and expectations of students worldwide.

The main recommendation for academic teachers is to consider whether completing a specific course on an educational platform, aligned with the module's content, could be recognized or rewarded in some way when grading the module. It is important to note that this should not necessarily be a mandatory component of module credit since some courses on these platforms may require payment, and students should not be obligated to access them. However, for more active students who have invested their time and resources in completing these courses, acknowledging their effort when determining the final module grade could be a motivating incentive. Regarding the recommendation for teachers of universities in Kazakhstan to help students use the opportunities presented by these programs, this is a good opportunity for students, who may not have a high level of proficiency in English. Encouraging students to use these resources should depend on the level of the course.

An obvious limitation of educational platforms is the absence of direct interaction with a teacher or mentor who can provide motivation, serve as a positive role model in the discipline, and offer personalized support aligned with students' individual needs. The educational platforms examined in this study do not provide artificial intelligence modules that could partially mimic a teacher's support. Future research should explore the impact of artificial intelligence-based modules available on educational platforms and their influence on the learning process of students.

Acknowledgements

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References

Chromiński, K., Przybyła-Kasperek, M., Smyrnova-Trybulska, E., Bazarbayeva, A., Morze, N. (2023) Comparative International Research In Area Of Educational Platform And MOOCS In Opinion Of IT Students Using Data Mining Analysing In E. Smyrnova-Trybulska (ed.) *E-learning & Artificial Intelligence. „E-learning" Series.* Vol. 15 Katowice-Cieszyn: STUDIO NOA for University

of Silesia. ISSN 2451-3644 (print edition), ISSN 2451-3652 (digital edition), ISBN 978-83-66055-39-1, https://doi.org/10.34916/el.2023.15.

Grover, S., Pea, R., & Cooper, S. (2015) Designing for Deeper Learning In A Blended Computer Science Course For Middle School Students, *Computer Science Education*, 25:2, 199–237. https://doi.org/10.1080/08993408.2015.1033142.

Limone, P., Pati, S., Toto, G. A., Di Fuccio, R., Baiano, A., & Lopriore, G. (2022). Literature Review on MOOCs on Sensory (Olfactory) Learning. *Computers*, *11*(3), 32. MDPI AG. Retrieved from http://dx.doi.org/10.3390/computers11030032.

Miranda, P., Isaias, P., & Pifano, S. (2015). Model for the evaluation of MOOC platforms. *8th International Conference of Education, Research and Innovation (ICERI),* Seville, Spain, Nov 16–20, 2015. Valencia, Spain: IATED Academy.

Nguyen, L.Q. (2022) Learners' satisfaction of courses on Coursera as a massive open online course platform: A case study. *Frontiers in Education* 7:1086170. https://doi.org/10.3389/feduc.2022.1086170.

Papadimitriou, A. (2023). Adaptive and Intelligent MOOCs: How They Contribute to the Improvement of the MOOCs' Effectiveness. *International Journal of Research in E-Learning*, *9*(1), 1–21. https://doi.org/10.31261/IJREL.2023.9.1.01.

Smyrnova-Trybulska, E., Morze, N. & Varchenko-Trotzenko, L. (2015). MOOCS – selected social and educational aspects. In Hruby, M. (Ed.), *Distance learning, simulation and communication 2015. Proceedings (Selected papers)* (pp. 127–134). University of Defence. Brno. https://dlsc.unob.cz/data/Proceedings%20of%20the%20DLSC%202015%20conference.pdf.

Smyrnova–Trybulska, E., Morze, N., Yakovleva, O., Issa, Tomayess & Issa, Theodore (2017). Some methodological aspects of MOOCs developing. In Smyrnova-Trybulska, E. (Ed.), *Effective development of teachers' skills in the area of ICT* (pp. 139–158). Serie on *E-learning*, 9. Studio Noa for University of Silesia. https://us.edu.pl/wydzial/wsne/wp-content/uploads/sites/20/Nieprzypisane/Effective-Development-of-Teachers%E2%80%99-Skills-in-the-Area-of-ICT-and-E-learning.pdf.pdf.

Smyrnova–Trybulska, E., Ogrodzka-Mazur, E., Szafrańska-Gajdzica, A., Morze, N., Makhachashvili, R., Noskova, T., Pavlova, T., Yakovleva, O., Issa, Tomayess, & Issa, Theodora (2016). MOOCs – theoretical and practical aspects: comparison of selected research results: Poland, Russia, Ukraine, and Australia. *Proceedings of the International Conferences on Internet Technologies & Society 2016 (ITS 2016)*, *International Conference Educational Technologies 2016 (ICEduTech 2016)*, and *Sustainability, Technology and Education 2016 (STE 2016)* (pp. 107–114). P. Kommers, T. Issa, T. Issa, E. McKay, P. Isaías, Eds. Melbourne, Australia 6–8 December, 2016. https://files.eric.ed.gov/fulltext/ED571589.pdf.

Smyrnova-Trybulska, E., Sekret, I., & Morze, N. (2021). Preliminary Analysis of the Development and Implementation of the MOOC Project: A Case Study. In Smyrnova-Trybulska, E. (Ed.), *E-learning in the Time of COVID-19* (pp. 137–150). Serie on *E-learning*, Vol. 13. Studio Noa for University of Silesia. https://doi.org/10.34916/el.2021.13.12.

Smyrnova-Trybulska, E., Sekret, I., Morze, N., & McKay, E. (2022). Evaluation of the MOOCs quality and its effectiveness for teachers' training in the field of digital competences and their use ineEducation: A case study. *International Journal of Research in E-Learning*, *8*(1) 1–34. https://journals.us.edu.pl/index.php/IJREL/article/view/13794.

Smyrnova-Trybulska, E., Sekret, I., Morze, N., & McKay, E. (2022). Evaluation of the MOOCs Quality and Its Effectiveness for Teachers' Training in the Field of Digital Competences and Their Use in Education: A Case Study. *International Journal of Research in E-Learning*, *8*(1), 1–34. https://doi.org/10.31261/IJREL.2022.8.1.03.

Veletsianos, G., & Shepherdson, P. (2016). A Systematic Analysis and Synthesis of the Empirical MOOC Literature Published in 2013–2015. *The International Review of Research in Open and Distributed Learning*, *17*(2). https://doi.org/10.19173/irrodl.v17i2.2448.

Wang, R., Cao, J., Xu, Y., & Li, Y. (2022) Learning Engagement In Massive Open Online Courses: A Systematic Review. *Frontiers in Education* 7: 1074435. https://doi.org/10.3389/feduc.2022.1074435.

Zhu, M., Bonk, C. J., Berri, S. (2022). Fostering self-directed learning in MOOCs: Motivation, learning strategies, and instruction. *Online Learning,* 26(1), 153–173. https://doi.org/10.24059/olj.v26i1.2629.

Zhu, M., Sari, A. & Lee, M.M. (2018). A systematic review of research methods and topics of the empirical MOOC literature (2014–2016). *Internet and Higher Education, 37*(1), 31–39. Elsevier Ltd. Retrieved July 9, 2023 from https://www.learntechlib.org/p/199200/.

Zhu, M., Sari, A.R. & Lee, M.M. (2020). A comprehensive systematic review of MOOC research: Research techniques, topics, and trends from 2009 to 2019. *Education Technology Research and Development,* 68, 1685–1710. https://doi.org/10.1007/s11423-020-09798-x.

Małgorzata Przybyła-Kasperek, Kornel Chromiński, Eugenia Smyrnova-Trybulska, Nataliia Morze, Ainur Bazarbayeva

Znaczenie, popularność i elementy platform edukacyjnych – badanie opinii studentów z Polski, Ukrainy i Kazachstanu

S t r e s z c z e n i e

W artykule zaprezentowano analizę porównawczą wyników międzynarodowych badań, dotyczących opinii studentów informatyki z Polski, Ukrainy i Kazachstanu na temat znaczenia, popularności i elementów platform edukacyjnych. Zastosowano statystyczny test Kruskala-Wallisa. Otrzymano odpowiedzi na pytania badawcze: : RQ1: Które platformy edukacyjne, ogólnie i ściśle rzecz biorąc, są najbardziej popularne wśród studentów z Polski, Ukrainy i Kazachstanu? RQ2: Jakie tematy są najczęściej wyszukiwane na platformach edukacyjnych i co motywuje studentów z Polski, Ukrainy i Kazachstanu do angażowania się w naukę za pośrednictwem platform edukacyjnych? RQ3: Jak uczniowie z Polski, Ukrainy i Kazachstanu oceniają przydatność różnych rodzajów treści publikowanych na platformach edukacyjnych i czy używają różnych platform do udostępniania swojego kodu? RQ4: Jak studenci z Polski, Ukrainy i Kazachstanu oceniają elementy kursów na platformach edukacyjnych, które uważają za najważniejsze lub najbardziej przydatne? RQ5: Jak studenci z Polski, Ukrainy i Kazachstanu oceniają wartość kursów oferowanych na platformach edukacyjnych. Zaproponowano pięć hipotez: Kraj pochodzenia nie wpływa na częstotliwość korzystania z platform edukacyjnych. Kraj pochodzenia wpływa na tematy kursów, którymi studenci są zainteresowani na platformach edukacyjnych. Kraj pochodzenia nie wpływa na motywację do uczestnictwa w kursach na platformach edukacyjnych. Kraj pochodzenia nie wpływa na ocenę elementów kursów na platformach edukacyjnych, które studenci uważają za najważniejsze lub najbardziej przydatne. Kraj pochodzenia wpływa na ocenę wartości kursów oferowanych na platformach edukacyjnych. Najpopularniejszymi tematami na platformach edukacyjnych są programowanie i sieci komputerowe, natomiast studentów z Kazachstanu bardzo interesują także tematy związane ze sztuczną inteligencją i grafiką komputerową. Dodatkowo przeanalizowano warunki kształcenia i nauczania modułów specjalistycznych na każdej uczelni, m.in. wymagania nauczycieli, programy nauczania, możliwość praktycznego wdrożenia nowej wiedzy przez studentów. Również analizowano elementy zajęć, które

są dla studentów najbardziej istotne, m.in. nagrania wideo wykładów, filmy instruktażowe, zadania praktyczne i rozwiązania zadań. Na zakończenie artykułu przedstawiono dyskusję i wnioski.

S ł o w a k l u c z o w e: Platformy edukacyjne, Opinia studentów, Tutoriale, Ćwiczenia praktyczne, Kwestionariusz, Test Kruskala-Wallisa

Małgorzata Przybyła-Kasperek, Kornel Chromiński, Eugenia Smyrnova-Trybulska, Nataliia Morze, Ainur Bazarbayeva

Importancia, popularidad y elementos de las plataformas educativas: estudio de las opiniones de estudiantes de Polonia, Ucrania y Kazajstán

R e s u m e n

El artículo presenta un análisis comparativo de los resultados de una investigación internacional sobre las opiniones de estudiantes de informática de Polonia, Ucrania y Kazajstán sobre la importancia, la popularidad y los elementos de las plataformas educativas. Se utilizó la prueba estadística de Kruskal-Wallis. Se respondieron las siguientes preguntas de investigación: RQ1: ¿Qué plataformas educativas, en general, son las más populares entre los estudiantes de Polonia, Ucrania y Kazajstán y qué plataformas específicas? RQ2: ¿Qué temas se buscan con más frecuencia en las plataformas educativas y qué motiva a los estudiantes de Polonia, Ucrania y Kazajstán a participar en el aprendizaje a través de plataformas educativas? RQ3: ¿Cómo evalúan los estudiantes de Polonia, Ucrania y Kazajstán la utilidad de los diferentes tipos de contenidos publicados en las plataformas educativas, y utilizan varias plataformas para compartir su código? RQ4: ¿Cómo evalúan los estudiantes de Polonia, Ucrania y Kazajstán los elementos de los cursos de las plataformas educativas que consideran más importantes o útiles? RQ5: Cómo evalúan los estudiantes de Polonia, Ucrania y Kazajstán el valor de los cursos ofrecidos en plataformas educativas. Se proponen cinco hipótesis: El país de origen no afecta a la frecuencia de uso de las plataformas educativas. El país de origen afecta a los temas de los cursos que interesan a los estudiantes en las plataformas educativas. El país de origen no afecta a la motivación para realizar cursos en plataformas educativas. El país de origen no afecta a la evaluación de los elementos de los cursos en plataformas educativas que los estudiantes consideran más importantes o útiles. El país de origen afecta a la evaluación del valor de los cursos ofrecidos en las plataformas educativas. Otra hipótesis es que el país de origen de un estudiante influye en los temas de los cursos que les interesan en las plataformas educativas. Los temas más populares en las plataformas educativas son la programación y las redes informáticas, mientras que los estudiantes de Kazajstán también están muy interesados en temas relacionados con la inteligencia artificial y los gráficos por ordenador. Además, se analizaron las condiciones de educación y enseñanza de módulos especializados en cada universidad, p.e. Requisitos de los profesores, planes de estudio, posibilidad de implementación práctica de nuevos conocimientos por parte de los estudiantes. Además, aquellos elementos del curso que son más importantes para los estudiantes, p.e. Se analizaron grabaciones de vídeo de conferencias, vídeos instructivos/instructivos, tareas prácticas y soluciones de tareas. Al final del artículo se presenta una discusión y conclusiones.

P a l a b r a s c l a v e: Plataformas educativas, Opinión de los estudiantes, Tutoriales, Tarea práctica, Cuestionario, Pruebas de Kruskal-Wallis

Малгожата Пшибыла-Касперек, Корнел Хроминский, Евгения Смирнова-Трыбульска, Наталья Морзе, Айнур Базарбаева

Важность, популярность и элементы образовательных платформ - исследование мнений студентов из Польши, Украины и Казахстана

Аннотация

В статье представлен сравнительный анализ результатов международного исследования мнений студентов-компьютерщиков из Польши, Украины и Казахстана о важности, популярности и элементах образовательных платформ. Использовался статистический критерий Краскела-Уоллиса. Были даны ответы на следующие вопросы исследования: RQ1: Какие образовательные платформы в целом наиболее популярны среди студентов из Польши, Украины и Казахстана и какие конкретно? RQ2: Какие темы чаще всего ищут на образовательных платформах и что мотивирует студентов из Польши, Украины и Казахстана участвовать в обучении с помощью образовательных платформ? RQ3: Как студенты из Польши, Украины и Казахстана оценивают полезность различных типов контента, размещенного на образовательных платформах, и используют ли они различные платформы для обмена кодом? RQ4: Как студенты из Польши, Украины и Казахстана оценивают те элементы курсов на образовательных платформах, которые они считают наиболее важными или полезными. RQ5: Как студенты из Польши, Украины и Казахстана оценивают ценность курсов, предлагаемых на образовательных платформах. Предлагается пять гипотез: Страна происхождения не влияет на частоту использования образовательных платформ. Страна происхождения влияет на тематику курсов, которые интересуют студентов на образовательных платформах. Страна происхождения не влияет на мотивацию к изучению курсов на образовательных платформах. Страна происхождения не влияет на оценку элементов курсов на образовательных платформах, которые студенты считают наиболее важными или полезными. Страна происхождения влияет на оценку ценности курсов, предлагаемых на образовательных платформах. Другая гипотеза заключается в том, что страна происхождения студента влияет на темы курсов, которые интересуют студентов на образовательных платформах. Самыми популярными темами на образовательных платформах являются программирование и компьютерные сети, при этом студентов из Казахстана также очень интересуют темы, связанные с искусственным интеллектом и компьютерной графикой. Кроме того, были проанализированы условия образования и преподавания специализированных модулей в каждом университете, например: требования преподавателей, учебные планы, возможность практического применения студентами новых знаний. Кроме того, те элементы курса, которые наиболее важны для студентов, например, анализировались видеозаписи лекций, обучающие видеоролики, практические задания и решения задач. В конце статьи представлены обсуждение и выводы.

Ключевые слова: Образовательные платформы, Мнение студентов, Учебные пособия, Практические занятия, Анкета, Тест Крускала-Уоллиса

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Fabunmi Kazeem Olaiya
University of Ilorin, Department of Educational Technology, Nigeria
https://orcid.org/0009-0009-8911-5763

Yakubu Ibrahim Umar
Federal University of Technology Minna, Department of Industrial and Technology Education, Nigeria
https://orcid.org/0009-0004-7133-5649

Assessing the Awareness and Perception of Open Educational Resources (OER) among Nigerian University Students: A Case Study

Abstract

This study investigated Nigerian university students' awareness and how this influences their perception and use of Open Educational Resources (OER). The study adopted a descriptive method of quantitative research. 4 research questions were developed and answered and a hypothesis was also tested to determine the relationship between students' awareness of and their perceptions of OER. Percentage, frequency, mean, standard deviation and t-test were used for the analysis. A correlation coefficient was employed to test the hypothesis. The findings of the study were: Nigeria university students have a high level of awareness of OER; the most popular OER among the Nigeria university students were Coursera, EdX, and OpenStax; OER are generally well-perceived by Nigerian university students; lack of digital literacy skills and lack of adequate knowledge to determine the quality assurance of OER are the only challenges hindering the effective use of OER among the students, and there is a significant relationship between awareness and the perception of OER by the students. The study concluded that the majority of Nigerian university students are familiar with OER and have positive perceptions of OER. The research recommends that educational institutions provide training on digital literacy skills for students to access and effectively use these OER. Also,

efforts should be made to improve the quality assurance mechanisms for OER, including the involvement of educational experts in reviewing and curating OER materials. Lastly, universities, lecturers and librarians should continue to promote OER usage in teaching and learning activities to promote its adoption.

K e y w o r d s: Open Educational Resources (OER), Technology Adoption, Awareness, Perception, University Students

Introduction

Among the major problems being faced today in education are the low availability of good quality educational materials and the increasing cost of access to those materials in many locations. The widespread availability of internet access has opened up new possibilities for accessing educational content and resources. The study by Colvard, Watson, and Park (2018), revealed that "Online platforms, digital libraries, and learning management systems have become integral components of educational institutions, providing students with unprecedented access to a vast array of educational materials. The internet enables easy dissemination of information, facilitates collaborative learning, and promotes self-directed learning opportunities (Raja & Nagasubramani, 2018). The integration of Internet technology into the educational system has revolutionized the way students access and interact with educational resources (Emeka & Nyeche, 2016). One significant development in this regard is the emergence of Open Educational Resources (OER).

There are numerous attempts to define the concept of Open Educational Resources (OER). UNESCO (2015) defined OER as teaching, learning, and research materials in any medium, digital or otherwise, that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation, and redistribution by others with no or limited restrictions. According to Wiley and Hilton Iii, (2018), "OER are freely accessible and openly licensed educational materials that can be used, shared, and modified by educators and learners". These resources encompass a wide range of content, including textbooks, lecture notes, multimedia materials, and interactive learning modules. A definition of OER should highlight that a license should be as open as possible and that anyone can access, repurpose or adapt the resources.

The adoption of OER holds immense potential for enhancing the user experience and improving access to educational resources, particularly among university students in Nigeria. Open Educational Resources have provided students with new chances to overcome the restrictions of printed materials in terms of time and location. OER are educational materials that are freely available and openly licensed,

allowing users to access, use, adapt, and redistribute them without legal or financial barriers. OER encompass various formats, including textbooks, lecture notes, courseware, simulations, and multimedia resources (Zimmermann, Mayweg-Paus, Ruwe, & Maine, 2023).

Colvard, et al., (2018) pointed out that Open Educational Resources play a crucial role in the educational system by fostering accessibility, affordability, and inclusivity. Analyzing their findings, the adoption of OER provides several key benefits. Firstly, OER can significantly reduce the financial burden on students, as they can access high-quality learning materials for free or at a much lower cost compared to traditional textbooks. The affordability aspect makes education more accessible to students from economically disadvantaged backgrounds. Open educational resources promote inclusivity by providing educational resources in multiple languages and accommodating diverse learning styles. Open licensing allows educators to adapt and customize the materials to suit the specific needs of their students, thereby enhancing the relevance and effectiveness of the learning experience. Additionally, OER facilitate the sharing of best practices, enabling educators to learn from one another and collaboratively develop educational content (Cheung, Wong, & Li, 2023).

Massachusetts Institute of Technology (MIT), in 2001, made all of its courses available on the Internet for free. As the number of institutions adopting free or Open Courseware (OCW) keeps increasing, UNESCO in the year 2002 held the inaugural Global Open Educational Resources Forum where the term "OER" was coined. The forum emphasized the importance of OER in increasing access to education, particularly in developing nations. The outcome of this Forum has made many institutions and organizations around the world start providing open access to their courseware (Umar, Kodhandarama, & Kanwar, 2013). Today, OER have become a medium for increasing global access to high-quality educational content by making high-quality courses and materials freely available online (Ofoegbu, Asogwa, & Ogbonna, 2021). OER is a concept that intends to bridge the educational gap by making high-quality learning resources available for free. OER can be utilized to improve higher education quality and give more people the opportunity to get higher education at a lower cost (Raja & Nagasubramani, 2018).

Several Nigerian educational institutions have made commendable efforts to embrace OER and incorporate them into their teaching and learning practices. For instance, Ahmadu Bello University (ABU) has developed an OER repository that provides open access to a wide range of learning resources, including lecture notes, past examination questions, and course materials. This initiative has not only enhanced access to quality educational resources but also encouraged collaborative content creation among ABU faculty members (Ikegulu & Oranusi, 2014). The study of Agbu, Mulder, De Vries, Tenebe, and Caine (2016), also supported that the National Open University of Nigeria (NOUN) has been a pioneer in OER adoption. NOUN has developed its own OER platform, called the NOUN OER Repository,

which houses a diverse collection of learning materials for various disciplines. This initiative has enabled NOUN students to access up-to-date resources and engage in self-directed learning, thereby enriching their educational experience.

Despite the potential benefits of OER, several challenges hinder its widespread awareness and usage in Nigerian educational institutions. Firstly, limited internet access and unreliable connectivity pose significant obstacles to the effective utilization of OER. Inadequate infrastructure and insufficient internet penetration in certain regions of Nigeria restrict students' ability to access online educational resources consistently (Zaid & Alabi, 2021). Secondly, a lack of awareness and understanding among educators and students about OER limits their adoption. Many educators are unfamiliar with the concept of OER and the benefits they offer. Consequently, they may be hesitant to explore and integrate OER into their teaching practices. Students, on the other hand, may not be aware of the existence of OER or how to locate and effectively utilize these resources (Gambo & Sani, 2017). Also, the absence of institutional policies and support systems for OER integration hampers their adoption. The lack of clear guidelines and incentives for educators to create and share OER contributes to the limited availability of open educational resources. Additionally, the absence of a sustainable funding model for OER initiatives poses challenges to their scalability and long-term viability (Zaid & Alabi, 2021).

To enhance the usability and uptake of OER in Nigerian universities, several strategies can be employed. Firstly, it is essential to raise awareness and build capacity among educators and students regarding OER. Training programs, workshops, and professional development sessions can be organized to educate stakeholders about the benefits of OER, how to find and evaluate open educational resources, and how to integrate them effectively into teaching and learning practices. Secondly, establishing institutional policies and support structures for OER integration is crucial. Nigerian universities should develop guidelines and frameworks that encourage educators to create, adapt, and share OER. Recognizing and rewarding faculty members for their contributions to open education can incentivize their engagement with OER initiatives. Collaborative platforms and communities of practice can be established to facilitate the sharing of OER and foster a culture of collaboration and innovation among educators.

Thirdly, addressing the infrastructure challenges related to internet access and connectivity is essential. Nigerian universities should invest in improving internet infrastructure and providing reliable and affordable internet access to students and educators. Efforts should be made to bridge the digital divide and ensure equitable access to educational resources, particularly in underserved areas (Tlili, et al., 2022).

Statement of the Problem

The utilization of Open Educational Resources (OER) in Nigerian universities has gained attention as a potential solution to challenges such as limited access to quality educational materials and the high costs of traditional textbooks for anybody who wants to study. Oluwayimika and Idoghor (2023) stated that "Students still continue to struggle with using online learning and research platforms to address and respond to their research demands. This could be due to a lack of user-friendliness of the platforms. And users will not utilize a site if it is difficult to obtain its material (Okwu, Ogunbodede, & Suleiman, 2023). So, the accessibility of OER platforms is one of the most important factors to determine their adoption by users. Hence, the user experience and perception of OER among Nigerian university students remain largely unexplored, which is what this study aims to investigate, by examining the factors influencing their usage patterns, perceptions, and barriers.

The Objective of the Study

The main purpose of this study was to examine the awareness and perception of OER among Nigerian university students. Precisely, this study:

1. Assessed the level of awareness of OER and the most commonly used Open Educational Resources (OER) among Nigerian university students;
2. Investigated how the students perceive OER; and lastly
3. Examined the challenges of using OER among Nigerian university students.

Literature Review

The perception of any technology is primarily influenced by the level of information available at a time about the technology and the simplicity with which it could be used. Open Educational Resources (OER) are digital educational materials that can be used by both teachers and their students freely. These resources include classroom activities, quizzes, textbooks, multimedia applications, and course models (Wiley et al., 2018). As established in the study of Fabunmi and Onasanya (2023), that teachers' attitudes towards any learning-enhance technology have a significant effect on how the students would perceive the technology. This, therefore, means that teachers are one of the influential factors in the adoption of technology for teaching and learning in our institutions. The adoption of OER in higher institutions is becoming increasingly important, as resources have the potential to save costs, enhance teaching and learning experiences, promote collaboration among educators, and support professional development (Wiley et al., 2018).

The study conducted on the use of OER by Nagaiah and Thanuskodi (2021), has revealed that most students at Alagappa University in India were aware of OER and use them for educational purposes. In the African context, the findings of Oppong and Maluleka (2022) on the evaluation of users' awareness and use of research assistance platforms among undergraduates at Kumasi Technical University in Ghana showed that most of the students were unaware of the university's online library research help platforms. Most students were unable to identify the online library research help platforms they had lately used in the university library or elsewhere. The results also showed that undergraduate students found the research platforms difficult to use. The study, therefore, recommended that the University library should adopt awareness strategies that inform the students of the existence and benefits of this library research assistant and to employ a user-friendly platform.

Similarly, Wiche and Ogunbodede's (2021) study on awareness and use of OER by library and information science students at the Ignatius Ajuru University of Education in Rivers State here in Nigeria revealed that students have a high degree of awareness of OER and a high level of use of various forms of OER. But the study pointed out information literacy skills, insufficient electrical supply, bad internet access, lack of library sensitization, and lack of support from lecturers on the usage of OER as the major barriers to the effective usage of OER. And basically, it suggested that. school administration should organize digital literacy skills training for students. In contrast, Itasanmi (2020) examined the OER awareness and their usage among open and distance learning students in southwestern Nigeria. The results of the findings showed that though the students use OER often, except that their general knowledge of the repositories was limited. The participants had a positive perception of OER in general, and they profited from using the materials in a variety of ways.

In terms of the benefits of OER, Pounds and Bostock (2019), opined that OER have the potential to increase teaching efficiency, improve the quality of teaching, and reduce economic and geographic barriers to quality education. However, there are also challenges and hindrances to the access and use of OER, these include low awareness, copyright policies, mistrust in OER quality, and technological limitations (Pounds & Bostock, 2019).

No doubt that some of the reviewed studies are similar to this present study because some of them examined OER, usage, usability level, and the challenges in the use of OER among undergraduate students. However, the researchers identified some aspects of these studies that were different from the previous studies. For instance, none of the studies proved statistically the relationship that exists between awareness and perception of OER. Hence, this study intends to fill this gap as it will prove statistically the relationship that exists between awareness and perception of OER among Nigerian undergraduate students.

Methodology

This research was a descriptive method of quantitative research. A total of 30 students from the Faculty of Education of the University of Abuja were randomly sampled to participate in the study. The 30 students, representing 30% of the total population of 100 students considered for the study were chosen using a simple random sampling procedure. This study's sample size was determined using the Taro Yamane sample model. The instrument used to collect data was a questionnaire. Experts in educational technology evaluated the questionnaire.

The questionnaire was tested for reliability on ten (10) randomly selected students from the Faculty of Law of the same university, using an independent sampling technique as it allows for the selection of samples from the same population to be used for the study for pilot testing. The Faculty of Law of the university was selected as it is not the one targeted for the study. The data gathered from the pilot study was analyzed to check for internal consistency of reliability and the Cronbach alpha value of 0.98 was obtained. So, the questionnaire was deemed credible based on the coefficient obtained.

Data were collected using a researcher-designed questionnaire titled "Assessing the Awareness and Perception of OER among Nigerian University Students (AAPOER). It was divided into two parts. Part A elicited demographic information from the respondents while Part B sought information based on university students' awareness and use of OER. The response to each of the items was weighted on a 4-point Likert-type scoring scale. Strongly Agree (SA) = 4 points, Agree (A) = 3 points, Disagree (D) = 2 points and Strongly Disagree (SD) = 1 point. From the scale, a criterion score of 2.5 was adopted. The 2.5 Criterion score was arrived at as thus: (4+3+2+1) /4 = 2.5. So, items that have a mean score greater than or equal to the criterion score of 2.5 were accepted while the items below 2.5 were not accepted. The data collected were analysed using descriptive statistics (frequency counts, percentages, and mean), while a correlation coefficient was used to test the hypothesis.

Research Questions

The following research questions were set to guide the study:

1. What is the student's level of awareness of OER?
2. What are the most commonly used Open Educational Resources (OER) among Nigerian university students?
3. How do Nigerian university students perceive the quality and usefulness of OER in their learning experience?
4. What are the challenges being faced by Nigerian university students when accessing and using OER?

Hypothesis

There is no significant relationship between the awareness and perception of OER among Nigerian university students.

Data analysis

The data collected were coded, edited, and analysed. Descriptive statistics was the statistical tool used for analysing the data. In order to get the position of the respondents on the items that were given, frequency counts and percentages were used to analyse research question 2 while mean and standard deviation were used for the analysis of research questions 1, 3 and 4. The null hypothesis was tested by the Pearson Product – Moment Correlation Coefficient using Excel. The results are presented and discussed in the subsequent sections.

Analyses Regarding Research Questions and Hypothesis

Analysis of the background data of the respondents is presented in Table 1 below:

Table 1
Demographic Characteristics of Respondents

Gender of the Respondents	Frequency	Percentage (%)
Male	23	76.7
Female	7	23.3
Total	**30**	**100**

S o u r c e: Own work.

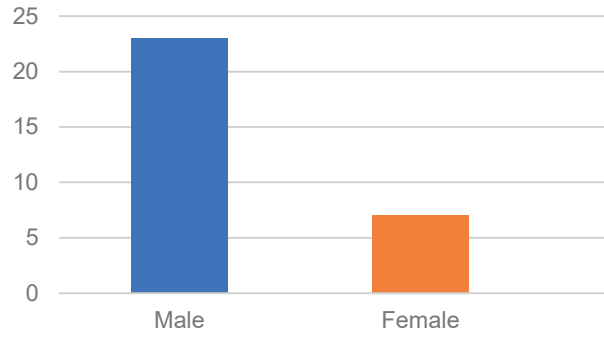

Figure 1. Demographic Characteristics of Respondents

S o u r c e: Own work.

Table 1 with figure 1 shows that 23(76.7%) of the students were male while 7(23.3%) were female. This implies that the majority of the students under study were male.

The findings of the study are presented in the following tables with explanations.

Research Question 1: **What is your level of awareness of open educational resources?**

The first research question sought to investigate the level of students' awareness of OER. The results are presented in Table 2.

Table 2
Student's Level of Awareness

S/N	Awareness of OER	S A	A	D	S D	Mean	S.D.	Remark
1.	I am aware of open educational resources	16	12	1	1	3.4	0.61	High-Level Awareness
2.	I am aware that OER provides quality free materials for learning and research.	15	12	2	1	3.4	0.64	High-Level Awareness
3.	I am aware that open educational resources are in online/electronic format	17	12	1	0	3.5	0.58	High-Level Awareness
4.	I am aware that open educational resources are readily available for teaching, learning, and research.	15	13	2	0	3.4	0.61	High-Level Awareness
5.	I am aware that anyone can legally and freely copy, adapt and re-share OER.	13	14	2	1	3.3	0.69	High-Level Awareness
	Grand Mean					3.4	0.63	

S o u r c e: Own work.

Table 2 shows the student's level of awareness of OER. All the items in Table 2 have mean values that are above the criterion mean of (2.5); also, the grand mean (3.4) is greater than the criterion mean (2.5). This shows that the students have a high level of awareness of OER.

One-sample t-test was conducted to determine if the sample mean, based on a sample size of 30, a population mean of 3.512, a sample mean of 3.4, and a sample standard deviation of 0.63, is significantly different from the population mean. The calculated t-value was approximately -0.974. When comparing this to the critical t-value at a 0.05 significance level with 29 degrees of freedom, the absolute value of the t-value was found to be less than the critical t-value ($|-0.974| \leq 2.045$). As such, there is insufficient evidence to reject the null hypothesis. Therefore, it

is concluded that the sample mean awareness of OER is not significantly different from the overall population mean awareness at 0.05 level of significant.

Research Question 2: **What are the most commonly used Open Educational Resources (OER) among Nigerian university students?**

The second research question sought to find out the mostly used OER among Nigerian students. The results are presented in Table 3.

Table 3
Most commonly used Open Educational Resources (OER) among Nigerian university students

OER	Frequency	Percentage (%)
OER Commons	9	30.02
OpenStax	6	20.00
Coursera	5	16.66
Khan Academy	4	13.33
MIT Open Courseware	3	10.00
EdX	2	6.66
Others	1	3.33

S o u r c e: Author.

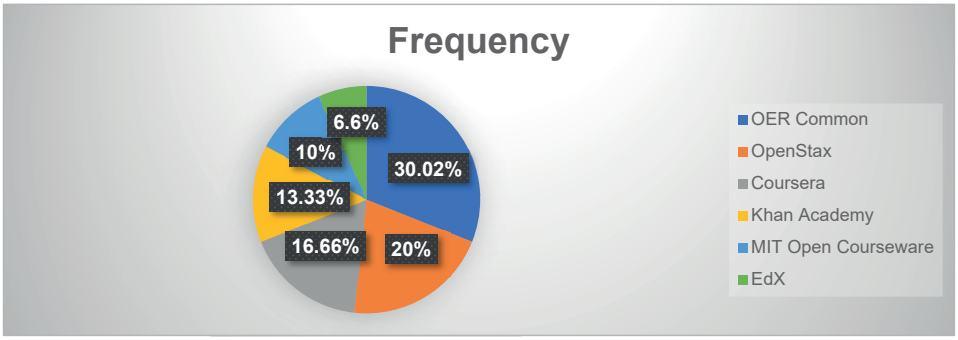

Figure 2. Most commonly used Open Educational Resources (OER) among Nigerian university students. (in percentage)

S o u r c e: Own work.

Table 3 with figure 2 shows that the most commonly used OER among the respondents were OER Common, OpenStax, and Coursera with 30.02%, 20.00% and 16.66% respectively. These three OER accounted for over 60% of the total respondents. The remaining respondents used a variety of other OER, including Khan Academy, MIT Open Courseware, edX, and other unspecified OER. The ta-

ble also revealed that the percentage of respondents who used each OER is evenly distributed. This suggests that the 30 respondents are familiar with all the OER.

Research Question 3: **How do Nigerian university students perceive the quality and usefulness of OER in their learning experience?**

The third research question sought to find out how Nigerian university students perceive the quality and usefulness of OER in their learning experience. The results are presented in Table 4.

Table 4
Perception of Nigerian university students of OER

Students' Perception of OER	S A	A	D	S D	Mean	S.D.	Remark
I find OER to be of high quality.	16	11	2	1	3.4	0.71	Well-Perceived
I find OER to be useful in my learning experience.	15	13	1	1	3.4	0.69	Well-Perceived
OER have helped me to improve my academic performance.	15	12	2	1	3.4	0.71	Well-Perceived
OER have made it easier for me to access high-quality education.	17	12	1	0	3.5	0.64	Well-Perceived
OER have helped me to save money on textbooks.	14	12	2	2	3.3	0.82	Well-Perceived
Grand Mean					3.4	0.76	

S o u r c e: Own work.

Table 4 reveals the student's perception of OER. All the items in Table 4 have mean values that are above the criterion mean of (2.5), also, the grand mean (3.4) is greater than the criterion mean (2.5), which indicates that OER are generally well-received by Nigerian university students.

To determine whether the sample mean is significantly different from the population mean, one-sample t-test was carried out. The calculated t-value of –1.44 falls within the range (–2.045<–1.44<2.045), indicating that there is not enough evidence to reject the null hypothesis. Therefore, there is no sufficient grounds to conclude that the sample mean is significantly different from the population mean at the 0.05 significance level. Hence, this analysis suggests that there is no statistically significant difference between the sample mean and the population mean. The perception of sample mean of OER is not significantly different from the overall population mean perception at 0.05 level of significant.

Research Question 4: **What challenges do Nigerian university students face when accessing and using OER?**

The fourth research question sought to investigate the potential challenges in accessing and using OER. The results are presented in Table 5.

Table 5
Challenges in the Use of OER

S/N	Challenges in using OER	S A	A	D	S D	Mean	S.D.	Remark
1.	Lack of digital literacy skills	8	16	5	1	3.0	0.80	Agree
2.	Lack of awareness of Intellectual Property Right Issues	2	3	18	7	2.0	0.75	Not Agree
3.	Lack of library/lecturer sensitization on the use of OER	2	2	18	8	1.3	0.76	Not Agree
4.	Lack of awareness of the availability of OER.	2	2	15	11	1.8	0.81	Not Agree
5.	Poor Internet connectivity	1	2	19	8	1.9	0.68	Not Agree
6.	Lack of relevant OER materials in my course of study	1	2	16	12	1.7	0.69	Not Agree
7.	Lack of adequate knowledge to evaluate OER.	11	10	5	4	2.9	0.75	Agree
	Grand Mean					2.0	0.72	

S o u r c e: Own work.

Table 5 reveals the challenges in the use of OER by the students. Items 2–6 have mean values that are lesser than the criterion mean of (2.5), and the grand mean (2.0) is also less than the criterion mean of (2.5). Item 1 and 7, have a mean value that is above the criterion mean of (2.5). This indicates that item 1, which is the lack of digital literacy skills and item 7, which is the lack of adequate knowledge to determine the quality assurance of OER, are the only challenges hindering the effective use of OER in this study.

One-Sample T-Test Analysis was carried out to determine if the sample mean is significantly different from the population mean at a 0.05 significance level. The result revealed that the calculated t-statistic (1.68) is less than the critical t-value (1.699), the null hypothesis is not rejected. This implies that there is insufficient evidence at the 0.05 significance level to conclude that the sample mean is significantly different from the population mean. Therefore, we do not have grounds to suggest a significant deviation of the sample mean from the population mean in terms of the challenges in the use of OER.

Hypothesis Testing

There is no significant relationship between the awareness and perception of OER among Nigerian university students.

Table 6
Relationship between awareness and perception of OER by students

	Awareness	Perception
Awareness	1	
Perception	0.790569415	1

S o u r c e: Own work.

Table 6 presents the relationship between awareness and the perception of OER by students. This relationship between the two factors was tested by the Pearson Product – Moment Correlation Coefficient using program spreadsheet application of Excel. The calculated correlation coefficient between awareness and perception was 0.790569415. A t-test was conducted to determine the statistical significance of this correlation coefficient. The test statistic was found to be 2.058, which is greater than the critical value of 1.833 at a significance level of 0.05. Therefore, the null hypothesis was rejected which means that the correlation coefficient is statistically significant.

Hence, there is a significant relationship between awareness and the perception of OER by students of Nigerian universities. This implies that when Awareness goes up, Perception tends to rise as well.

Discussion

This study assessed the level of awareness and perception of OER among Nigerian university students. This seeks to check their perception of OER and the mostly used OER among the students. The analysed data revealed that Nigerian university students are highly aware of OER. This is reflected in the grand mean score of 3.4. This finding conforms with the finding of Nagaiah & Thanuskodi (2021), that the majority of students are aware of OER. The high level of awareness could be attributed to the high cost of textbooks and other physical learning materials. This could also be due to several OER promotion campaigns and workshops across the Nigerian universities. It will be recalled that since MIT announced its Open Courseware Program in 2001, OER have gradually become popular in higher institutions of learning.

The results of this study also revealed the most popular OER among Nigerian university students. Analysis of the data collected shows that OER Commons, OpenStax, and Coursera were the most used OER with 30.02%, 20.00% and 16.66% respectively. These three OER accounted for over 60% of the total respondents. This finding is in support of the study of Hew and Cheung (2013) in

which it was reported that different types of OER were accessed by the respondents of which video resources were the most frequently used. This is also in line with the study of Harsasi (2015) in which some students responded that by watching the video, they can see the examples of a topic they are studying in a real case. The students responded that watching videos while learning a topic, is more attractive, and avoids boredom, rather than only reading a text.

From the analyzed data, it was revealed that OER were positively perceived by the students as having the capacity to improve their learning experience. This can be attributed to the fact that OER are of high quality, OER could be used to access qualitative education and can enhance the learning experience, among other factors. This confirms the findings of the study by Harsasi (2015), which opined that the use of OER is perceived by students as something interesting because it's new for them and can help them to have a better understanding of a topic.

The only challenges to effective use of OER as revealed in this study are lack of digital literacy skills and the lack of adequate knowledge to determine the quality assurance of OER. This finding is in agreement with the findings of Hylén (2020), who also found that among other major challenges to the effective use of OER is a lack of internet search skills and time to look for suitable resources.

Finally, the hypothesis test reveals that there is a significant relationship between awareness and perception of OER among Nigerian university students. The level of awareness of OER among the students will help shape their perceptions about it. This study supports the findings of Manzo & Kannan (2020), who opined that students' perception and use of e-resources are highly influenced by students' awareness of them.

Conclusion and Recommendations

The increasing rise of OER awareness is helping to reposition educational offerings in higher institutions around the world, most especially in underdeveloped countries where access to high-quality educational materials is capital-intensive. Nigerian university students are highly aware of OER as revealed in this study and that the only challenges to the effective use of OER are a lack of digital literacy skills coupled with a lack of required skills to determine the quality assurance of OER. There is also an indication that OER are generally well-perceived by Nigerian university students. The students find OER to be of high quality, useful, and helpful in their learning experience. OER have also helped students to save money and improve their academic performance.

The hypothesis test reveals that there is a significant relationship between the students' awareness of OER and their perception of them. It is therefore recom-

mended that the school administrators and librarians provide adequate training on digital literacy skills for students to effectively access and use OER. Also, efforts should be made to improve the quality assurance mechanisms for OER, including the involvement of educational experts in reviewing and curating OER materials. Again, institutions should intensify their collective and individual efforts in promoting OER usage among students to sustain its use. It is important to note that this is just a small sample of the data that could be collected on this topic. A larger study would be needed to confirm these findings and to explore other factors that may influence students' perceptions and use of OER.

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References

Agbu, J. F., Mulder, F., De Vries, F., Tenebe, V. & Caine, A. (2016). The best of two open worlds at the National Open University of Nigeria. *Open Praxis, 8*(2), 111–121. https://doi.org/10.5944/openpraxis.8.2.279.

Cheung, S., Wong, B. & Li, K. (2023). Perceived usefulness of open educational resources: Impact of switching to online learning for face-to-face and distance learners. *Frontiers in Psychology*, 13. https://doi.org/10.3389/fpsyg.2022.1004459.

Colvard, N. B., Watson, C. E. & & Park, H. ((2018). The impact of open educational resources on various student success metrics. *International Journal of Teaching and Learning in Higher Education, 30*(2), 262–276. https://www.oer.iastate.edu/files/inline-files/IJTLHE3386.pdf.

Emeka, U. J. & Nyeche, O. S. (2016). Impact of Internet usage on the academic performance of undergraduates students: A case study of the University of Abuja, Nigeria. *International Journal of Scientific & Engineering Research, 7*(10), 1018–1029. https://www.ijser.org/researchpaper/Impact-of-Internet-Usage-on-the-Academic-Performance-of-Undergraduates-Students--A-case-study-of-the-University-of-Abuja--Nigeria.pdf.

Fabunmi, K. O. & Samuel, O. A. (2023). Psychology of Learning Relating to Assessment Using Technology in Schools: A Prognostic Discourse. *Pedagogia, 21*(2). https://ejournal.upi.edu/index.php/pedagogia/article/view/60755/pdf.

Gambo, R. D. & Sani, M. A. (2017). Use of open educational resources and print educational materials by Federal College of Education Katsina, Nigeria: A study. *DESIDOC Journal of Library & Information Technology, 37*(6), 437. https://doi.org/10.14429/djlit.37.10628.

Harsasi, M. (2015). The use of open educational resources in online learning: A study of students' perception. *Turkish Online Journal of Distance Education, 16*(3), 74–87. https://doi.org/10.17718/tojde.46469.

Hew, K. F. & Cheung, W. S. (2013). *Use and Production of Open Educational Resources (OER): A Pilot Study of Undergraduate Students' Perceptions.* International Association for the Development of the Information Society. https://files.eric.ed.gov/fulltext/ED557188.pdf.

Hylén, J. (2020). Open educational resources: Opportunities and challenges. https://www.oecd.org/education/ceri/37351085.pdf.

Ikegulu, B. & Oranusi, S. (2014). Distance and open learning in Nigeria: Progress, concerns and prospects. *Journal of Education and Practice, 5*(35), 167–171. https://www.iiste.org/Journals/index.php/JEP/article/view/17699/18080.

Itasanmi, S. A. (2020). OER awareness and usage among open and distance learning students in South-Western Nigeria. *International Journal of Indonesian Education and Teaching (IJIET), 4*(2), 343–357. https://e-journal.usd.ac.id/index.php/IJIET/article/view/2643.

Manzo, B. S. & Kannan, S. (2020). Use of social networking site by students of hassan usman katsina polytechnic. *IOSR Journal of Research & Method in Education, 10*(5), 24–31. https://doi.org/10.9790/7388-1005062431.

Nagaiah, M. & Thanuskodi, S. (2021). Utilization of open educational resources among college students affiliated to Alagappa university in India. *Linguistics and Culture Review, 5*(S3), 1384–1399. https://doi.org/10.21744/lingcure.v5nS3.1822.

Ofoegbu, O. T., Asogwa, U. D. & Ogbonna, C. S. (2021). Open educational resources and courseware development in dual mode universities in Nigeria. *Education Tech Research Dev*. https://doi.org/10.1007/s11423-021-10014-7.

Okwu, E., Ogunbodede, K. F. & Suleiman, A. B. (2023). Faculty Perceptions of the Use of Open Educational Resources in State Universities in Bayelsa and Rivers States Nigeria. *Asian Journal of Information Science & Technology (AJIST), 13*(1), 35–40. https://doi.org/10.51983/ajist-2023.13.1.3485.

Oluwayimika, K. & Idoghor, U. (2023). Awareness and Use Of Open Educational Resources And Its Benefits To University Students. *Innovare Journal of Education, 11*(3), 32–35. https://doi.org/10.22159/ijoe.2023v11i3.47718.

Oppong, M. & Maluleka, J. R. (2022). The Use of Online Research Support Platforms among Undergraduate Students at the Kumasi Technical University in Ghana. *Journal of Library & Information Services in Distance Learning, 16*(3–4), 232–243. https://doi.org/10.1080/1533290X.2022.2104423.

Pounds, A. & Bostock, J. (2019). Open educational resources (OER) in higher education courses in aquaculture and fisheries: opportunities, barriers, and future perspectives. *Aquaculture International, 27*, 695–710. https://link.springer.com/article/10.1007/s10499-019-00355-9.

Raja, R. & Nagasubramani, P. C. (2018). Impact of modern technology in education. *Journal of Applied and Advanced Research, 3*(1), 33–35. https://doi.org/10.21839/jaar.2018.v3iS1.165.

Tlili, A., Altinay, F., Huang, R., Altinay, Z., Olivier, J., Mishra, S. & Burgos, D. (2022). Are we there yet? A systematic literature review of Open Educational Resources in Africa: A combined content and bibliometric analysis. *Plos one, 17*(1), e0262615. https://doi.org/10.1371/journal.pone.0262615.

Umar, A., Kodhandarama, B. & Kanwar, A. (2013). Can Open Educational Resources thrive in closed educational systems? Some reflections on OER in developing countries. *Commonwealth of Learning, Athabasca University*, 193–206.

UNESCO (2015). *Open educational resources.* https://www.unesco.org/en/open-educational-resources.

Wiche, H. I. & Ogunbodede, K. F. (2021). Awareness and use of open educational resources by Library and Information Science students of Ignatius Ajuru University of Education, Rivers

State, Nigeria. *Library Philosophy and Practice (e-journal)*. https://digitalcommons.unl.edu/libphilprac/5373.

Wiley, D. & Hilton Iii, J. L. (2018). Defining OER-enabled pedagogy. *The International Review of Research in Open and Distributed Learning, 19*(4). https://doi.org/10.19173/irrodl.v19i4.3601.

Zaid, Y. A. & Alabi, A. O. (2021). .Open Learning: Sustaining open educational resources (OER) initiatives in Nigerian universities. *The Journal of Open, Distance and e-Learning, 36*(2), 181–197. https://doi.org/10.1080/02680513.2020.1713738.

Zimmermann, M., Mayweg-Paus, E., Ruwe, T. & Maine, F. (2023). Teacher evaluations of open educational resources designed to support dialogic cultural literacy learning in schools. *European Journal of Open, Distance and E-Learning, 25*, 136–147. https://doi.org/10.2478/eurodl-2023-0011.

Fabunmi Kazeem Olaiya, Yakubu Ibrahim Umar

Ocena świadomości i postrzegania otwartych zasobów edukacyjnych (OER) wśród studentów nigeryjskich uniwersytetów: studium przypadku

S t r e s z c z e n i e

W badaniu tym zbadano świadomość studentów nigeryjskich uniwersytetów oraz wpływ, jaki ma to na ich postrzeganie i korzystanie z otwartych zasobów edukacyjnych (OER). W badaniu przyjęto opisową metodę badań ilościowych. Opracowano cztery pytania badawcze i udzielono na nie odpowiedzi, a także przetestowano hipotezę w celu określenia związku pomiędzy świadomością uczniów a ich postrzeganiem OER. Do analizy wykorzystano procent, częstotliwość, średnią i odchylenie standardowe. Do sprawdzenia hipotezy wykorzystano współczynnik korelacji. Wyniki badania były następujące: studenci uniwersytetów w Nigerii mają wysoki poziom świadomości na temat OER; najpopularniejszymi OER wśród studentów uniwersytetów w Nigerii były Coursera, EdX i OpenStax; OER są na ogół dobrze postrzegane przez nigeryjskich studentów; brak umiejętności korzystania z technologii cyfrowych i brak odpowiedniej wiedzy umożliwiającej określenie sposobu zapewniania jakości OER to jedyne wyzwania utrudniające skuteczne korzystanie z OER wśród studentów, przy czym istnieje znaczący związek pomiędzy świadomością a postrzeganiem OER przez studentów. Z badania wynika, że większość nigeryjskich studentów uniwersytetów zna OER i pozytywnie je postrzega. W badaniu zalecono, aby instytucje edukacyjne zapewniały studentom szkolenia w zakresie umiejętności informatycznych, umożliwiające im dostęp do OER i skuteczne korzystanie z nich. Należy także podjąć wysiłki w celu ulepszenia mechanizmów zapewniania jakości OER, w tym – zaangażowania ekspertów ds. edukacji w przeglądanie i selekcję materiałów OER. Wreszcie, uniwersytety, wykładowcy i bibliotekarze powinni w dalszym ciągu promować wykorzystanie OER w działaniach dydaktycznych i edukacyjnych, aby upowszechniać ich przyjęcie.

S ł o w a k l u c z o w e: Otwarte zasoby edukacyjne, przyjęcie technologii, świadomość, postrzeganie, studenci

Fabunmi Kazeem Olaiya, Yakubu Ibrahim Umar

Evaluación DEL conocimiento y la Percepción de los recursos educativos abiertos (REA) Entre Estudiantes Universitarios Nigerianos: un estudio de Caso

Resumen

Este estudio investigó la conciencia de los estudiantes universitarios nigerianos y cómo esto influye en su percepción y uso de los Recursos Educativos Abiertos (REA). El estudio adoptó un método descriptivo de investigación cuantitativa. Se desarrollaron y respondieron cuatro preguntas de investigación y también se probó una hipótesis para determinar la relación entre el conocimiento de los estudiantes y sus percepciones sobre los REA. Para el análisis se utilizaron porcentaje, frecuencia, media y desviación estándar. Se empleó un coeficiente de correlación para probar la hipótesis. Las conclusiones del estudio fueron: los estudiantes universitarios de Nigeria tienen un alto nivel de conocimiento de los REA; los REA más populares entre los estudiantes universitarios de Nigeria fueron Coursera, EdX y OpenStax; En general, los estudiantes universitarios nigerianos perciben bien los REA; la falta de habilidades de alfabetización digital y la falta de conocimiento adecuado para determinar el aseguramiento de la calidad de los REA son los únicos desafíos que obstaculizan el uso efectivo de los REA entre los estudiantes, y existe una relación significativa entre el conocimiento y la percepción de los REA por parte de los estudiantes. El estudio concluyó que la mayoría de los estudiantes universitarios nigerianos están familiarizados con los REA y tienen percepciones positivas de ellos. La investigación recomienda que las instituciones educativas brinden capacitación sobre habilidades de alfabetización digital para que los estudiantes accedan y utilicen efectivamente estos REA. Además, se deben hacer esfuerzos para mejorar los mecanismos de garantía de calidad de los REA, incluida la participación de expertos en educación en la revisión y curación de materiales de REA. Por último, las universidades, profesores y bibliotecarios deberían seguir promoviendo el uso de REA en actividades de enseñanza y aprendizaje para promover su adopción.

Palabras clave: Recursos Educativos Abiertos, Adopción de Tecnología, Conciencia, Percepción, Estudiantes universitarios

Фабунми Казим Олайя, Якубу Ибрагим Умар

Оценка осведомленности и восприятия открытых образовательных ресурсов (ООР) среди студентов нигерийских университетов: практический пример

Аннотация

В этом исследовании изучалась осведомленность нигерийских студентов университетов и то, как это влияет на их восприятие и использование открытых образовательных ресурсов (ООР). В исследовании принят описательный метод количественного исследования. Были сформулированы 4 исследовательских вопроса, на которые были даны ответы, а также проверена гипотеза для определения взаимосвязи между осведомленностью студентов и их восприятием ООР. Для анализа использовались процент, частота, среднее и стандартное отклонение. Для проверки гипотезы был использован коэффициент корреляции. Результаты исследования были следующими: Студенты университетов Нигерии имеют высокий уровень осведомленности об ООР; наиболее популярными ООР среди студентов университетов Нигерии были Coursera, EdX и OpenStax; ООР обычно хорошо воспринимаются студентами нигерийских

университетов; отсутствие навыков цифровой грамотности и отсутствие адекватных знаний для определения обеспечения качества ООР — единственные проблемы, препятствующие эффективному использованию ООР среди учащихся, и существует значительная взаимосвязь между осведомленностью и восприятием ООР учащимися. Исследование пришло к выводу, что большинство студентов нигерийских университетов знакомы с ООР и положительно относятся к ним. Исследование рекомендует образовательным учреждениям проводить обучение навыкам цифровой грамотности, чтобы учащиеся могли получить доступ к этим ООР и эффективно их использовать. Кроме того, следует предпринять усилия по совершенствованию механизмов обеспечения качества ООР, включая привлечение экспертов в области образования к рассмотрению и курированию материалов ООР. Наконец, университеты, преподаватели и библиотекари должны продолжать поощрять использование ООР в преподавании и учебной деятельности, чтобы способствовать их внедрению.

К л ю ч е в ы е с л о в а: открытые образовательные ресурсы, Внедрение технологий, Осведомленность, Восприятие, Студенты университета

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Artem Yurchenko
Sumy State Pedagogical University named after A. S. Makarenko, Ukraine
https://orcid.org/0000-0002-6770-186X

Volodymyr Proshkin
Borys Grinchenko Kyiv University, Ukraine
https://orcid.org/0000-0002-9785-0612

Olha Naboka
Donbas State Pedagogical University, Ukraine
https://orcid.org/0000-0003-4635-0009

Volodymyr Shamonia
Sumy State Pedagogical University named after A. S. Makarenko, Ukraine
https://orcid.org/0000-0002-3201-4090

Olena Semenikhina
Sumy State Pedagogical University named after A. S. Makarenko, Ukraine
https://orcid.org/0000-0002-3896-8151

The Use of Digital Technologies in Education: The Case of Physics Learning

Abstract

The article reveals the trends in the use of digital technologies in teaching physics by summarizing scientific results over the past 20 years. To solve the problem, a bibliographic analysis of the sources of the scientometric database of the WOS was used with the involvement of the computer tool VOSviewer (for the construction and visualization of bibliographic data) as of June 2023. The tool was used to analyse publications by keywords (a network of connections is built on the basis of all keywords of given publications). Networks of connections of keywords were built according to the queries: “physics learning”, “physics education”, “physics teaching” and “technologies”, as well as “digital technologies in teaching physics”, “physics application”, “mobile physics learning”, “virtual physics

laboratory", "digital physics laboratory", "virtual reality & physics", "augmented reality & physics". The situation of the use of digital technologies in teaching physics is characterized by four aspects (general, technological, educational-motivational, and educational-organizational). Modern trends in teaching physics are singled out: the use of environments where simulation, modelling, visualization, virtualization of physical processes, etc. are possible. The increasing popularity of virtual, augmented, and mixed reality tools; use of mobile applications for learning physics; using artificial intelligence to teach physics; organization of an educational environment based on mobile or online learning, where active learning methods are determined to be appropriate. The importance of developing young people's intellectual skills (computational skills, algorithmic thinking skills, modelling processes, etc.) and visual thinking for the successful mastery of various sections of physics has been confirmed. The demand for integration links between natural sciences, mathematics, engineering, and digital technologies for STEM education has been monitored. Recommendations for the training of physics teachers have been formulated.

K e y w o r d s: digital technologies; teaching physics; learning physics; physics education; physics teacher; teacher training; professional preparation; digital technology in education; higher education

The development of digital technologies has had a significant impact on society as a whole and on the scientific industry in particular. Computer tools are in demand in mathematics (Semenikhina et al., 2019; Astafieva et al., 2019; Semenikhina & Drushliak, 2015), computer science (Yurchenko et al., 2021), etc. Such tools can be either narrowly specialized (for solving a specific class of problems, for example, in mathematics, statistical data processing programs (for example, Statistica), or powerful universal programs that have digital tools for processing numerical data (for example, table processors like MS Excel), modelling of processes (for example, virtual laboratories like Proteus), programming of solutions of classes of applied problems (for example, programming environments like Eclipse IDE / IntelliJ IDEA or systems of computer mathematics like Maple). The types of tools used by scientists are also different; not only specialized software of the industry but also cloud services (Google Apps, Azure, Canva), mobile applications (WolframAlpha, CamScanner, Science Explorer, Graphical Analysis), digital or sensors on mobile devices (Proximity Sensor, Accelerometer, Light Sensor, Gyroscope Sensor, Vernier), etc.

Problem of Research

Learning physics is not a trivial task. This science has always been hard to understand (Hsiao et al., 2023). Awareness and assimilation of physical concepts and processes, which are not obvious, require significant intellectual efforts from students (thinking, comparing, looking for analogies, critically evaluating, etc.). Therefore, physics teachers are constantly searching for new approaches, techniques, and methods that would interest students in physics and help students master complex material (Izadi et al., 2022). Among such approaches, the digital one stands out (Jugembayeva & Murzagaliyeva, 2023). In particular, demonstration video materials of Internet resources and presentation materials that improve the visual support of physics classes are quite popular in Ukraine (Semenikhina et al., 2020), less popular is the involvement of physical guidance software. World practices of using DT (digital technologies) in teaching physics with the development of DT are also constantly changing. The use of DT is presented in numerous publications of the results of educational research, which, unfortunately, are not summarized as existing successful pedagogical experiences.

Research Focus

The purpose of the article is to characterize the situation of the use of digital technologies in teaching physics on the basis of bibliographic analysis of scientific and methodological works.

Methodology of research

General Background of Research

Publications related to the use of digital technologies in teaching physics and indexed by the Web of Science scientometric database for the years 2005–2023 became the basis of the research. The search was conducted in the Web of Science database on June 25, 2023.

Instrument and Procedures

The tools of bibliographic analysis were the Web of Science database itself and the freely distributed tool VOSviewer (https://www.cwts.nl). The tool is designed

for building and visualizing bibliographic data from various database sources (Web of Science, Scopus, Dimensions, CrossRef, Medline). The developers of the tool provided the possibility to process citations, bibliographic links, joint citations, and co-authorship. The tool was used to analyse publications by keywords (a network of connections is built on the basis of all keywords of given publications). You can limit the network by setting, in particular, a minimum number of connections. The network also breaks the words into clusters. Each cluster has a different color and consists of circles (or words) of different sizes. Size is determined by frequency. The larger the word, the more often the word is used in research (Al Husaeni & Nandiyanto, 2022). The type of analysis in VOSviewer is Co-occurrence. Analysis unit are all keywords. The selection limit (minimum number of keywords found) was determined depending on the number of found works and keywords in general. As a result of using the VOSviewer tool, networks of connections of keywords were built for various queries. Based on the identified relationships between keywords in the publications, a qualitative analysis of trends was carried out and conclusions were drawn.

The problem of the study has defined the criteria for choosing keywords belonging to the field of physics education and the field of information technology. The search was based on keywords for publications from the Web of Science database (we proceed from the fact that the authors, exploring the problem, correctly select keywords for their research). When the number of keyword meetings was relatively small (up to 100 search results), the annotations' texts were also searched since the abstract describes in more detail the direction of scientific research and the results obtained.

We have identified several words that have become search tools. By the criterion of belonging to the field of education, we took the words: education, learning, teaching, and laboratory. Words like "university, secondary education, student, distance \ blended learning" were not considered due to a narrower focus. By the criterion of belonging to the IT industry, we took the words: technology, digital technologies, applications, virtual, and mobile. The terms "cloud\mobile technologies" are excluded because they are included in digital technologies. The word "software" is also excluded, as online services and mobile applications are becoming increasingly popular today. The word "virtual" is involved because today, IT companies present developments in virtual reality that can be used in teaching physics.

In the WOS database, we searched as follows: the search field entered the word of our choice, which by the type of request was characterized as the keyword of the publication. The result of the search was the set of publications that include this word in their list of keywords. The number of publications was limited, and we took into account publications over the past 20 years. If the total number of publications was too small, we chose the search among the abstracts of the WOS database publications.

To identify general trends, we searched the annotations for the words "physic education" and "technology" or "physic learning" and "technology" or "physic teaching" and "technology". The words "physics and technology" were obligatory in the abstracts, and the words education, training, teaching could meet either all together, or at least one of them. In this way, we researched all publications that presented physics education and technology.

Results of research

Since we investigated trends in the use of digital technologies in teaching physics, the following words were used to organize the bibliographic analysis: "physics learning", "physics education", "physics teaching" and "technologies", as well as "digital technologies in teaching physics", "physics application", "mobile physics learning", "virtual physics laboratory", "digital physics laboratory", "virtual reality & physics", "augmented reality & physics". Below are the results of processing requests.

Search by words "physics learning"

A search for the words "physics learning" revealed 7713 keywords, among which 55 words were found that were mentioned at least 25 times. The network of connections indicates (Figure 1) the presence of three clusters: physical education (science, knowledge, presentation, motivation, instructions, active learning, simulations); physics (mathematics, education, training); model (algorithms, design, computer modelling, simulation, optimization, etc.).

Search by words "physics learning" and "technologies"

A search for the words "physics learning" and "technologies" revealed a total of 435 keywords. 11 of them had 5 or more repetitions. Network analysis (Figure 2) revealed three similar clusters: physical education (e-learning, enhanced learning technologies); educational technologies (learning); physics (science, technology).

Search by words "physics education" and "technologies"

Searching for the words "physics education" and "technologies" revealed 448 keywords, 10 of which were repeated at least 5 times. The constructed network (Figure 3) shows three clusters: physics (mathematics, education, simulations); technologies (science, educational research in physics); physical education (educational technologies, engineering education).

Search by words "physics teaching" and "technologies"

A search for the words "physics teaching" and "technologies" revealed 354 keywords, of which 18 keywords appeared in the publications more than three

times. The constructed network (Figure 4) shows the presence of four clusters by directions: physics teaching, physics, technologies, and training.

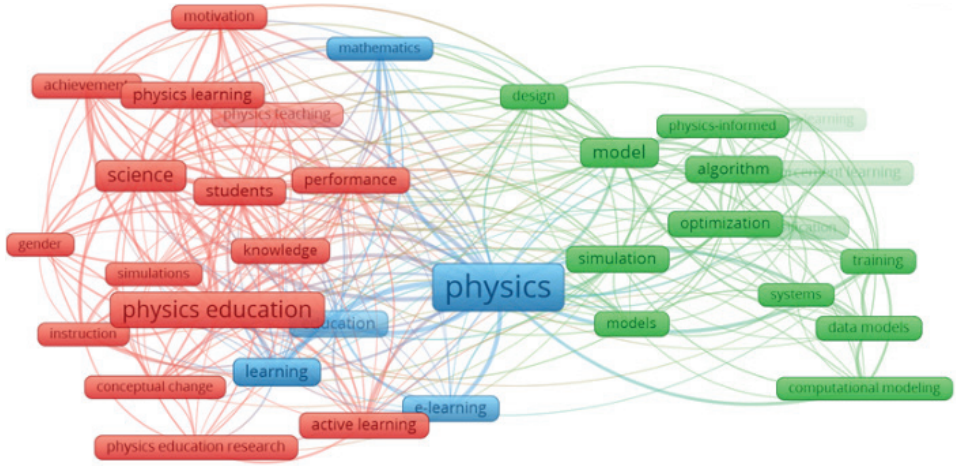

Figure 1. Network for «physics learning»

S o u r c e: Own work.

Figure 2. Network for «physics learning» & «technologies»

S o u r c e: Own work.

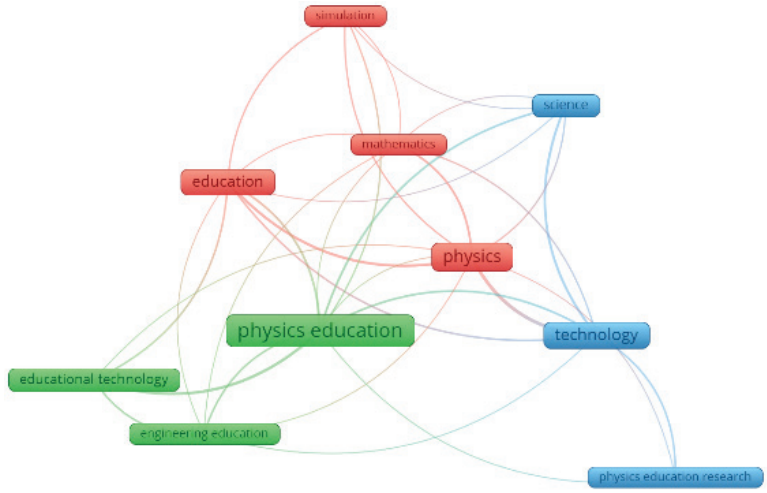

Figure 3. Network for «physics education» & «technologies»

S o u r c e: Own work.

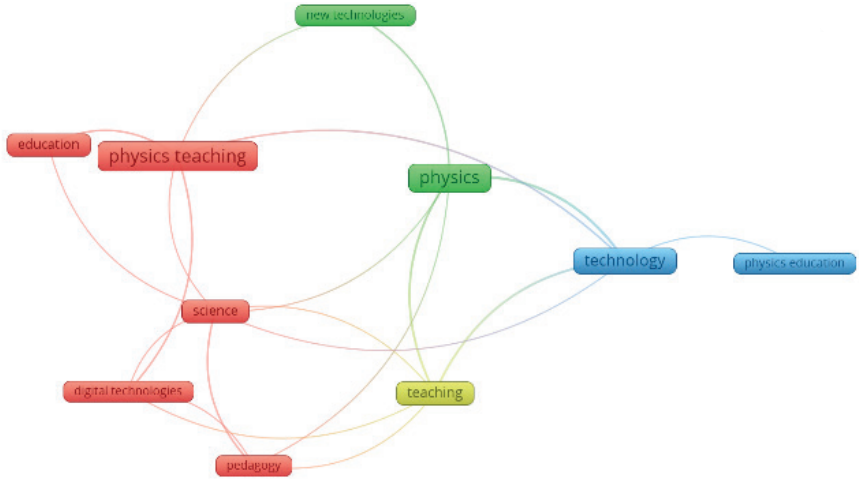

Figure 4. Network for «physics teaching» & «technologies»

S o u r c e: Own work.

A generalized search using the keywords “physics learning” and “technologies” or “physics education” and “technologies” or “physics teaching” and “technologies” in the Web of Science system shows that the vast majority of materials relate to educational research (1,813 or 41%) and educational scientific research (873 or 20%). We also note the presence of such areas as Engineering electrical Electronic (354 or 8%), Computer Science Interdisciplinary Applications (328 or 7%), and Computer Science Information Systems (302 or 7%), which indicates the popularity

of the use of computer science in engineering and the development of applications for interdisciplinary programs.

Search by words “Digital technologies in physics teaching”

A search for the words “digital technologies in teaching physics” revealed a network of keywords (Figure 5) divided into seven main clusters: education, technology, students, physics, digital technologies, science, and teaching. In total, 69 (out of 1,718) unique keywords that appear in 5 or more publications became interconnected. The dynamics of the number of publications and the most used keywords in different periods are interesting (Table 1). Thus, in 1995–1999, the number of publications on the use of DT in teaching physics (Web of Science database) was low and amounted to 5, and unique keywords – 9, including system, information, teaching-file, interactive multimedia, world-wide-web, training, networks, internet, media imaging. Data for subsequent years are presented in the table (Table 1).

Table 1
Data on publications upon request “Digital technologies in teaching physics”, 2005-2023

Years	Number of works	Number of keywords in works		Keywords that were used most often
		Generally	The most popular	
2005–2009	20	98	9	Computer, physics, curriculum, secondary education, teaching/learning strategies, applications in subject areas, agent, XML, e-learning
2010–2014	46	196	13	Education, higher education, technology, knowledge, inquiry, physics, teaching, framework, ICT, design, model, science teachers
2015–2019	187	734	15	Technology, physics, education, teachers, ICT, learning, physics education, motivation, design, science, mobile learning, students, pedagogical content knowledge, social media, physical education
2020–2023	194	919	21	Students, education, technology, motivation, information, digital technologies/technology, performance, higher education, online learning, feedback, classroom, knowledge, science, teaching, pedagogical content knowledge, pedagogy, education technology, model, impact

S o u r c e: Own work.

The selection of publications for the years 2020–2023 divides them into three clusters: education, physics education, and technology.

Search by words “physics” and “digital technologies”

A search using the words “physics” and “digital technologies” revealed 28 publications from 2006 to 2023. In half of the cases, their subject concerns the educational field (Education Educational Research – 43%, Education Scientific Disciplines – 7%). A search for the same words in the abstracts revealed 981 sources, starting from 1990, and as of 2019, an average of 80 of them. Most of the publications relate to various sections of physics, but more than 17% relate to education (Education Educational Research – 12%, Education Scientific Disciplines – 5.6%).

Search by words “Physics application”

A search using the keywords “Physics application” revealed 208 publications. The total number of keywords is 1984, of which 37 words have 5 or more repetitions. The constructed network (Figure 6) revealed 6 clusters, of which the main ones are: application (simulation, education, etc.), physics (algorithms, visualization), and engineering (simulations, machine learning). A search for the words “Physics application” among the annotations revealed 62,500 resources.

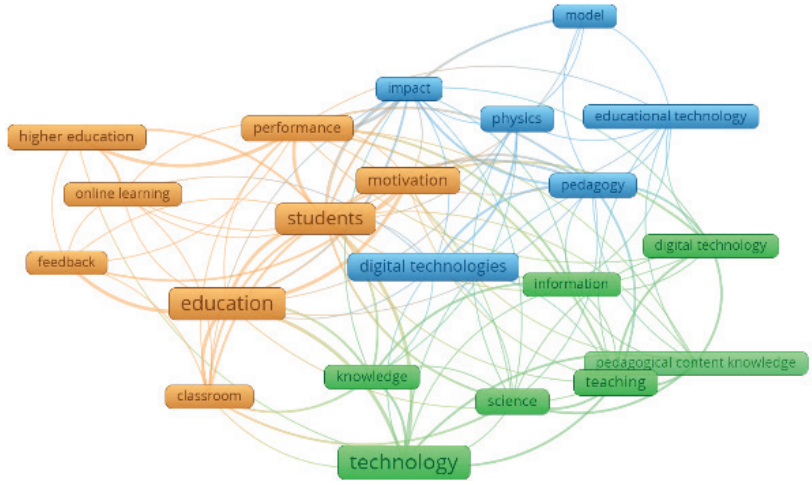

Figure 5. Network for «Digital technologies & teaching physics»

Source: Own work.

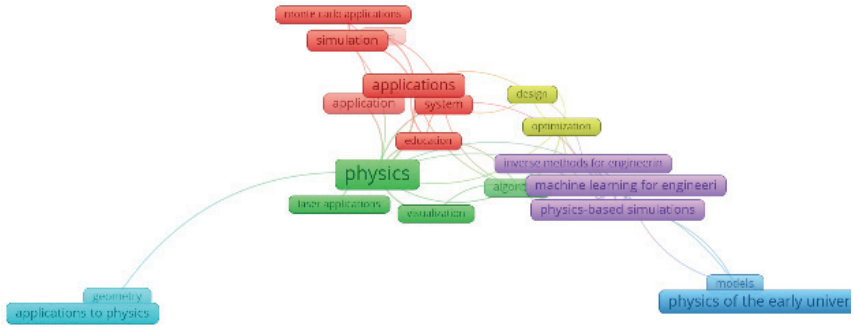

Figure 6. Network for «Physics application»

Source: Own work.

With the "education" specification, there are 822 results in the system, which are also presented in various sections of physics, which indicates the prevalence of such applications. The majority relate to the field of education (319 and 203 publications, which is 64%).

Search by words "application to physics"

A search for the word "application to physics" revealed 35 publications. At the same time, 13 words were found 3 or more times. Analysis of the network (Figure 7) shows that mathematical transformations, differential equations, geometry, and numerical fields are relevant here.

Search by words "physics learning mobile"

A search for the words "physics learning mobile" revealed 37 publications. The total number of keywords is 206. Among the keywords, 14 words are mentioned 3 or more times. The constructed network (Figure 8) revealed four clusters related to the teaching of physics and which proved not only the relevance of mobile but also mixed and e-learning, as well as means of augmented reality and guided experiments. A search in the abstracts of publications using the words "physics learning mobile" revealed 236 items, of which more than 60% are related to education (Education Educational Research – 42%, Education Scientific Disciplines – 20%).

Search by words "virtual physics laboratory"

A search among the abstracts using the specified keywords revealed about 1109 publications for the period since 2005, in which almost half of the scientific results are related to education: Education Educational Research – 25%, Education Scientific Disciplines – 19%. Searching for the keywords "virtual physics laboratory" found 29 publications since 2007. They recorded 199 keywords, of which 17 words occur more than twice. The network distinguishes clusters such as virtual physics laboratory, virtual experiment, virtual laboratory, and simulation.

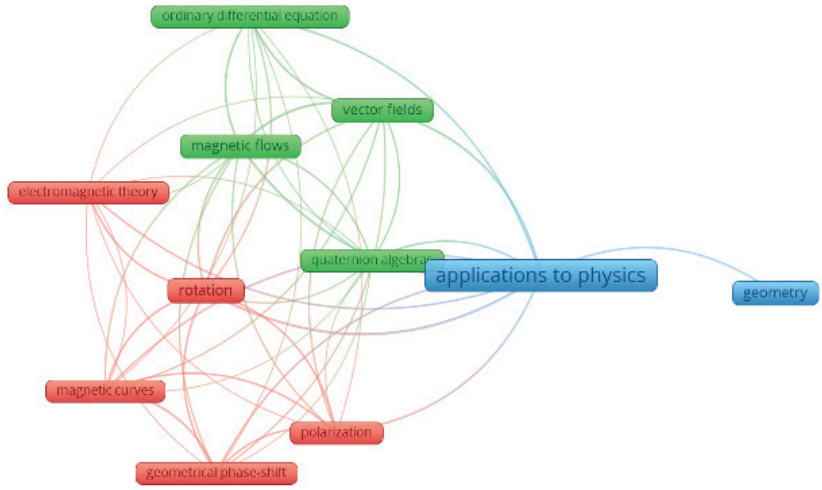

Figure 7. Network for «application to physics»

S o u r c e: Own work.

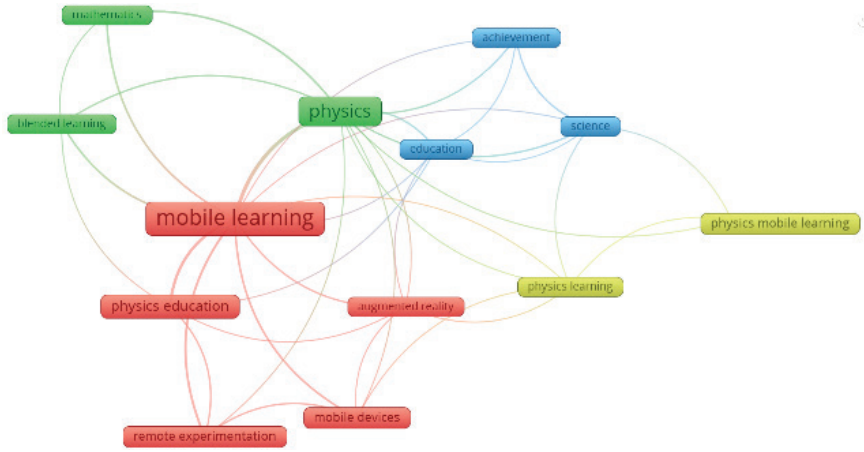

Figure 8. Network for «Physics learning mobile»

S o u r c e: Own work.

Search by words “digital physics laboratory”

A search among the abstracts using the specified keywords revealed more than 300 publications for 2005-2023, in which almost half of the scientific results are related to education; Education Scientific Disciplines – 16%, Education Educational Research – 11%. If you search among the keywords, only 3 results were found, which have a total of 10 keywords, some of which form a network. Searching for the words “digital laboratory” among the keywords revealed more publications – 382, which form a set of 2308 keywords. If we select those of them

that occur 10 or more times, we will get a network, which forms three clusters such as education, laboratories, and systems.

Search by words “virtual reality & physics”

A search for the words “virtual reality & physics” among the publications revealed 97 sources, which together formed a set with 442 keywords. Building a network of these words (Figure 9), which had 5 or more repetitions, forms five clusters such as virtual reality (simulation, engineering), physics, physical education, physical modelling, and physical simulations. A search in the annotations for these words yields more than 500 sources, that is Education Educational Research – 12%, Education Scientific Disciplines – 8%.

Search by words “augmented reality & physics”

Searching for the words “augmented reality & physics” yields 55 publications. They form a cloud of 249 keywords, of which 11 occur 4 or more times. The network of words (Figure 10) forms two clusters: physical education and design, and architecture. If we analyse the topics of the works that have the words mentioned in the abstracts, then almost half of them are research in education that is Education Educational Research – 23%, Education Scientific Disciplines – 16%. A search in the database among the annotations using the words “augmented reality & physics” revealed publications related to education: education educational research – 33%, education scientific disciplines – 18%.

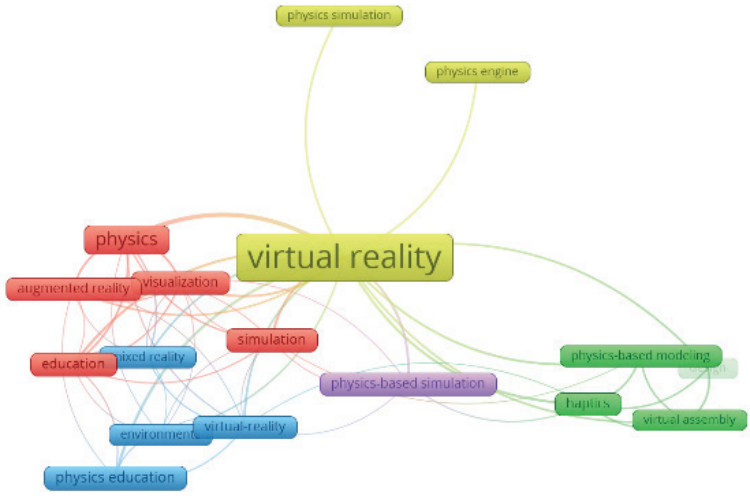

Figure 9. Network for «virtual reality & physics»

S o u r c e: Own work.

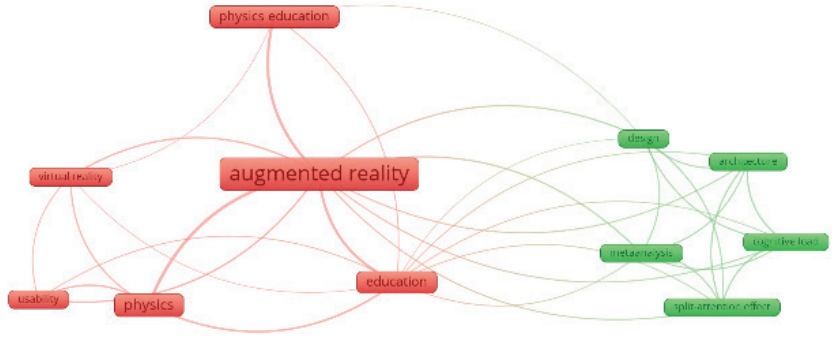

Figure 10. Network for «augmented reality & physics»

S o u r c e: Own work.

These were the quantitative results of the bibliographic analysis. Let's move on to their qualitative analysis.

The network of connections according to the words "physics learning" proves that the cluster that characterizes "physics education" connects not only scientific knowledge but also active learning based on research, demonstrations, models, simulation of processes, etc. The second largest cluster "physics" connects physics with mathematics and learning, including electronics. The third cluster indicates close connections with algorithms, design, computer modelling, simulation, etc. The generalization of network connections proves that the teaching of physics today by scientists is connected not only with motivated learning but also with mathematical and informatics education, which includes algorithmic thinking and active modelling of physical processes.

The network of connections for the words "physics learning" and "technologies" revealed connections between three clusters ("physics education", "educational technologies" and "physics"). The connections confirm the relevance of certain educational technologies in teaching physics such as electronic learning technologies and technologies of active and advanced learning.

The network of connections between the words "physics education" and "technologies" showed three leading clusters ("physics", "technology" and "physics education") that connect educational technology, engineering and mathematics education, physical science research, and simulations. The generalization of connections shows the importance of developing interdisciplinary connections with mathematics and engineering.

The network of connections between the words "physics teaching", and "technologies", revealed the presence of four clusters, which confirmed the importance of digital technologies for teaching physics.

Summarizing the directions of publications by the keywords "physics learning" and "technologies" or "physics education" and "technologies" or "physics teaching"

and "technologies" shows that among the presented scientific results, more than half relate to educational and scientific research.

The network of connections according to the words "digital technologies in teaching physics" connected seven clusters that is education, technology, students, physics, digital technologies, science, and teaching. Summarizing the most used keywords they showed that:

- in the period 1995–1999, research on digital technologies in physics was mainly related to www technologies, the Internet, and interactive multimedia;
- in the period 2005–2009, the emphasis shifts to the use of digital technologies in education, problems of secondary education are raised in the context of teaching physics, teaching and learning strategies, research on electronic learning is updated;
- in 2010–2014, works published revealed the problems of teaching physics in higher education, the problems of the effectiveness of existing teaching models were raised, and the emphasis was on knowledge and technologies. In this period, the use of ICT in the teaching of physics and natural sciences begins;
- in 2015–2019, aspects of the use of not only ICT but also social networks and mobile learning are more actively covered, and attention is updated to the motivation of using digital technologies in teaching physics;
- in 2020–2023, the keyword "digital technology" appears for the first time, and the attention of scientists turns to online education and the search for tools to increase the motivation for studying physics, and to develop students' creativity. A retrospective of the emphasis of the publications (we took only those keywords that appeared in the publications more than three times) is presented in Figure 11.

The analysis shows that although publications over the last 5 years has formed a network of only three clusters (education, technology, and digital technology), the focus on learning and teaching technologies, as well as on motivation, remains relevant. Summarizing the search results by the words "physics" and "digital technologies" proved the presence of a significant number of sources devoted to the search for effective technologies in physics, as well as in teaching physics.

The network of connections based on the keywords "physics application" revealed the presence of six clusters that connect models and simulations (application), algorithms and visualization (physics), physical simulations and machine learning (engineering), geometry with applications (applications for physics), design and optimization. The generalization of connections indicates the use of specialized applications in physics education, and at the same time, the importance of modelling, process simulations, and data visualization in physics education. Over the past five years, scientific intelligence has been updated in two directions: physics (algorithms, systems, applications) and machine learning (physical simulations, artificial intelligence, data engineering). This indicates the search for ways to teach physics using machine learning and artificial intelligence.

A more detailed study of the sources for the word "physics-based simulations" demonstrates tendencies towards the simulation of all kinds of physical processes that relate to different sections of physics. The most popular is the plasma and black hole simulation. Along with this, we note the presence of works related to animation, computer modelling, numerical simulations, and data coding. The presence of such keywords in clusters proves the importance of understanding information processes and processing various kinds of data for research in physics. Analysis of the word "physics application" with the clarification of "education" confirmed the popularity of using applications for learning/teaching physics. A search for the word "application to physics" confirmed the importance of mathematical knowledge for teaching physics (about mathematical transformations, differential equations, geometry, and numerical fields).

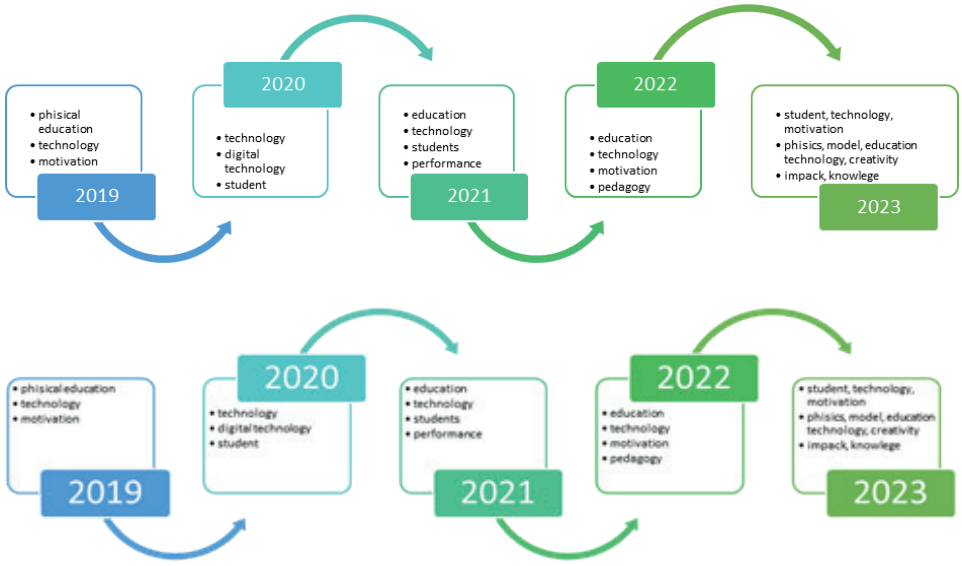

Figure 11. The topics of publications that contain words "Augmented reality & physics" in abstracts

S o u r c e: Own work.

The network of connections according to "physics learning mobile" revealed four clusters that link physics learning, achievement, and teaching. The generalization of connections proves the popularity of modern trends in the field of education that is mobile, mixed, and e-learning, as well as means of augmented reality in teaching physics. A search in the abstracts of publications further confirms the use of mobile learning technologies in teaching physics.

The network of connections for the words "virtual reality & physics" revealed clusters such as virtual reality, physics, etc. The generalization of network

connections shows the importance of physical modelling, physical simulations, visualization, and mixed reality for the virtualization of physical processes. A search in the abstracts for these words shows that every fifth publication is related to learning/teaching physics. Over the past 5 years, a search for the words "virtual reality and physics" has revealed several clusters, the main one of which connects education, physics, and visualization. At the same time, mixed and augmented reality is updated, which indicates the search for new methods and means of teaching physics.

The network of connections under the words "augmented reality & physics" forms two clusters that connect physical education and design. The directions of research (two out of five) that have the words mentioned in the abstracts touch on the problems of physical education. In the past five years, the augmented reality cluster has seen clear connections with virtual reality, physics learning, game-based learning technologies, and visualization. This indicates the trends of active teaching of physics and the use of mixed reality in the educational process. A search among the abstracts for the words "augmented reality & physics" showed that every second publication is related to learning\teaching.

So, in describing today's situation of the use of digital technologies in teaching physics, the following important characteristics should be highlighted:

1) General – the use of digital technologies in teaching physics is an actual topic of modern research.
2) Technological – the use of DT in teaching physics takes place in different directions:
    a. the use of digital tools as a means of researching physical processes;
    b. solving physics problems using special programs or mobile applications;
    c. the use of virtual and digital physical laboratories;
    d. the use of virtual, augmented, and mixed reality for teaching physics;
    e. the use of specialized environments for modelling physical processes;
3) educational and motivational:
    a. motivation to study physics and motivation to use digital technologies to study physics;
    b. motivation to deepen mathematical knowledge and skills;
    c. motivation to develop both intellectual skills (computing skills, algorithmic thinking skills, process modelling, etc.), and creative and visual thinking skills;
    d. mastering physics will be successful if interdisciplinary connections between natural sciences, mathematics, engineering, and digital technologies are developed, which separately STEM education.
4) Educational and organizational:
    a. teaching physics today relies on digital technologies and tools that enable simulation, modelling, visualization, and virtualization of physical processes;

b. teaching physics today is connected with the technologies of electronic (including mobile) and mixed, as well as online learning;
c. involves the use of active learning methods, which involve the involvement of DT;
d. physics education today is considered from the angle of machine learning and artificial intelligence as a promising education model.

Discussion

When describing the situation of the use of digital technologies in teaching physics (hereinafter – the situation), one should take into account the modern development of digital technologies and tools. Since the latter develop quickly and powerfully, they form new directions of development in the field of education. It is DT that determines the trend of this topic in scientific publications of the world. This correlates with the conclusions of review works (Liu & Hwang, 2021; Pando, 2018; Sianes-Bautista et al., 2022).

Another review (Yun, 2020) summarizes the results of 2,959 articles from the American Journal of Physics and 745 articles from Physics Review Physics Education Research. The authors record the growth of interest in the pedagogical content of knowledge in the field of teaching physics, assessment of achievements, and gender of students. They claim that it is pedagogical education and the reasoning process of students that remain the objects of modern research in the field of physics education. At the same time, solving physics problems is a topic in which interest is decreasing. These conclusions correspond to the thesis that the motivation to learn and the ability to realize, understand, and demonstrate are more important today. The ability to solve a problem is increasingly reduced to the ability to use a digital tool.

The technological characteristics of the situation are characterized by various aspects, which are confirmed by review articles of other scientists. Thus, an overview of digital tools as a means of studying physical processes is presented in Camargo et al (2021); Zhang et al., (2023) and others. A generalization of the results of using virtual and digital physical laboratories is presented in Ali et al., (2022). The authors analyse the results of 86 publications and provide recommendations on how to improve their use in teaching physics.

A description of scientific results regarding the use of virtual, augmented, and immersive reality in physics education is provided by Hamilton et al.,(2021), where 29 articles were analysed. The authors claim that they have confirmed a significant advantage of using immersive virtual reality in education. At the same time, the authors emphasize that the correct assessment methods were not always used in

the conducted research, and therefore the choice of the correct diagnostic apparatus is important for understanding the potential of immersive augmented reality as a pedagogical method.

The use of specialized environments for modelling physical processes is considered in a review paper (Banda & Nzabahimana, 2021), which presents an analysis of 31 sources that describe the use of PhET simulations in the physics education process. The authors emphasize the conclusion that students' conceptual understanding of physics improves with the use of simulations. Such simulations support the idea of active learning.

The educational and motivational characteristic of the situation is characterized by motivation for various types of educational activities. This is emphasized by Li et al. (2018); McDowell (2019). In particular, the relevance of the problem of motivation to study physics (Alstein et al., 2021) and motivation to use digital technologies in education (Gerhard et al., 2023) are widely researched. It also requires strengthening the motivation to study mathematics (Alipour et al., 2023), the development of intellectual skills (Lv et al., 2022), and visual thinking (Trakosas et al., 2023). The conclusion about the importance of developing interdisciplinary connections correlates with the conclusions of reviews on the implementation of STEM education. Thus, the work of McLure et al. (2022) presents an overview of 35 works related to the organization of STEM projects in various educational institutions. The authors conclude about the diversity of STEM approaches in the literature and note that engineering and natural sciences, including physics, are the most common integrated fields. At the same time, the authors raise the question: to what extent do the projects meet the students' requests, which actualizes the problem of motivation for studying physics?

The educational and organizational characteristic of the situation describes the peculiarities of the organization of physics education. It includes the use of DT for simulation, modelling, visualization, and virtualization of physical processes. In the work of Velasco & Buteler (2017), an analysis of 17 publications was carried out, based on which the importance of using computer simulation in physical education was noted and its possible effects on learning outcomes were noted. Scientists also emphasize the transition to e-learning, which includes mobile and online learning. A review by Cascarosa et al. (2021) examines the concepts of physics education and focuses on the feasibility of building knowledge models that can be implemented in blended learning in higher physics education.

Active learning methods are also important in modern physics education, as confirmed by Odden et al. (2023). Another aspect of teaching physics using machine learning and artificial intelligence is analysed in a review by Dimiduk et al. (2018), which focuses on some positive results and shows that new technologies have the potential to have a transformative impact on approaches to teaching physics.

Analysis of the dynamics of queries in Google Trends shows that among the queries "physics learning," "physics education," and "physics teaching," the

most significant interest in the world over the past five years has been observed for "physics education" (an average of 40 points of popularity and out of 100 versus 14 and 17 for the queries "physics learning" and "physics teaching" respectively). The query "physics application" shows an average of 50 points of popularity, and "virtual physics laboratory" – only 2. There are no trends for the query "digital technologies in teaching physics" (not enough data). A similar situation (not enough data) is observed for requests for "digital physics laboratory," "virtual reality & physics," and "augmented reality & physics." Therefore, it can be argued that analytics from Google confirms the popularity of physics applications and education but does not provide detailed information about perspectives on their development.

Conclusion

The conducted research allows us to draw the following conclusions.

Physics education today is in demand in society. The development of digital technologies and tools supports physics education and its growth. The developers of specialized computer environments and applications provide simplification of calculations, construction of models and the possibility of simulations, etc. At the same time, scientific and pedagogical research traces the problem of young people's unwillingness to master physics (that fact is based on the appearance of the word "motivation"). Physics for young people is not only tricky but also uninteresting. Therefore, the direction of educational research associated with increasing interest and motivation to study physics based on/ with the usage of digital technology is a trend.

The situation of the use of digital technologies in teaching physics is characterized by four aspects (general, technological, educational-motivational, and educational-organizational). These aspects highlight modern trends in teaching physics. One of the trends is the use of environments where simulation, modelling, visualization, virtualization of physical processes, etc., are possible (the discovered sets of keywords confirm this). Virtual, augmented, and mixed reality are gradually becoming popular. They predetermine the emergence and introduction of new methods of active physics teaching. The popularity of using mobile applications for teaching physics is also increasing. Attempts are being made to use artificial intelligence to teach physics. Another trend in teaching physics is the organization of an educational environment based on mobile or online learning, where active teaching methods are appropriate. Therefore, the leading models of teaching physics become models based on a digital approach and provide interactive teaching methods for their implementation.

The bibliographic analysis by keywords and qualitative analysis of scientific and pedagogical research results in the discussion confirms the importance of developing young people's intellectual skills (computational skills, algorithmic thinking skills, process modeling, etc.) and visual thinking for successful mastery of various physics branches. A demand for integration links between natural sciences, mathematics, engineering, and digital technologies is a trend, further confirmed by the enhanced development of STEM education based on interdisciplinary connections of sciences, technology, engineering, and mathematics. Therefore, the educational process in the future will be saturated with applied tasks, which in their solution, involve using digital technologies and research projects that involve modeling physical processes and predicting possible consequences.

The study additionally actualizes the problem of appropriate training/internship for teachers of natural and mathematical subjects (physics, mathematics, biology, chemistry). The programs of their training today should include mastering various digital technologies and means of teaching physics. The future educational and professional programs should:

- develop intellectual, creative, computational, and visual thinking in future teachers;
- focus on the readiness of physics teachers to develop similar skills among young people;
- form the experience of organizing an electronic educational environment, which provides interactive interaction and high-quality support for teaching physics visually;
- develop the teacher's ability to work with a variety of intelligent systems (virtual laboratories, artificial intelligence, programming environments) to support physics training;
- prepare teachers for the implementation of STEM projects in their professional activities.

The presented research made it possible to describe the situation of the use of computer science in teaching physics and opened up directions for the following scientific investigations in the field of professional training of science teachers: STEM projects in teaching physics, the development of intellectual, creative, computational, visual thinking of students in the process of teaching physics, the effectiveness of using intellectual systems (virtual laboratories, artificial intelligence, programming environments) to support physics education.

References

Husaeni, D. F. & Nandiyanto, A. B. D. (2022). Bibliometric using Vosviewer with Publish or Perish (using google scholar data): From step-by-step processing for users to the practical examples in the analysis of digital learning articles in pre and post-Covid-19 pandemic. *ASEAN Journal of Science and Engineering,* 2(1), 19–46.

Ali, N., Ullah, S. & Khan, D. (2022). Interactive Laboratories for Science Education: A Subjective Study and Systematic Literature Review. *Multimodal Technologies and Interaction*, 6(10), 85. https://doi.org/10.3390/mti6100085.

Alipour, M., Aminifar, E., Geary, D. C. & Ebrahimpour, R. (2023). Framing mathematical content in evolutionarily salient contexts improves students' learning motivation. *Learning and Motivation,* 82, 101894. https://doi.org/10.1016/j.lmot.2023.101894.

Alstein, P., Krijtenburg-Lewerissa, K. & van Joolingen, W. (2021). Teaching and learning special relativity theory in secondary and lower undergraduate education: A literature review. *Physical Review Physics Education Research,* 17(2), 023101. https://doi.org/10.1103/PhysRevPhysEducRes.17.023101.

Astafieva M., Bodnenko D. & Proshkin V. (2019). Using computer-oriented geometry means in the process of critical thinking formation of future mathematics teachers. *Information Technologies and Learning Tools,* 3, 102–121. https://doi.org/10.33407/itlt.v71i3.2449.

Banda, H. & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on students' conceptual understanding in physics: A review of the literature. *Physical Review Physics Education Research*. 17. https://doi.org/10.1103/PhysRevPhysEducRes.17.023108.

Camargo, C., Gonçalves, J., Conde, M. Á., Rodríguez-Sedano, F. J., Costa, P. & García-Peñalvo, F. J. (2021). Systematic Literature Review of Realistic Simulators Applied in Educational Robotics Context. *Sensors* (Basel, Switzerland), 21(12), 4031. https://doi.org/10.3390/s21124031.

Cascarosa, E., Sánchez-Azqueta, C., Gimeno, C. & Aldea, C. (2021). Model-based teaching of physics in higher education: a review of educational strategies and cognitive improvements. *Journal of Applied Research in Higher Education,* 13(1), 33–47. https://doi.org/10.1108/JARHE-11-2019-0287.

Dimiduk, D. M., Holm, E. A. & Niezgoda, S. R. (2018). Perspectives on the Impact of Machine Learning, Deep Learning, and Artificial Intelligence on Materials, Processes, and Structures Engineering. *Integrating materials and manufacturing innovation,* 7(3), 157–172. https://doi.org/10.1007/s40192-018-0117-8.

Gerhard, K., Jäger-Biela, D. & König, J. (2023). Opportunities to learn, technological pedagogical knowledge, and personal factors of pre-service teachers: understanding the link between teacher education program characteristics and student teacher learning outcomes in times of digitalization. Zeitschrift fur erziehungswissenschaft. https://doi.org/10.1007/s11618-023-01162-y.

Hamilton, D., McKechnie, J., Edgerton, E. & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education,* 8, 1–32. https://doi.org/10.1007/s40692-020-00169-2.

Hsiao, H. S., Chen, J. C., Chen, J. H., Chien, Y. H., Chang, C. P. & Chung, G. H. (2023). A study on the effects of using gamification with the 6E model on high school students computer programming self-efficacy, IoT knowledge, hands-on skills, and behavioral patterns. *Educational Technology Research and Development.* https://doi.org/10.1007/s11423-023-10216-1.

Izadi, D., Willison, J., Finkelstein, N., Fracchiolla, C. & Hinko, K. (2022). Towards mapping the landscape of informal physics educational activities. *Physical Review Physics Education Research,* 18. https://doi.org/10.1103/PhysRevPhysEducRes.18.020145.

Jugembayeva, B. & Murzagaliyeva, A. (2023). Physics Students' Innovation Readiness for Digital Learning within the University 4.0 Model: Essential Scientific and Pedagogical Elements That Cause the Educational Format to Evolve in the Context of Advanced Technology Trends. *Sustainability,* 15(1), 233. https://doi.org/10.3390/su15010233.

Li, J., Ye, H., Tang, Y., Zhou, Z. & Hu, X. (2018). What Are the Effects of Self-Regulation Phases and Strategies for Chinese Students? A Meta-Analysis of Two Decades Research of the Association Between Self-Regulation and Academic Performance. *Frontiers in Psychology,* 9, 2434. https://doi.org/10.3389/fpsyg.2018.02434.

Liu, Ch. & Hwang, G.-J. (2021). Roles and research trends of touchscreen mobile devices in early childhood education: review of journal publications from 2010 to 2019 based on the technology-enhanced learning model. *Interactive Learning Environments*, 31, 1–20. https://doi.org/10.1080/10494820.2020.1855210.

Lv, L., Zhong, B. & Liu, X. (2022). A literature review on the empirical studies of the integration of mathematics and computational thinking. *Education and Information Technologies,* 28, 1–23. https://doi.org/10.1007/s10639-022-11518-2.

McDowell, L. D. (2019). The roles of motivation and metacognition in producing self-regulated learners of college physical science: a review of empirical studies. International Journal of Science Education, 41(17), 2524-2541. https://doi.org/10.1080/09500693.2019.1689584.

McLure, F., Tang, K.-S. & Williams, P. J. (2022). What do integrated STEM projects look like in middle school and high school classrooms? A systematic literature review of empirical studies of iSTEM projects. *International Journal of STEM Education,* 9. https://doi.org/10.1186/s40594-022-00390-8.

Odden, T. O. B., Lauvland, A., Boe, M. V. & Henriksen, E. K. (2023). Implementing the learning assistant model in European higher education. *European journal of physics,* 44(3), 035701. https://doi.org/10.1088/1361-6404/acb39e.

Pando, V. F. (2018). Teaching Trends in Virtual Education: An Interpretative Approach. *Purposes and Representations,* 6(1), 463–505. http://dx.doi.org/10.20511/pyr2018.v6n1.167.

Semenikhina, E., Drushlyak, M., Bondarenko, Yu., Kondratiuk, S. & Dehtiarova, N. (2019). Cloud-based service GeoGebra and its use in the educational process: the BYOD-approach. *TEM Journal,* 8(1), 65–72. https://doi.org/10.18421/TEM81-08.

Semenikhina, O., Drushlyak, M., Lynnyk, S., Kharchenko, I., Kyryliuk, H. & Honcharenko, O. (2020). On Computer Support of the Course "Fundamentals of Microelectronics" by Specialized Software: the Results of the Pedagogical Experiment. *TEM Journal,* 9(1), 309–316. https://doi.org/10.18421/TEM91-43.

Semenikhina, O. V. & Drushliak, M. H. (2015). Dynamic mathematics software: a quantitative analysis in the context of the preparation of math teacher. *Information Technologies and Learning Tools,* 48(4), 35–46. https://doi.org/10.33407/itlt.v48i4.1253.

Sianes-Bautista, A, Rosado-Castellano, F. & Flores-Rodríguez, C. (2022). Research Trends in Education in the Context of COVID-19 in Spain: A Systematic Literature Review. *Sustainability,* 14(19), 12235. https://doi.org/10.3390/su141912235.

Trakosas, D., Tikva, C. & Tambouris, E. (2023). Visual programming and computational thinking environments for K-9 education: a systematic literature review. *International Journal of Learning Technology,* 18(1), 94–121. https://doi.org/10.1504/IJLT.2023.131313.

Velasco, J. & Buteler, L. (2017). Computational Simulations in Physics Education: a critical review of the literature. Enseñanza de las Ciencias. *Revista de investigación y experiencias didácticas,* 35, 161. https://doi.org/10.5565/rev/ensciencias.2117.

Yun, E. (2020). Review of trends in physics education research using topic modeling. *Journal of Baltic Science Education,* 19, 388–400. https://doi.org/10.33225/jbse/20.19.388.

Yurchenko, A., Drushlyak, M., Sapozhnykov, S., Teplytska, S., Koroliova, L. & Semenikhina, O. (2021). Using online IT-industry courses in the computer sciences specialists' training. *International Journal of Computer Science and Network Security*, 21(11), 97–104. https://doi.org/10.22937/IJCSNS.2021.21.11.13.

Zhang, J., Zhang, J., Chen, Q., Deng, X. & Zhuang, W. (2023). Measurement of g Using a Steel Ball and a Smartphone Acoustic Stopwatch. *The Physics Teacher,* 61(1), 74–75. https://doi.org/10.1119/5.0058374.

Artem Jurczenko, Władimir Proszkin, Olga Naboka, Władimir Shamonia, Elena Semenikhina

Wykorzystanie technologii cyfrowych w edukacji: perspektywa nauczania fizyki

S t r e s z c z e n i e

Artykuł ukazuje trendy w wykorzystaniu technologii cyfrowych w nauczaniu fizyki poprzez podsumowanie wyników badań naukowych z ostatnich 20 lat. Aby rozwiązać problem, zastosowano analizę bibliograficzną źródeł naukometrycznej bazy danych WOS z wykorzystaniem narzędzia komputerowego VOSviewer (do budowy i wizualizacji danych bibliograficznych) według stanu na czerwiec 2023 roku. Narzędzie to wykorzystano do analizy publikacji według słów kluczowych (sieć powiązań budowana jest w oparciu o wszystkie słowa kluczowe danych publikacji). W oparciu o zapytania zbudowano sieci powiązań słów kluczowych: „nauka fizyki", „edukacja fizyki", „nauczanie fizyki" i „technologie", a także „technologie cyfrowe w nauczaniu fizyki", „zastosowanie fizyki", „mobilna nauka fizyki", aplikacje fizyczne", „wirtualne laboratorium fizyczne", „cyfrowe laboratorium fizyczne", „wirtualna rzeczywistość i fizyka", „rozszerzona rzeczywistość i fizyka". Wykorzystanie technologii cyfrowych w nauczaniu fizyki charakteryzuje się czterema aspektami (ogólnym, technologicznym, edukacyjno-motywacyjnym i edukacyjno-organizacyjnym). Wyróżniono współczesne trendy w nauczaniu fizyki: wykorzystanie środowisk, w których możliwa jest symulacja, modelowanie, wizualizacja, wirtualizacja procesów fizycznych itp.; rosnąca popularność narzędzi rzeczywistości wirtualnej, rozszerzonej i mieszanej; wykorzystanie aplikacji mobilnych do nauki fizyki; wykorzystanie sztucznej inteligencji w nauczaniu fizyki; organizacja środowiska edukacyjnego opartego na nauce mobilnej lub online, gdzie za odpowiednie uznaje się aktywne metody uczenia się. Potwierdzono znaczenie rozwijania umiejętności intelektualnych młodych ludzi (umiejętności obliczeniowych, umiejętności myślenia algorytmicznego, procesów modelowania itp.) i myślenia wizualnego dla pomyślnego opanowania różnych działów fizyki. Monitorowano zapotrzebowanie na powiązania integracyjne między naukami przyrodniczymi, matematyką, inżynierią i technologiami cyfrowymi w edukacji STEM. Sformułowano zalecenia dotyczące kształcenia nauczycieli fizyki.

S ł o w a k l u c z o w e: technologie cyfrowe; nauczanie fizyki; nauka fizyki; edukacja fizyczna; nauczyciel fizyki; szkolenie nauczycieli; profesjonalne przygotowanie; technologia cyfrowa w edukacji; wyższa edukacja

Artem Yurchenko, Volodymyr Proshkin, Olha Naboka, Volodymyr Shamonia, Olena Semenikhina

Artem Yurchenko, Volodymyr Proshkin, Olga Naboka, Volodymyr Shamonya, Olena Semenikhina

Aplicación de tecnologías tecnológicas en el ámbito de la tecnología: tierra firme y física

Resumen

El artículo revela las tendencias en el uso de tecnologías digitales en la enseñanza de la física al resumir los resultados científicos de los últimos 20 años. Para solucionar el problema se utilizó un análisis bibliográfico de las fuentes de la base de datos cienciométrica de la WOS con la participación de la herramienta informática VOSviewer (para la construcción y visualización de datos bibliográficos) a partir de junio de 2023. La herramienta se utilizó para analizar publicaciones. por palabras clave (se construye una red de conexiones sobre la base de todas las palabras clave de determinadas publicaciones). Se construyeron redes de conexiones de palabras clave según las consultas: “aprendizaje de física”, “educación física”, “enseñanza de la física” y “tecnologías”, así como “tecnologías digitales en la enseñanza de la física”, “aplicaciones de la física”, “física móvil”. aprendizaje”, “laboratorio de física virtual”, “laboratorio de física digital”, “realidad virtual y física”, “realidad aumentada y física”. El panorama del uso de las tecnologías digitales en la enseñanza de la física se caracteriza por cuatro vertientes (general, tecnológica, educativo-motivacional y educativo-organizativa). Se destacan las tendencias modernas en la enseñanza de la física: el uso de entornos donde sea posible la simulación, modelado, visualización, virtualización de procesos físicos, etc.; la creciente popularidad de las herramientas de realidad virtual, aumentada y mixta; uso de aplicaciones móviles para aprender física; utilizar inteligencia artificial para enseñar física; organización de un entorno educativo basado en el aprendizaje móvil o en línea, donde se determina que los métodos de aprendizaje activo son apropiados. Se ha confirmado la importancia de desarrollar las habilidades intelectuales de los jóvenes (habilidades computacionales, habilidades de pensamiento algorítmico, procesos de modelado, etc.) y el pensamiento visual para el dominio exitoso de varias secciones de la física. Se ha monitoreado la demanda de vínculos de integración entre ciencias naturales, matemáticas, ingeniería y tecnologías digitales para la educación STEM. Se han formulado recomendaciones para la formación de profesores de física.

Palabras clave: tecnologías digitales; enseñanza de física; aprender física; educación física; profesor de física; formación de docentes; preparación profesional; tecnología digital en educación; educación más alta

Артем Юрченко, Владимир Прошкин, Ольга Набока, Владимир Шамоня, Елена Семенихина

Использование цифровых технологий в образовании: ландшафт изучения физики

Аннотация

В статье путем обобщения научных результатов за последние 20 лет раскрываются тенденции использования цифровых технологий в преподавании физики. Для решения задачи был использован библиографический анализ источников наукометрической базы данных WOS с привлечением компьютерного инструмента VOSviewer (для построения и визуализации библиографических данных) по состоянию на июнь 2023 года. Инструмент использовался для

анализа публикаций по ключевым словам (сеть связей строится на основе всех ключевых слов данных публикаций). Сети связей ключевых слов были построены по запросам: «обучение физике», «физическое образование», «преподавание физики» и «технологии», а также «цифровые технологии в обучении физике», «физические приложения», «лаборатория виртуальной физики», «лаборатория цифровой физики», «виртуальная реальность и физика», «дополненная реальность и физика». Ландшафт использования цифровых технологий в обучении физике характеризуется четырьмя аспектами (общий, технологический, учебно-мотивационный и учебно-организационный). Выделены современные тенденции в преподавании физики: использование сред, в которых возможно моделирование, визуализация, виртуализация физических процессов и т.д.; растущая популярность инструментов виртуальной, дополненной и смешанной реальности; использование мобильных приложений для изучения физики; использование искусственного интеллекта для преподавания физики; организация образовательной среды на основе мобильного или онлайн-обучения, где активные методы обучения признаны целесообразными. Подтверждена важность развития у молодежи интеллектуальных навыков (вычислительных навыков, навыков алгоритмического мышления, процессов моделирования и др.), а также наглядного мышления для успешного освоения различных разделов физики. Выделена потребность в интеграционных связях между естественными науками, математикой, инженерией и цифровыми технологиями для STEM-образования. Сформулированы рекомендации по подготовке учителей физики.

К л ю ч е в ы е с л о в а: цифровые технологии; преподавание физики; изучение физики; физическое образование; учитель физики; курсы для преподавателей; профессиональная подготовка; цифровые технологии в образовании; высшее образование

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Anna Smelkowska
Poznan University of Medical Sciences, Department of Neurological Nursing
https://orcid.org/0000-0003-0319-4130

Agnieszka Karbownik
Poznan University of Medical Sciences, Department of Clinical Pharmacy and Biopharmacy
https://orcid.org/0000-0002-3724-0548

Barbara Purandare
Poznan University of Medical Sciences, Department of Occupational Therapy
https://orcid.org/0000-0003-4518-5881

Katarzyna Zaorska
Poznan University of Medical Sciences, Department of Histology and Embryology
https://orcid.org/0000-0002-3894-781X

Marta Jokiel
Poznan University of Medical Sciences, Department of Traumatology, Orthopedics and Hand Surgery, Physiotherapy Department
https://orcid.org/0000-0002-6078-4498

Maurycy Jankowski
Poznan University of Medical Sciences, Department of Computer Science and Statistics
https://orcid.org/0000-0001-9476-0235

Magdalena Roszak
Poznan University of Medical Sciences, Department of Computer Science and Statistics
https://orcid.org/0000-0001-6495-6771

Successful Examples of Asynchronous Teaching in Polish Interactive Remote Medical Education

Abstract

A thorough theoretical and practical preparation is crucial in the education of medical professionals. Present-day knowledge recipients expect a broad range of multimedia and interactive resources in the consumed media. The article

discusses examples of such implementations for the nationwide education of a pharmacy technician, massage technician, medical sterilization technician, and occupational therapy technician. These examples were created for the Integrated Education Platform of the Ministry of Education and Science in Poland, as part of an EU-funded project. This study delineates the characteristics of e-materials, such as instructional and educational videos, film sequences, scenario-based learning games, interactive documentation, 3D animations, simulators and virtual tours. We prepared a learner benefit analysis based on the e-materials discussed. We aimed to formulate recommendations and guidelines for designing and developing multimedia and interactive resources, paying special attention to educational values and content for the medical industry. Regardless of the type of multimedia, profession and content, materials should prioritize realism, interactivity and detailed presentation of the situations/cases. The same multimedia rarely achieve different learning objectives and learning outcomes. To design and produce high-quality multimedia, it is necessary to know their characteristics and to work with a team of subject matter experts experienced in e-learning development.

K e y w o r d s: medical education, multimedia, interactive resources, e-materials, evaluation, blended-learning, video, interactive documentation, animation, simulator, virtual tour, distance education, medical sterilization technician, pharmacy technician, occupational therapy technician, massage technician

1. Introduction

The demands of medical education require a thorough academic and practical education of future medical professionals. Current developments and technological advances offer great opportunities for preparing teaching materials for remote education, including various types of multimedia and interactive resources expected by the modern consumer of knowledge (Roy, 2017; Roszak et al., 2020; Roszak et al., 2023). The achievement of the necessary learning outcomes in the education of medical personnel, sometimes difficult within traditional education, becomes possible by implementing an asynchronous e-learning component (Olivier et al., 2020; Roszak et al., 2021). Implementing innovative education in such a way seems to be the most optimal and effective method for reaching learning outcomes, as indicated by scientific reports across various fields (Kirkova-Bogdanova et al., 2018; Tabakova, 2020; Nagata, Chino et al., 2022; Silva et al., 2022; Hwang et al., 2023). This provides the opportunity, among other things, for students to repeatedly engage with e-resources, making mistakes based on individual needs. This deliberate didactic procedure, cannot take place in real-world conditions dur-

ing classes, e.g. in hospitals or pharmacies (Grześkowiak et al., 2020; Szczeszek et al., 2023).

Integrated Educational Platform

The authors point out that when designing and creating e-learning based on interactive and multimedia materials, special attention should be paid to 1) ensuring educational values through an appropriate methodology for creating such e-resources (types of multimedia and interactive resources tailored for different teaching purposes), 2) preparing authorized curricular content, and 3) implementing the technical aspect of multimedia (Roszak, 2019; Kanikowska et al., 2023). The article presents selected results of the work related to the Integrated Educational Platform of the Ministry of Education and Science in Poland. The focus is on post-secondary education in the professions of medical caregiver, pharmaceutical technician, massage therapist technician, medical sterilization technician, occupational therapy technician, orthopedic technician, and elements for the profession of medical electronics and information technology. The presented materials are the result of 2 years of work under a nationwide EU-funded e-materials project.

Multimedia and interactive resources produced

The project resulted in the creation of diverse resources, including but not limited to photo galleries, interactive boards, infographics, mind maps, e-books and audiobooks, educational videos, instructional videos, film sequences, educational games, interactive scenario-based learning type tools, exercise programs, 3D animations, multimedia and interactive atlases, simulators, virtual tours, virtual laboratories, and virtual reality tools (Smelkowska et al., 2023). This innovative government initiative promotes good quality interactive e-education, which can also inspire the preparation of a educational standards based on interactive and multimedia resources in academic teaching.

Promotion of good quality curricular content

The results of this project will be available on a nationwide scale for future post-secondary education graduates and teachers from 2023. The e-resources can also be used by other parties interested in the medical field, such as medical professionals and students. The benefits of implementing such a project include the promotion of good quality interactive e-education with access to authorized

teaching contents. All prepared resources underwent mandatory external content reviews before their final publication on the platform.

Implementation team

Multimedia and interactive e-material content preparation for medical education requires the work of an interdisciplinary team of experts. Such a team should include: content writers, content consultants (industry experts or specialists in the profession, vocational education teachers), methodologists, vocational education methodological advisors, editors, and, particularly WCAG specialists. WCAG, or Web Content Accessibility Guidelines, comprise a set of standards developed by the Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3C) to ensure that the web content is accessible to people with a wide range of disabilities. Knowledge providers educated at medical universities with experience in teamwork and with expertise in interdisciplinary activities are the most desirable content authors for medical e-learning. Naturally, they must have experience in the field of e-education both in the role of knowledge recipient and knowledge provider (Roszak et al., 2021).

The content resources created for the educational platform, referred to as e-resources, were categorized according to subject matter. Their main elements included selected multimedia and interactive e-materials, along with a teaching framework for the entire e-resource. The teaching framework includes: interactive review materials, a vocabulary glossary, teaching guides for both teachers and students, bibliography and netography, and instructions for using the e-resource. Everything adhered to content and teaching standards, prepared to support selected learning objectives in line with the profession's core curriculum.

The Ministry of Education and Science, as part of the project guidelines, pre-established the quantity, the subject diversity of e-resources, and the variety of multimedia employed within a specific profession, as well as the professions for which e-materials were created according to predefined standards. The article discusses examples of implementation of the integrated educational platform for the professions of medical sterilization technician, massage therapy technician, occupational therapy technician and pharmacy technician. The article presents specific types of multimedia which, according to the authors, pose challenges in terms of content or technical development. In addition, their implementation is associated with a high financial cost. Due to the extent of the issue, the authors plan to present examples for the other health professions within the project (medical career, orthopedic technician, electronics and medical informatics technician) in subsequent publications.

2. Characteristics of the analyzed multimedia and interactive resources

This chapter highlights key features of specific multimedia and interactive materials, with practical examples showcased in point 3.

Videos, both educational and instructional, as well as shorter formats like film sequences covering several topics, are an important and interesting element of remote education. According to the research available, students themselves admit that the use of videos in education improves the quality of education and increases their involvement in the learning process (McAlister, 2014).

Video sequences

These sequences allow for the presentation of individual processes and the implementation of specific professional tasks. Graphics and diagrams are placed throughout the sequence to facilitate comprehension, with each video sequence lasting approximately 5 minutes. The material also includes a voiceover and a soundtrack.

Instructional/educational videos

These videos allow for the presentation of individual processes and the implementation of certain professional tasks. Graphics and diagrams are placed throughout the sequence to facilitate comprehension, with each video sequence lasting approximately 15 to 30 minutes. The material also includes a voiceover and a soundtrack.

Interactive scenario-based learning tools (decision-making game, SBL)

These games are based on interactive scenarios containing a plot description and rules defining the permitted and prohibited student behaviors during the game (Wong et al., 2016; Yilmaz et al., 2020). At certain points in the game, the player is tasked with making a decision affecting its further stages. In addition, the game provides an opportunity to develop and reinforce the learner's readiness to act, take risks and take responsibility for making decisions, but also allows for interrupting and resuming the game at any time. The participant receives feedback for both correct and incorrect decisions – followed by hints helping to make the correct decision.

In e-learning, it is worthwhile to use different types of multimedia resources in order to impart reliable knowledge. According to medical students, e-learning allows for the widespread use of high-end educational resources, serving as a reliable study support tool. While games and videos are relatively easily associated with multimedia materials (Szczeszek et al., 2023), seemingly less interactive content, such as documentation related to therapy planning, can also be successfully implemented in e-learning in the form of interactive documentation.

Interactive documentation

This component includes sample documents/forms, along with description instructions for its completion. It provides students the possibility to complete it on their own, get feedback on its completion correctness, and, in case of error, receive guidance on the correct completion of the form. The module incorporates examples of correctly completed documents.

Methodologically valuable elements of e-education include more elaborate multimedia and interactive materials, such as 3D animations, simulators and virtual tours. However, they require the work of a team with higher IT skills, often related to programming, and a subject matter expert. Given the time-consuming and costly nature of this process, it is advisable to create such resources on a nationwide level, rather than individually by educational units.

3D animation

This feature presents a 2D or 3D model depicting various aspects, such as the operation of equipment in a process, or the components of an item. It may contain various types of graphics that allow observation from different perspectives. It contains a textual or voiceover description of the object, including its construction, its operation or its mode of use. It demonstrates the performance of standard work activities and tasks, and the respective required equipment, including the outcome of performing the activity. The users can move and rotate the object around all axes. An audio track may be included in this type of media.

Simulator

This tool allows the student to carry out professional exercises, such as learning about the operation of a specific device or apparatus necessary to perform certain professional processes. It includes a description of the device's operation or construction, including interactive diagrams. It allows the student to independently

simulate activities involving the operation of the device, perform measurements or processes, select tools, interpret results, and troubleshoot potential malfunctions. A voiceover text or an audio track may be integrated.

Virtual tour

This functionality allows the student to see in detail the interior of given locations, through a guided tour of the facility, offering additional information. It gives the opportunity to get acquainted with the layout plan of the given premises presented in a graphic form (projection), as well as allows image manipulation (zooming in/out of the object). The virtual tour also includes a description of professional activities performed in the location, along with the identification of specialized equipment.

The next section discusses examples of the implementation of selected multimedia and interactive resources for teaching selected medical professions (Smelkowska et al., 2023).

All the illustrative material (figures 1–24) of the article are print screens of the multimedia and interactive material created within the framework of the EU project implemented by the Poznan University of Medical Sciences (all authors of the article are employed at the PUMS and participated in the project) and Lodz University of Technology – POWR.02.15.00-00-3051/20. The illustrative material is available on the website: https://zpe.gov.pl/szukaj?query=&stage=KZ&subject=bran%C5%BCa+opieki+zdrowotnej (license: CC BY-SA 3.0).

3. Examples of implemented e-materials

3.1. Medical sterilization technician

– a comprehensive look at the implementation of selected materials, such as simulators, animations, and instructional videos.

Simulators

For the profession of a medical sterilization technician, three simulators were created, providing students with a hands-on experience in operating a total of five different devices. These encompass an automatic washer-disinfector, a large steam sterilizer, a small steam sterilizer (autoclave), a plasma sterilizer and an ethylene

oxide gas sterilizer. The student, as a medical sterilization technician, virtually operates the device, from turning it on, testing its efficiency and setting process parameters, methodically arranging instruments and medical devices, packing them in sterile barriers, selecting process indicators, all the way to analyzing the printout and releasing the load. The simulator (Figure 1) is designed authentically to replicate reality, ensuring a seamless transition to real-world tasks (Rowan et al., 2023).

Figure 1. Simulator of the automatic washing and disinfecting device

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Interestingly, some of the most common errors and malfunctions (Smith et al., 2016) have also been integrated, which prepares the student to deal with them in daily practice (e.g., insufficient drying of tools, failure of the device to achieve the required physical parameters of the process, air-locking of components of the system supplying chemicals to the device chamber) – Figure 2.

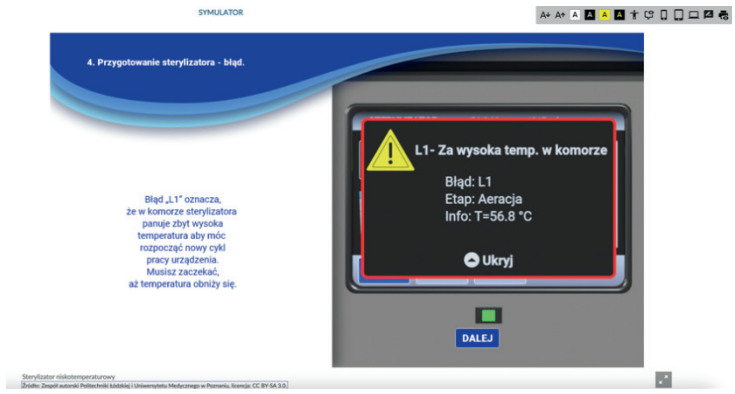

Figure 2. Low temperature – gas sterilizer simulator, error during the preparation of the device for operation

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The simulator gives brief instructions and explanations of subsequent steps, yet it incorporates stages where the student makes decisions. Examples include selecting the appropriate sterile barrier to pack the selected medical device, or determining the adequate tests and indicators to control the ongoing process. This further keeps the student engaged and requires him/her to recall knowledge gained from previous materials. The tool features visually captivating elements, enabling the student, for instance, to verify the results of biological tests and chemical indicators, such as observing the color change in the test field or bacterial medium. This aspect emphasizes the authenticity of the activity – Figure 3.

Figure 3. High-temperature-steam sterilizer simulator, Bowie-Dick test stained correctly and incorrectly

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Output documents from the device maintain authenticity and are useful in subsequent stages and at the process's conclusion. The analysis of these printouts is essential for determining the correct progression of the process and making informed decisions on whether to ultimately release the batch of tools.

3D animations

3D animations are examples of multimedia elements with attractive visuals. They present tools and medical devices in a 360-degree rotating view, while showing their assembly and disassembly. This process is very important for the proper preparation of medical devices for decontamination. The student can analyze the step-by-step assembly and disassembly of the device components in the correct order (Figure 4, Figure 5). The tool is complemented by a brief description of the construction and function of the device in question. Similar to the simulators, the graphics here also faithfully represent the structure and operation of medical equipment.

Figure 4. 3D animation 'Disassembly and assembly of medical equipment', Veress needle assembly

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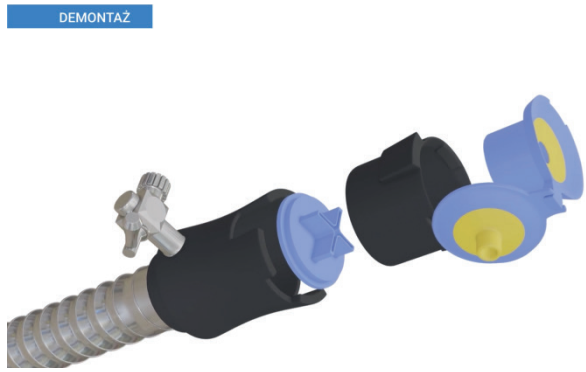

Figure 5. 3D animation 'Disassembly and assembly of medical equipment', disassembly of 12.5 cm laparoscopic troacar

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Instructional videos

A total of five instructional videos have been created for the profession of a medical sterilization technician. They describe and show in detail all the activities performed by a central sterilization room employee, covering the entire process from receiving contaminated instruments from the operating theatre to returning them to hospital units. It is worth noting that all the videos for this profession were carried out in the same central sterilization room, which gives the learner the additional opportunity to follow the layout of the rooms of the dirty, clean and sterile zones, along with the layout of the equipment and elements in each of them.

The videos also highlight the personal protective equipment required for each zone and activity, as well as detailed documentation of each stage of the process. Sample frames from the instructional videos are presented below (Figure 6, Figure 7).

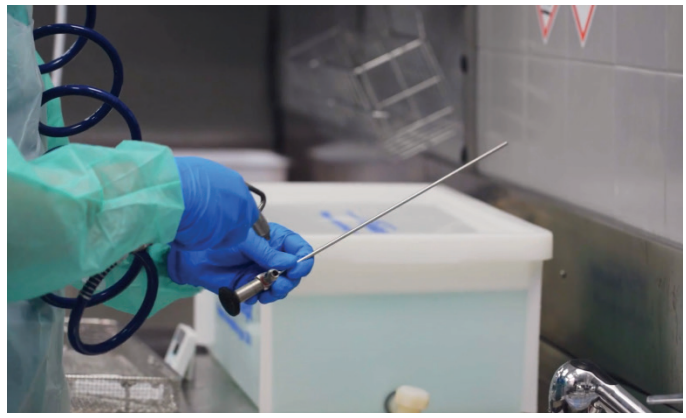

Figure 6. A frame from the 'Machine and manual decontamination' instructional video

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Figure 7. A frame from the 'Control of cleaning and disinfection processes, control of sterilization processes' instructional video

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3.2. Massage technician

– examples of implementation of selected materials, such as an educational video with 3D animations, film sequences and a scenario-based learning game.

Educational video with 3d animations

The main purpose of the presented educational video is to provide a spatial representation of the complex three-dimensional structure of one of the basic elements of the human body – the skin.

The video utilizes a 3D animation to delve into the intricacies of skin structure and the spatial arrangement of its elements (Figure 8). Students have the unique opportunity to learn about the layered structure of skin and the distribution of the relevant receptors in space. Through animation, the video vividly portrays the response of individual skin elements to specific massage techniques (Figure 9). This allows students to consolidate their knowledge of how individual receptors react to touch, but also allows them to visualize the effects of the treatment. The video additionally features a detailed voiceover commentary, which explains in detail the successive stages of the reaction. Students can stop watching the video at any time, take notes, or revisit a particular section of the material.

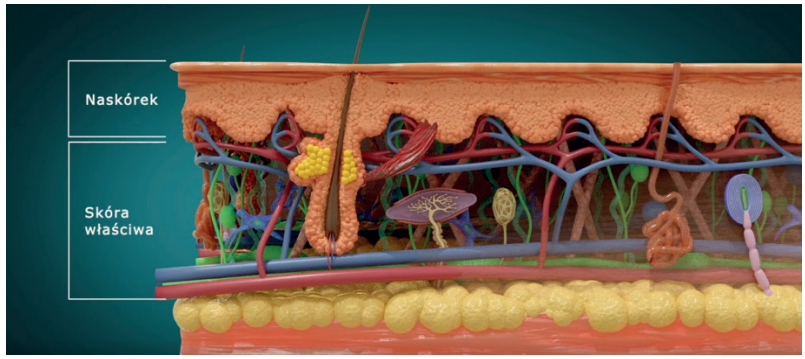

Figure 8. A frame from an educational video with 3D animations 'Skin Structure'

S o u r c e: Project POWR.02.15.00-00-3051/20, license CC BY-SA 3.0.

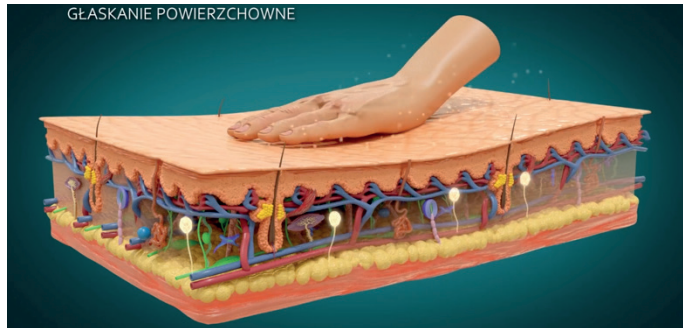

Figure 9. Frame from an educational film with 3D animations – 'Response of the skin and its elements to the technique of superficial stroking'

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For students with special needs, the video includes a detailed description of the elements on the screen, allowing even those with visual impairments to familiarize themselves with the material.

Video sequences

The video sequences are designed to give students a hands-on introduction to the entire process of manual lymphatic drainage, encompassing workstation preparation, patient setup, and the treatment of specific body parts. Due to the practical nature of the material, learners can familiarize themselves with the types of grips, the direction of each technique and their proper execution. Most of the material available to learners contains instructions on how to perform particular techniques or their elements. Our developed e-material takes a unique approach by presenting the application of manual lymphatic drainage techniques on a specific body area, illustrating the complete process rather than just its components (Figure 10). The material is additionally accompanied by a detailed voiceover commentary, which explains in detail how to perform each technique, as well as clarifies their clinical applications. Students have the option to pause the video and practically perform a given technique, in order to reinforce and consolidate their newly acquired skills.

Figure 10. Frame from a video sequence 'Individual techniques of manual lymphatic drainage performed on the thigh'

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Interactive scenario-based learning tool

While familiarizing themselves with the game, the students are introduced to two characters in the story – a massage therapist and a patient. As each scene is played, the learner is confronted with a series of decisions, the solution of which will affect the further course of the game. The learner's demonstration of knowledge, stress management capabilities, and comprehension of cause-and-effect relationships varies depending on the nature of the task, with each task being interconnected with other educational elements (Figure 11). The game also develops students' social competencies by posing problem-based tasks, such as coping with an adverse event during a massage. Students can solve tasks repeatedly by going through all the elements of the game, including interviewing the patient, prioritizing therapy, and performing individual techniques.

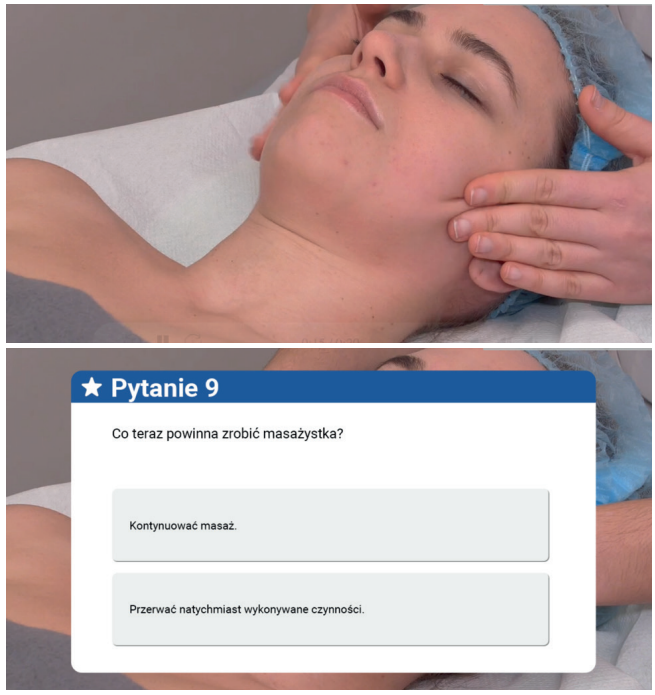

Figure 11. A frame from a video sequence 'Facial care massage'

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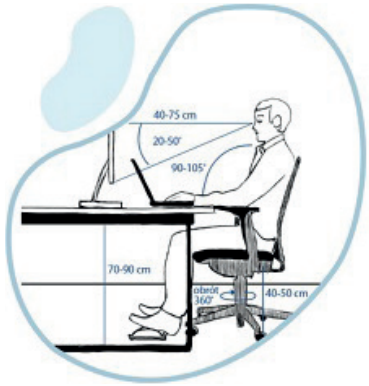
3.3. Occupational therapy

– examples of implementation of selected materials, such as a scenario-based learning game, film sequences and interactive documentation.

Interactive scenario-based learning tool

The game presented focuses on setting therapy aims. At the beginning of the game, the aims and rules are explained. Then, after selecting a patient, the player is given a detailed description (history of the disease, limitations, difficulties and the resources available to them), based on which they must make decisions that determine the therapy goals (Figure 12).



Terapeuta zajęciowy przeprowadza z Panią Agnieszką kurs oszczędzania energii. Trenuje prawidłowe nawyki związane z dystrybucją energii w ciągu dnia. Sporządza listę czynności z oceną ich wydatku energetycznego. W ten sposób Pani Agnieszka uczy się, w jakich godzinach najlepiej jest jej pracować, jak robić efektywne przerwy w pracy i jak następnie regenerować siły.

Dodatkowo terapeuta zmienia środowisko pracy kobiety na bardziej ergonomiczne. Proponuje pracę przy biurku, pomaga dobrać odpowiednie krzesło z regulacją wysokości i nachylenia oparcia. Terapeuta radzi, by Pani Agnieszka korzystała ze stacjonarnego monitora jako ekranu, dodatkowej klawiatury i myszy. W efekcie kobieta czuje, że praca mniej ją męczy. Pani Agnieszce udaje się nawet oddać ostatnie zlecenie dzień przed upływającym terminem.

Figure 12. A description of the consequences of a good choice of a therapy aim based on a previous description of the patient's needs from the 'Setting therapy goals' game

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The choice of a goal has consequences that affect the patient's outcome (Figure 13). In the case of a wrong choice, the participant receives formative feedback, including a detailed explanation of why the choice was inaccurate, considering the indications and contraindications pertinent to the patient.

Pani Agnieszka jest bardzo zadowolona ze zmian, które udało jej się wprowadzić z terapeutą zajęciowym. Funkcjonowanie w mieszkaniu oraz praca zawodowa są dla niej dużo łatwiejsze, kobieta cieszy się, że nie musi rezygnować z dotychczasowych zadań. Brakuje jej jedynie kontaktów społecznych, wcześniej miała więcej okazji do spotykania się ze znajomymi, szczególnie kiedy uczęszczała z mężem na zajęcia taneczne, z czego musiała zrezygnować.

Figure 13. The figure presents a further description of the case after the previous correct aim choice

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In case of correct choice, the participant gains new information about the patient, needed to set further therapy goals. Through this approach the student gains the ability to plan therapy comprehensively, by analyzing information regarding the functioning of the person with a disability. They gradually learn about the elements of the patient's medical history and functioning relevant to therapy planning.

In the case of the SBL game, the content included allows the student to acquire skills in accordance with the learning outcomes. Students learn to set therapeutic goals for the patient, describe the individual and group forms of occupational therapy activity organization, select methods, therapy techniques for the patient in relation to his health condition, needs, problems and degree of disability, as well as adjust therapy to the psychophysical condition of the patient.

Video sequences

The sequences depict scenes of an occupational therapist's work in individual hygiene and housekeeping workshops, allowing the student to familiarize themselves with different forms of social skills training. The multimedia material helps the student expand their knowledge of health and safety rules for social skills training and acquire skills in creating scenarios that could be used in a daily living workshop. Example one: hygiene training – brushing teeth. (Figure 14).

Figure 14. A frame from the 'Hygiene and Housekeeping' video on hygiene training, during which a therapist instructs clients on how to brush their teeth properly

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The educational value of the material is further enhanced by supplementing additional information pertinent to the video content after each sequence. In the example in question, this includes safety rules to be followed when brushing teeth, advantages of taking care of oral hygiene and types of toothpaste. After each sequence, the student has to solve a short test task based on the content they were presented. The introduction of such an element not only adds variety to the content being conveyed, but it is also an important element in supporting the acquisition and consolidation of knowledge. The learner, when confronted with the task, has the opportunity to verify knowledge and possibly quickly return to the relevant content. Example Two: Training in the use of household appliances – washing clothes in an automatic washing machine (Figure 15).

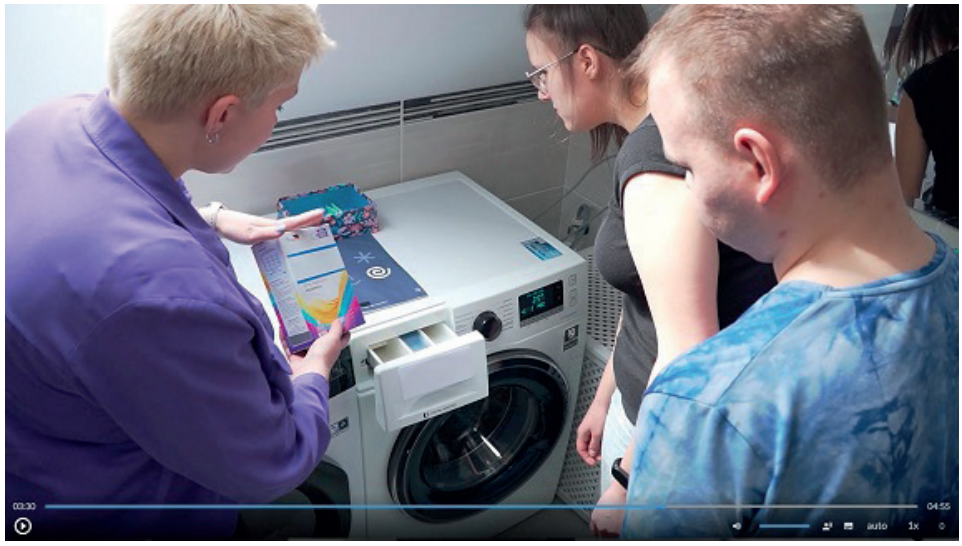

Figure 15. A frame from a video on housekeeping equipment training, during which a therapist instructs clients in operating a washing machine

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Similar to the first example sequence, the material contains additional relevant content, related to the required learning outcomes. The student has the opportunity to observe the correct execution of the training. They can return to the content and material unlimited times. The recorded educational content is reproducible and provides a model picture for the student.

At the end of the material there is a correctly completed scenario of classes for a group of adult Occupational Therapy Workshop participants. This scenario serves as a valuable source of knowledge and guidance for students undertaking individual work, offering a practical reference for their learning journey.

Interactive documentation

The student is assigned the responsibility of completing by filling out several interactive forms, each preceded by a set of necessary information. This necessitates the effective analysis of the provided information to accurately fill out the documents. For example, after reviewing the functional characteristics of a sample participant in a group therapy class – including the patient's physical, mental and social issues, their resources and capabilities, and the characteristics of their family and local environment – the task is to complete the section of the occupational therapy plan. This plan refers to the activation of the participant and cooperation with their family and local environment (Figure 16).

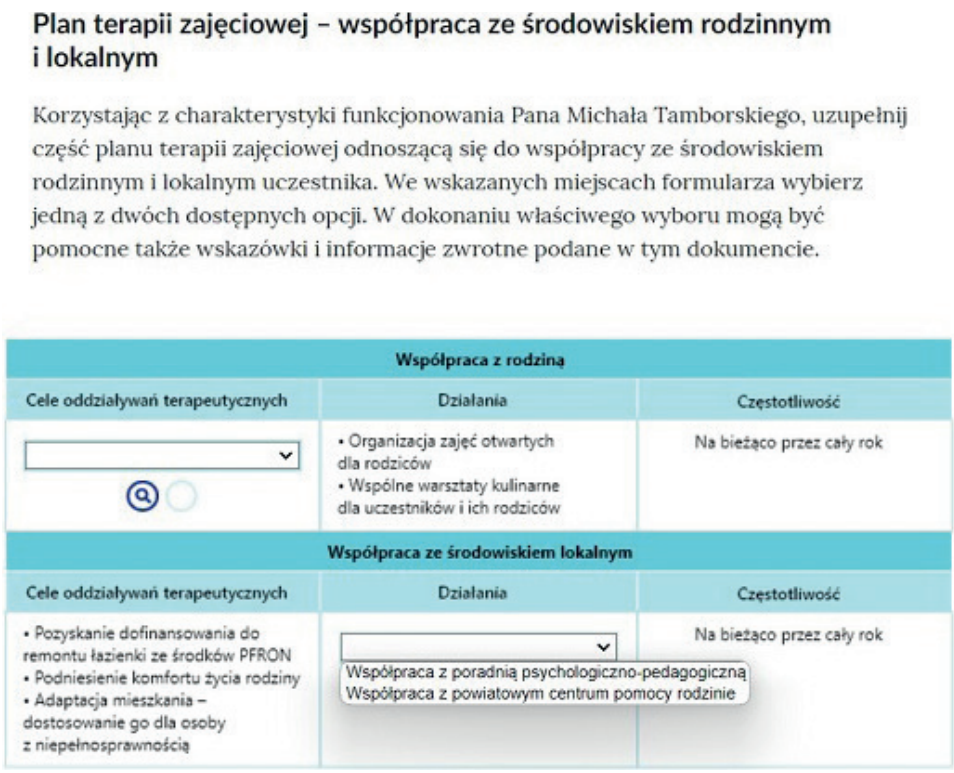

Figure 16. An excerpt from the interactive documentation covering the part of the occupational therapy plan relating to the participant's activation, and cooperation with the participant's family and local environment

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In the next step, the student is presented with a daily schedule of activities in the occupational therapy workshop, another element necessary to complete the scenario of therapeutic activities (Figure 17).

Figure 17. An excerpt from a script of therapeutic activities, including background information

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While performing the tasks, the students receive ongoing feedback on the correctness of filling out the documents. They receive guidance on how to correctly fill out each document if they make a mistake, an important part of effective learning. The material also includes sample documentation, such as a completed occupational therapy plan and a scenario for group therapy classes. Each of the documents can be downloaded if necessary, offering considerable flexibility in utilizing the provided materials at one's convenience. Utilizing this virtual tool, students can plan the therapeutic process by using the information from the diagnosis. Moreover, they can learn to analyze recommendations of specialists and multidisciplinary team. This includes the ability to select methods of working with the patient, their family, and social environment according to the recommendations of specialists. Additionally, students can select suitable tools and aids, and formulate scenarios for therapeutic activities.

3.4. Pharmacy technician

– examples of implementation of selected materials, such as virtual tour, interactive documentation, and instructional video.

Virtual tour

By handling the virtual tour, the learner becomes familiar with the interior of a general pharmacy (Hookham et al., 2014). Students have the chance to explore the premises through a complete panoramic view, experiencing it from the perspective of an observer rotating on their own axis. They can navigate through the facility, look down and up, zoom in and out, and select the direction of the tour (Figure 18).

Figure 18. Interior of the warehouse of prescription medicinal products with description

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At the beginning of the tour, the student is introduced to general information about the operation of the pharmacy, such as the characteristics of the activities performed and the tasks of various staff. There are two ways to take a virtual tour of the pharmacy. The first one is to move around the facility by "entering and exiting" the respective rooms one by one. This allows the student to see how the rooms are interconnected. The second one is to tour the pharmacy by selecting a specific room from the attached floor plan with the layout of the rooms (Figure 19).

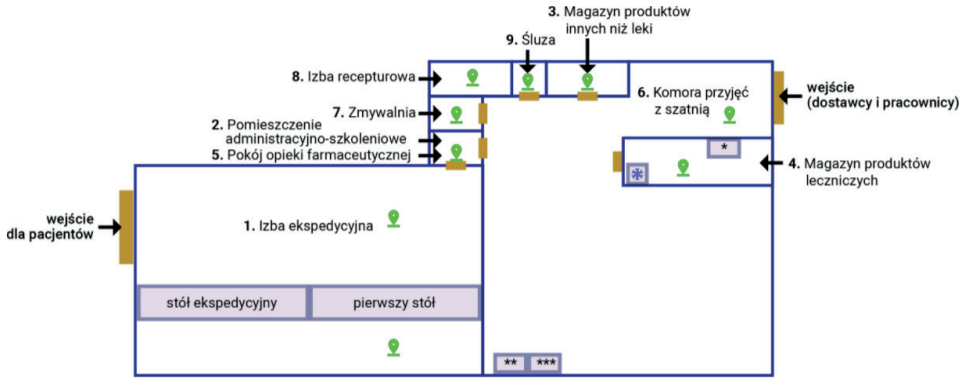

Figure 19. Floor plan of a public pharmacy with the layout of the premises

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The interactive bullet points are followed by descriptions of these rooms (their function, activities performed), and descriptions of the specialized equipment (Figure 20).

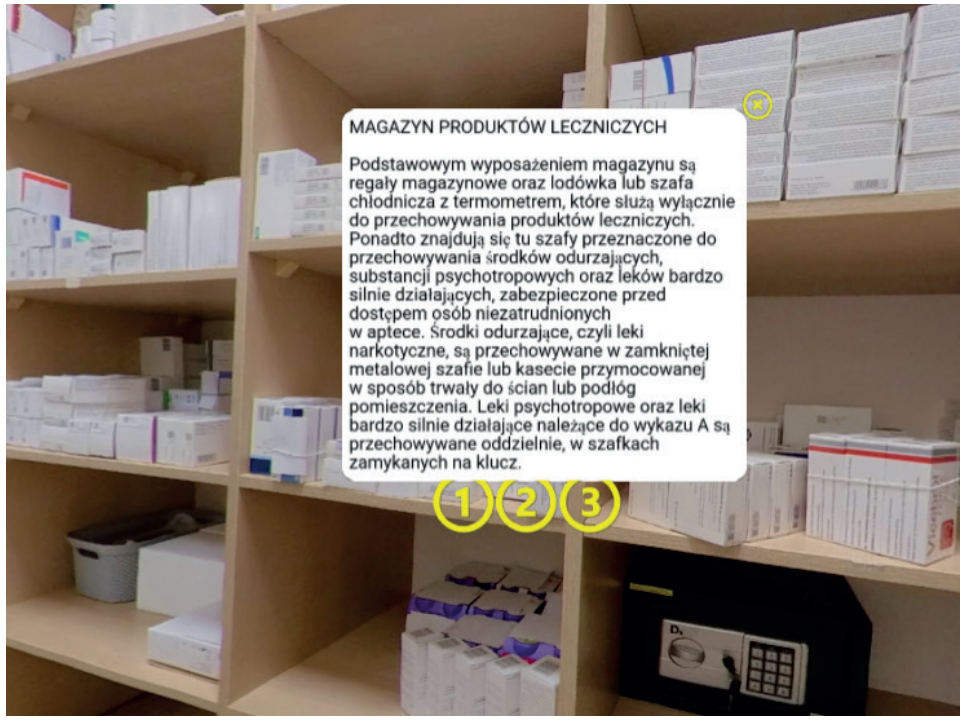

Figure 20. Interior of the warehouse of prescription medicinal products with description – the interactive bullet points

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Interactive documentation

Below is an example of an interactive medical record found in the profession of pharmacy technician. This includes documentation of adverse drug reactions, monitoring of the temperature range in the pharmacy, and the form for return and refund of goods in the pharmacy (Figure 21).

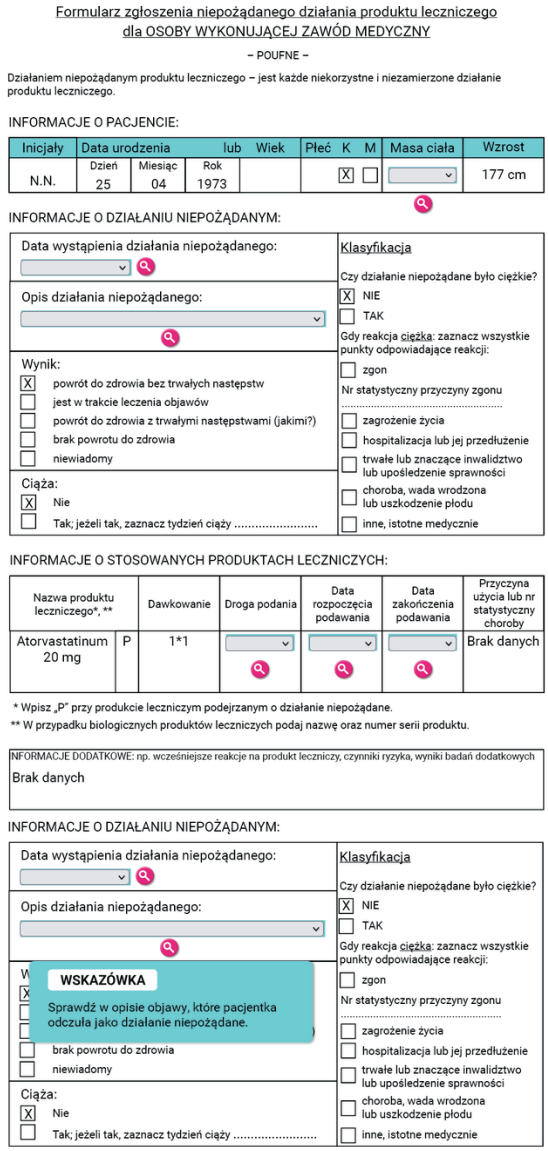

Figure 21. Excerpt from the Interactive Documentation 'Pharmacy Forms'

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The form for reporting an adverse drug reaction is shown below, along with a case description and the necessary elements for its completion, as well as prompts for filling it out.

Case description: On 14.05.2022, a patient with the initials N.N., born on 25.04.1973, with a body weight of 69 kg and height of 177 cm, reported to the pharmacy. The patient declares that she is not pregnant. Since 1.02.2022, she has been taking a drug containing Atorvastatinum at a dose of 20 mg, according to a regimen of 1 tablet orally once a day. It turned out that since 15.04.2022 she started experiencing constipation, abdominal pain, bloating, nausea, headaches, itching of the skin and observed edema. The above side effects were mild. On 1.05.2022 she discontinued the drug, and the symptoms described above ceded.

Instructional video

The instructional video serves as a valuable source for the development of knowledge and skills in the practical aspects of a pharmaceutical technician's work in a pharmaceutical laboratory. Specifically, this type of media guides users through the process of conducting an analysis of ointment substrate viscosity, as well as assessing the dynamic viscosity of the ointment itself. The video shows the operation and use of the equipment-rotational rheometer – RS/CPS Plus (Figure 22). The video was recorded in the Department of Drug Formulation Technology at the Poznan University of Medical Sciences.

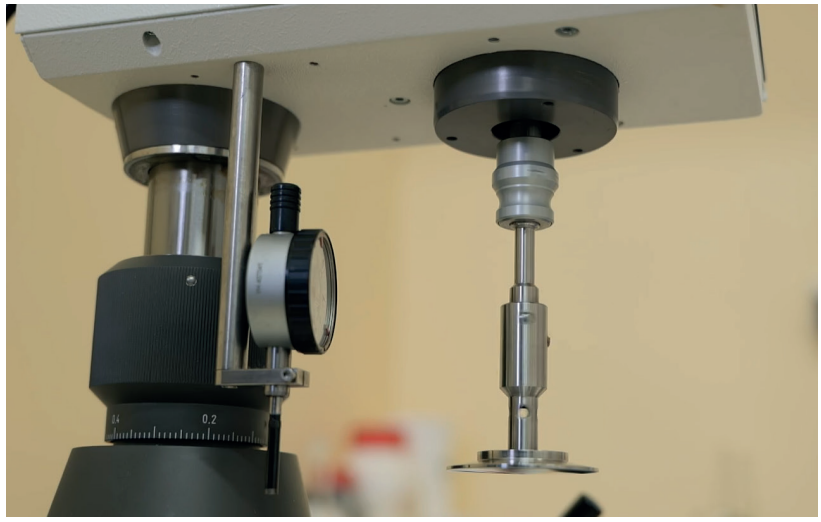

Figure 22. A frame from the instructional video 'Viscosity measurement of selected ointment substrates' showing the measurement system of a rotational rheometer

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Based on the pharmacopoeial analysis, the students are introduced to the results and they can determine the average value of the dynamic viscosity of the pharmaceutical ointment (Figure 23, Figure 24). During the course of the video, included graphics and diagrams facilitate the understanding of the content presented, while a voiceover provides additional content.

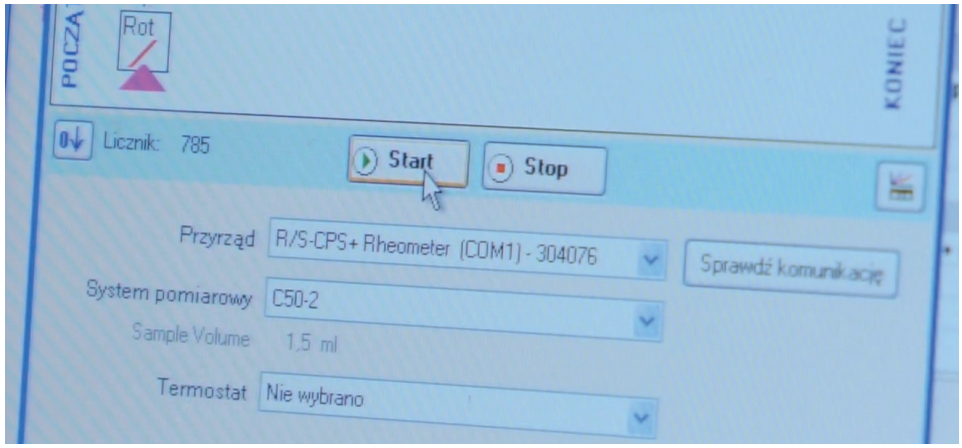

Figure 23. A frame from the instructional video 'Viscosity measurement of selected ointment substrates' showing the start of the measurement

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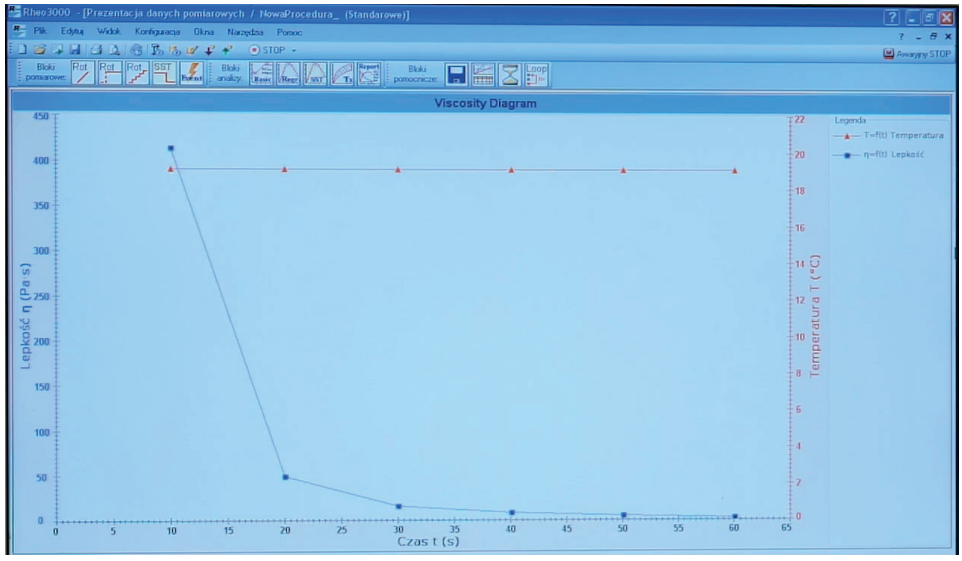

Figure 24. A frame from the instructional video 'Viscosity measurement of selected ointment substrates' showing the presentation of measurement results

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4. Discussion

The section presents an analysis of teaching outcomes on the basis of prepared e-materials tailored for selected professions in the medical industry (Table 1, Table 2, Table 3, Table 4). In addition, it aims to formulate recommendations and guidelines for the design and creation of multimedia and interactive resources, paying particular attention to educational values and content (Leszczyński et al., 2020). This discussion is an integral part of the broader discourse on standards for developing innovative educational materials, with a specific focus on their application at the academic level, not solely within the medical industry (Kanikowska et al., 2023; Roszak, 2019). These recommendations are based on the extensive teaching experience of the project's authors, who possess considerable expertise in e-education development.

The deliberate inclusion of frequently recurring multimedia types across various professions is a noteworthy aspect. Their implementation, influenced by the specifics of a given profession and the presented content, demonstrates variations, which serves as an example and inspiration or effectively employing the same multimedia elements to achieve diverse educational outcomes.

Table 1.
Medical Sterilization Technician

e-material	e-material aim	Student benefit	Recommendations, indications
Simulator	Learning about and performing the process of operating equipment	• Independently performs each step of the process, • Availability of equipment used in central sterilization facilities, • Preparedness to proceed in the event of an error/defect in the equipment	Visuals representing reality are required
3D animation	Presentation of medical instruments and devices	• The ability to observe in detail (i.e., step by step and in the correct order) both the assembly and disassembly of instruments, medical equipment	Requires graphics that accurately depict the construction and operation of the tool
Instructional video	Presentation of the everyday activities of a central sterilization room employee	• Opportunity to see the everyday activities of the employee in detail • Familiarization with the equipment and its operation	It is important to demonstrate the complete process accurately

S o u r c e: Authors' own work.

Recommendations relevant to the multimedia presented in the medical sterilisation technician profession: realism (reflecting reality), detail (accuracy of the process), construction and functioning of the process/apparatus.

Table 2.
Massage Therapy Technician

e-material	e-material aim	Student benefit	Recommendations, indications
Education video with 3D animations	Spatial presentation of human skin	The opportunity to learn about the layered structure and distribution of receptors in space - understanding the response of skin elements to a given massage technique	High quality animation creation in close consultation with an industry expert is required
Video sequences	Presentation of how to perform manual lymphatic drainage	Getting acquainted with the complete procedure and all its elements	A detailed presentation of the process is necessary, from the preparation of the workstation to the completion of the procedure
SBL (Scenario-based learning)	Deciding how to perform a facial care massage	The possibility to go through all the stages of the treatment yourself, the possibility to see the correct massage technique	The game should be based on film material, Tasks should be based on cause-effect relationships

S o u r c e: Authors' own work.

Recommendations relevant to the presented multimedia in the profession of a massage therapist: detailed presentation, cause-and-effect tasks (reflecting reality), high production quality.

Table 3.
Occupational Therapy Technician

e-material	e-material aim	Student benefit	Recommendations, indications
SBL (Scenario-based learning)	Making decisions ad setting therapy goals	• Independent comprehensive therapy planning, • The possibility of making a mistake, without consequences for the patient, • Taking responsibility for the decisions made, • Showing the consequences of the decisions made	Decisions made should have consequences, which affects the fate of the patient

Video sequences	• Presentation of the work of the therapist in the hygiene and household task workshops, • Familiarization with the types of training in social skills workshops	• Presentation of an exemplary therapeutic process, • Acquisition of skills to create scenarios for a daily living workshop	After each sequence, the student should solve a short task that consolidates knowledge and adds variety to the content
Interactive documentation	Completion of interactive forms	• Independent planning of the therapeutic process on diagnosis, • Analysis of the recommendations of specialists and a multidisciplinary team, • Ongoing feedback on the correctness of the completion of documents	Should present realistic case descriptions, which affects the effective absorption of knowledge

S o u r c e: Authors' own work.

Recommendations relevant to the presented multimedia in the occupational therapy technician profession: realistic case descriptions, cause-and-effect tasks.

Table 4.
Pharmacy Technician

e-material	e-material aim	Student benefit	Recommendations, indications
Virtual tour	• Getting acquainted with the interior of a general pharmacy, • Getting acquainted with the activities performed in a pharmacy and the tasks of the staff of various positions	• The opportunity to see how the premises of the pharmacy are interconnected, • The opportunity to enter places that are normally difficult to access	It is worth to enable different ways to take a virtual tour, such as „entering and exiting" the rooms one by one or selecting a room from the floor plan
Interactive documentation	Completion of documentation related to adverse drug reactions, monitoring of the temperature range in the pharmacy, return and refund form of pharmacy goods	The ability to complete the documentation yourself and verify its completion.	Documentation should include a description of the case to give realism to the situation.
Instructional video	Demonstration of how to measure the viscosity of ointment substrates and determine the dynamic viscosity of ointments.	• Demonstration of operation and use of equipment, • Rotational rheometer, • Great detail, accuracy of presented process	Should include examples of actual measurement results

S o u r c e: Authors' own work.

Recommendations relevant to the multimedia presented in the profession of a pharmacy technician: diversity of message, real examples (realism).

Common recommendations in the design and creation of multimedia for healthcare professions based on the examples presented in the article

Regardless of the type of multimedia, the profession and the content, they should be based on a high level of detail of the presented process/situation combined with a high production quality. In addition, it is crucial to present real-life situations/cases that the learner will encounter in future professional work (realism of the situation). The level of interactivity and interaction in the prepared multimedia (task/action/decision-making) is also important, together with the cause-effect presentation for common everyday tasks in every profession.

5. Conclusions

Multimedia and interactive resources allow for a comprehensive and detailed presentation of the issues necessary for future professional work in the medical field. Through visual media like graphics, videos, and 3D animations, coupled with auditory components like voiceovers and sound elements, students actively engage in the learning process, reinforcing and verifying their acquired knowledge to immerse themselves in the role of a medical professional, meticulously performing the step-by-step tasks and activities integral to their daily practice. It is worth remembering that case study-based resources are a very important educational method, especially for the medical profession, where critical thinking and analytical skills are essential in clinical work (Allen et al., 2019).

The effectiveness of a multimedia resource in achieving learning outcomes varies, and not all outcomes can be met using the same e-material. In addition, creating e-materials requires to know the types of multimedia and interactive elements and their characteristics. It is important to remember that multimedia elements share the common characteristics of realism, interactivity and detail. Successful design and execution demand collaboration with subject matter experts experienced in e-learning production. Examples of the use of e-materials in various fields can provide inspiration and suggestions for their use in the education of other professions.

References

Allen, D. D. & Toth-Cohen, S. (2019). Use of Case Studies to Promote Critical Thinking in Occupational Therapy Students. *Journal of Occupational Therapy Education,* 3(3). https://doi.org/10.26681/jote.2019.030309.

Grześkowiak, M., Chudzicka-Strugała, I., Zwoździak, B., Swora-Cwynar, E., Nijakowski, K., Jokiel, M. & Roszak, M. (2020). E-learning during the coronavirus pandemic – creating educational resources for teaching medical students. *Studies in Logic, Grammar and Rhetoric*, 64(1), 77−97. https://doi.org/10.2478/slgr-2020-0041.

Hookham, G., Nesbitt, K., Cooper, J. & Rasiah, R. (2014). Developing a Virtual Tour of a Community Pharmacy for use in Education. *IT in Industry*, 2(1). https://doi.org/10.17762/itii.v2i1.10.

Hwang, N. K., Shim, S. H. & Cheon, H. W. (2023). Digital learning designs in occupational therapy education: a scoping review. *BMC Medical Education*, 23(7). https://doi.org/10.1186/s12909-022-03955-x.

Kanikowska, D., Roszak, M. & Bręborowicz, A. (2023). E-learning during the COVID-19 pandemic. *Medical Education (Japan),* 54, suppl., p. 222 (abstr. IP-A2), *55th Annual Meeting of the Japan Society for Medical Education*. Nagasaki, Japan, Jul 28–29, 2023. p-ISSN: 0386-9644.

Kirkova-Bogdanova, A., Taneva, D., Tsokova, Y. & Marchev, Y. (2017). E-learning in pre-graduate healthcare training – good practice across the world. *KNOWLEDGE – International Journal*, 19(4): 1569–1575.

Leszczyński, P. K., Roszak, M., Binkowska, A., Świniarski, P., Wilk, A., Charuta, A., Zacharuk, T. & Kononowicz, A. A. (2020). E-learning practice at medical universities in Poland in the perspective of the SARS-CoV-2 pandemic. *Studies in Logic, Grammar and Rhetoric*, 64(1), 35−58. http://dx.doi.org/10.2478/slgr-2020-0039.

McAlister, R. B. (2014). Use of Instructor-Produced YouTube® Videos to Supplement Manual Skills Training in Occupational Therapy Education. *The American Journal of Occupational Therapy*, 68(Supplement_2), S. 67–S72. https://doi.org/10.5014/ajot.2014.685S04.

Nagata, M., Chino, H., Yasuhara, T. & Noma, H. (2022). Disaster medical education for pharmacy students using video recordings of practical disaster drills. *Currents in pharmacy teaching & learning*, 14(5): 582−590. https://doi.org/10.1016/j.cptl.2022.04.002.

Olivier, B., Verdonck, M. & Caseleijn, D. (2020). Digital technologies in undergraduate and postgraduate education in occupational therapy and physiotherapy: a scoping review. *JBI Evidence Synthesis* 18(5): 863−892. https://doi.org/10.11124/JBISRIR-D-19-00210.

Roszak, M. (2019). Ocena przydatności e-learningu w kształceniu medycznym z zakresu patofizjologii. Wydawnictwo Naukowe Uniwersytetu Medycznego im. Karola Marcinkowskiego w Poznaniu. p-ISBN: 978-83-7597-376-1.

Roszak, M., Leszczyński, P. K., Starosta, K., Wiktorzak, P., Torres, K., Świniarski, P. & Kononowicz, A. A. (2020). E-learning w kształceniu medycznym. Panorama e-edukacji w Polsce. Warszawa, Oficyna Wydawnicza Politechniki Warszawskiej, 73–89. ISBN: 978-83-8156-145-7.

Roszak, M., Mokwa-Tarnowska, I. & Markowska, J. (2023). E-learning practice and future education at universities in Poland. International Conference (hybrid mode) on "*Current developments in mathematical sciences and e-learning*". Ratlam, India, 16 January 2023.

Roszak, M., Sawik, B., Stańdo, J. & Baum, E. (2021). E-Learning as a factor optimizing the amount of work time devoted to preparing an exam for medical program students during the COVID-19 epidemic situation. Healthcare, 9(9), 1147. https://doi.org/10.3390/healthcare9091147.

Rowan, N. J., Kremer, T. & McDonnell, G. A. (2023). Review of Spaulding's classification system for effective cleaning, disinfection and sterilization of reusable medical devices: Viewed through

a modern-day lens that will inform and enable future sustainability. *Science of The Total Environment*, 878: 162976. https://doi.org/10.1016/j.scitotenv.2023.162976.

Roy, H. (2017). The role of e-learning in medical education. *Academic Medicine*, 92(4): 430. https://doi.org/10.1097/ACM.0000000000001596.

Silva, R. d. O. S., de Araújo, D. C. S. A. & dos Santos Menezes, P. W. (2022). Digital pharmacists: the new wave in pharmacy practice and education. *International Journal of Clinical Pharmacy*, 44(3): 775−780. https://doi.org/10.1007/s11096-021-01365-5.

Smelkowska, A., Karbownik, A., Szczeszek, K., Zaorska, K., Siwiec, S., Purandare, B., Jokiel, M., Keczmer, P., Jankowski, M., Sienicki, K. & Roszak, M. (2023). Interaktywne i multimedialne materiały dla branży medycznej jako propozycja ogólnopolskiego standardu kształcenia w środowisku zdalnym. IX Konferencja „e-Technologie w Kształceniu Inżynierów". Kraków, 19−20 września 2023. Centrum e-Learningu i Innowacyjnej Dydaktyki AGH, 2023: 33. p-ISBN: 978-83-963036-3-9.

Smith, S. J., Farra, S., Ulrich, D., Hodgson, E., Nicely, S. & William, M. (2016). Learning and retention using virtual reality in a decontamination simulation. *Nursing Education Perspectives*, 37(4): 210–214. https://doi.org/10.1097/01.NEP.0000000000000035.

Szczeszek, K., Smelkowska, A., Karbownik, A. & Roszak, M. (2023). Game based learning. The big book of online education for academics and other teaching proffesionals. Eds: Alina Guzik, Iwona Mokwa-Tarnowska, Marek Chodnicki. Gdańsk University of Technology: 104−113.

Tabakova, V. (2020). E-learning – from first experiences in medical physics and engineering to its role in times of crisis. *Health and Technology*, 10: 1385−1390. https://doi.org/10.1007/s12553-020-00474-x.

Unge, J., Lundh, P., Gummesson, C. & Amnér, G. (2018). Learning spaces for health sciences – what is the role of e-learning in physiotherapy and occupational therapy education? A literature review. *Physical Therapy Reviews*, 23:1, 50−60. https://doi.org/10.1080/10833196.2018.1447423.

Wong, K. L. & Chan Mei Ling, D. (2016). Using online and scenario-based learning to improve nurse-patient interaction and enhance patient experience. *World Hospitals and Health Services*, 2016; 52(2): 31−37.

Yilmaz, D. U., Palandoken, E. A., Ceylan, B. & Akbyik, A. (2020). The effectiveness of scenario-based learning to develop patient safety behavior in first year nursing students. *International Journal of Nursing Education Scholarship*, 17(1). https://doi.org/10.1515/ijnes-2020-0011.

Anna Smelkowska, Agnieszka Karbownik, Barbara Purandare, Katarzyna Zaorska, Marta Jokiel, Maurycy Jankowski, Magdalena Roszak

Interaktywne kształcenie asynchroniczne w edukacji medycznej w Polsce – wzorcowe przykłady

Streszczenie

W kształceniu osób mających wykonywać zawody medyczne bardzo ważne jest gruntowne przygotowanie merytoryczne i praktyczne. Dzisiejszy odbiorca wiedzy oczekuje różnego rodzaju zasobów multimedialnych i interaktywnych. W artykule omówiono przykłady takich realizacji dla ogólnopolskiego kształcenia technika farmaceutycznego, technika masażysty, technika sterylizacji medycznej, technika terapii zajęciowej. Tworzono je z myślą o zastosowaniu na Zintegrowanej Platformie Edukacyjnej Ministerstwa Edukacji i Nauki w Polsce w ramach projektu unijnego. Zde-

finiowano cechy charakterystyczne dla e-materiałów, takich jak: film instruktażowy i edukacyjny, sekwencje filmowe, gra typu scenario-based learning, dokumentacja interaktywna, animacja 3d, symulator i wirtualna ścieżka edukacyjna. Przygotowano analizę zysków dla uczącego się na bazie omówionych e-materiałów. Podjęto także próbę zbudowania zaleceń i wskazań przy projektowaniu i tworzeniu edukacyjnych zasobów multimedialnych i interaktywnych, zwracając szczególną uwagę na metody kształcenia i treści merytoryczne dla branży medycznej. Niezależnie od typu multimediów, zawodu i treści merytorycznych powinny one bazować na realizmie, interaktywności i szczegółowości prezentowanych sytuacji/przypadków. Nie wszystkie cele dydaktyczne i efekty kształcenia można zrealizować za pomocą tego samego multimedium. Aby dobrze zaprojektować i wykonać multimedia, konieczna jest znajomość ich cech charakterystycznych oraz praca zespołu ekspertów – autorów merytorycznych z doświadczeniem w tworzeniu e-edukacji.

S ł o w a k l u c z o w e: edukacja medyczna, multimedia, zasoby interaktywne, e-materiały, ewaluacja, blended-learning, wideo, dokumentacja interaktywna, animacja, symulacja, wirtualne ścieżki edukacyjne, edukacja zdalna, technik sterylizacji medycznej, technik farmaceutyczny, technik terapii zajęciowej, technik masażysta

Anna Smelkowska, Agnieszka Karbownik, Barbara Purandare, Katarzyna Zaorska, Marta Jokiel, Maurycy Jankowski, Magdalena Roszak

Ejemplos de éxito de la enseñanza asíncrona en la educación médica interactiva a distancia polaca

R e s u m e n

Una preparación teórica y práctica exhaustiva es crucial en la educación de las profesiones médicas. El receptor actual de conocimientos espera diversos tipos de recursos multimedia e interactivos. En este artículo se analizan ejemplos de este tipo de implementaciones para la educación a nivel nacional de técnico de farmacia, técnico de masajes, técnico de esterilización médica y técnico de terapia ocupacional. Estos ejemplos se crearon para la Plataforma de Educación Integrada del Ministerio de Educación y Ciencia de Polonia, en el marco de un proyecto financiado por la UE. Se definieron las características de los materiales electrónicos, como vídeos instructivos y educativos, secuencias de películas, juegos de aprendizaje basados en escenarios, documentación interactiva, animaciones en 3D, simuladores y visitas virtuales. Se preparó un análisis de los beneficios para el alumno basado en los materiales electrónicos analizados. También se intentó elaborar recomendaciones y directrices para el diseño y desarrollo de recursos multimedia e interactivos, prestando especial atención a los valores y contenidos educativos para la industria médica. Independientemente del tipo de multimedia, la profesión y el contenido deben basarse en el realismo, la interactividad y el detalle de las situaciones/casos presentados. No todos los objetivos y resultados del aprendizaje pueden alcanzarse con el mismo multimedia. Para diseñar y producir bien los multimedia, es necesario conocer sus características y trabajar con un equipo de expertos en la materia con experiencia en el desarrollo de la educación electrónica.

P a l a b r a s c l a v e: educación médica, multimedia, recursos interactivos, e-materiales, evaluación, blended-learning, vídeo, documentación interactiva, animación, simulador, visita virtual, educación a distancia, técnico de esterilización médica, técnico de farmacia, técnico de terapia ocupacional, técnico de masajes

A. Smelkowska, A. Karbownik, B. Purandare, K. Zaorska, M. Jokiel, M. Jankowski, M. Roszak

Анна Смелковска, Агнешка Карбовник, Барбара Пурандаре, Катажина Заорска, Марта Йокель, Маурици Янковски, Магдалена Рошак

Успешные примеры асинхронного обучения в польском интерактивном дистанционном медицинском образовании

Аннотация

Тщательная теоретическая и практическая подготовка имеет решающее значение при обучении медицинским специальностям. Современный получатель знаний ожидает использования различных видов мультимедийных и интерактивных ресурсов. В статье рассматриваются примеры таких реализаций для общенационального образования по специальностям «фармацевт», «массажист», «техник по медицинской стерилизации» и «техник по трудовой терапии». Эти примеры были созданы для Интегрированной образовательной платформы Министерства образования и науки Польши в рамках проекта, финансируемого ЕС. Были определены характеристики электронных материалов, таких как учебные и образовательные видеофильмы, кинофильмы, учебные игры по сценариям, интерактивная документация, 3D-анимация, симуляторы и виртуальные туры. На основе рассмотренных электронных материалов был подготовлен анализ преимуществ для обучающихся. Также была предпринята попытка выработать рекомендации по проектированию и разработке мультимедийных и интерактивных ресурсов, обратив особое внимание на образовательную ценность и контент для медицинской. Независимо от типа мультимедиа, профессия и содержание должны быть основаны на реалистичности, интерактивности и детализации представленных ситуаций/случаев. Не все цели и результаты обучения могут быть достигнуты с помощью одного и того же мультимедийного средства. Для того чтобы хорошо разработать и создать мультимедиа, необходимо знать характеристики мультимедиа и работать с командой экспертов в предметной области, имеющих опыт разработки электронного образования.

Ключевые слова: медицинское образование, мультимедиа, интерактивные ресурсы, электронные материалы, оценка, смешанное обучение, видео, интерактивная документация, анимация, симулятор, виртуальный тур, дистанционное образование, техник медицинской стерилизации, техник аптеки, техник трудовой терапии, техник массажа

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Krzysztof Dziedzic
Lublin University of Technology, Poland
https://orcid.org/0000-0003-4909-9980

Marcin Barszcz
Lublin University of Technology, Poland
https://orcid.org/0000-0002-9061-4414

Tomasz Wiśniewski
Euro-Forum, ul. Graniczna 4/7,8, 20-010 Lublin, Poland
https://orcid.org/0009-0007-4478-0968

Adaptation of the E-Learning Exercise Creator to the Needs of People with Disabilities with Impaired Access to Education

Abstract

This article focuses on the implementation of the WCAG (Web Content Accessibility Guidelines) 2.1 guidelines into e-learning courses. The Quizer e-learning platform, which enables the creation of interactive multimedia courses, has provided the basis for the introduction of the WCAG component. The platform includes two basic tools: an exercise creator and an exercise presenter. Once the Quizer Platform Exercise Wizard was analysed, a component was conceptualised and implemented to create e-learning courses compliant with WCAG guidelines and dedicated to people with disabilities. The technology for the implementation of this component was also presented. The function and validity of navigation through the courses using the keyboard and the use of screen readers were discussed as well. The research on the correctness of the WCAG standard implementation into e-learning courses was conducted with the use of designed cyber security quizzes. The final results of quizzes prepared according to WCAG guidelines and without WCAG were also compared. The research involved students majoring in computer science at Lublin University of Technology. Its results indicate the validity of using

the WCAG guidelines in the design of educational content for students with disabilities and equalizing their educational opportunities.

K e y w o r d s: e-learning, exercise creator, multimedia courses, WCAG

Introduction

Digital accessibility is currently one of the most important features of the content of websites, computer programs and mobile applications. This also applies to e-learning applications and platforms. The content, platforms and tools used in e-learning should be accessible to everyone, regardless of their skills, disabilities, equipment or other limitations. Failure to meet the digital accessibility standards in e-learning may cause difficulties in accessing education, in particular for people with disabilities, such as vision, hearing and mobility impairments. According to the data of the Statistical Office in Poland, in the academic year 2021/22, 19.9 thousand people with disabilities were educated at universities (1.7% of the total number of students). At many universities in this period, remote or mixed teaching was in force (some classes were held on-site and some remotely). The transition to distance learning on such a huge scale has caused many difficulties. One of them was often the lack of digital accessibility according to the applicable guidelines of the WCAG 2.1 standard. The then ongoing SARS-CoV-2 virus pandemic showed that the need to switch from higher education to remote learning should also take into account the needs and capabilities of people with disabilities in access to education. Therefore, an important topic in the area of e-learning is the development of digital accessibility of the solutions offered and determining its impact on the education of people with disabilities. It is worth emphasizing that digital accessibility is not only often a legal requirement, but also a moral responsibility enabling education for everyone, regardless of their individual limitations. Therefore, e-learning content creators should regularly test the digital accessibility of their materials, including interactive elements such as quizzes. It is important that people with different needs have equal opportunities to participate and understand this content.

The main aim of the article was to:

1. Create a component compatible with the interactive platform Quizer.pl that enables the creation of interactive exercises adapted to the WCAG 2.1 guidelines for people with disabilities, mainly visual impairments.
2. Assess the correctness of implementing the WCAG component into the Quizer elearning platform based on the feedback from users of cybersecurity courses.

The research questions RQ1-RQ5 of this study are:

RQ1. What specific elements and tools in the Quizer platform do need to be adapted to enable compliance with the WCAG 2.1 guidelines?
RQ2. What are the reactions and opinions of IT students about the new e-learning courses adapted to the needs of people with visual impairments?
RQ3. Did students with simulated visual impairment experience improvement in access to education thanks to the use of WCAG 2.1 in the designed e-learning courses?
RQ4. Does the use of WCAG guidelines in quiz preparation and presentation affect the results achieved by people with disabilities compared to the results of people using a standard quiz without WCAG?
RQ5. How did the students assess the correctness of the implementation of the WCAG 2.1 standard in the created quizzes from the point of view of cybersecurity?

The hypotheses H1-H4 of the research are:

H1. Adaptation of the Quizer e-learning platform to the WCAG 2.1 guidelines will have a positive impact on the accessibility of education for people with visual impairments who have difficult access to education.
H2. Creating dedicated e-learning courses in accordance with WCAG 2.1 guidelines will contribute to increasing the participation of people with visual impairments in the educational process.
H3. Preparing the quiz in accordance with WCAG guidelines will allow people with disabilities to achieve results at a level comparable to the results of people using a standard quiz without WCAG.
H4. The functionality of keyboard navigation and screen reader support in WCAG 2.1 compliant e-learning courses will be effective for people with various types of vision impairment.

Research Background

Many scientific articles discuss and examine the quality of life (QoL) of students with disabilities and their access to education (Chatzoglou et al., 2023). Madhesh in his work (Madhesh et al., 2023) points to a clearly lower quality of life (QoL) of students with disabilities at Shaqra University in Saudi Arabia. The factors mentioned include the failure to take into account all the needs of students with disabilities and low awareness among lecturers and peers of disabilities and their impact on the learning process. It further indicates that curricula and teaching tools did not meet the needs of these students and their demands for equal access. Contreras et al. documented in their study (Contreras et al., 2023) the significant impact of the pandemic on access to higher education for students with disabilities

in Chile. The access to education was limited for everyone, and it especially affected students with disabilities. As a conclusion, they emphasized the need for further actions aimed at increasing access to education and equalizing opportunities. Brain and Mariani in their work (Brain & Mariani, 2023) analyse the difficulties in equalizing accessibility for students with disabilities in Australia. They point out that despite government support, there are still significant differences between students without and with disabilities in terms of access to education, quality of life and educational achievements. Rizk and Hillier in their work (Rizk & Hillier, 2022) describe the roles of digital technologies in improving access to education and engagement of students with disabilities. Research shows that digital technology provides significant support for students with disabilities, enabling them to actively participate in classroom activities. The authors note that the use of IT tools significantly increases the interaction between students with disabilities and teachers and their peers. Despite progress in equalizing access to education for students with disabilities around the world, there is still a need for further work in this area. The development of programs, methods, teaching tools and courses that take into account the needs of these people undoubtedly contributes to equal educational opportunities. Burgstahler et al. (2004) emphasize in their work that distance learning creates learning opportunities for everyone if accessibility issues are taken into account in the process of designing university courses. Otherwise, unnecessary barriers may arise that hinder equal participation in education and careers for potential students and teachers with disabilities.

In today's society, the development of information and communication technologies plays an important role in many areas of life, such as medicine (Kabyshev & Kovalchuk, 2019), industry (Mon & René Del Giorgio, 2021), interpersonal communication (Lee, 2023), and organizational management. However, one area where the impact of these technologies is particularly evident is education (Fernández-Gutiérrez et al., 2020; Val et al., 2010; Rosa & Obillos, 2016), and specifically the development of e-learning, which is teaching based on internet technologies (Alfonso & Garcia, 2015; Petrovic et al., 2014). E-learning offers numerous benefits, such as accessibility, time and geographic flexibility, as well as individualization of the learning process (Stofkova et al., 2017). Through e-learning, students have the opportunity to acquire knowledge and skills in a flexible manner, tailored to their individual needs and pace of work. Regardless of location or time, education can be obtained remotely, using interactive e-learning platforms, video conferences, multimedia materials, and other digital tools. E-learning also enables access to diverse educational content, both in the form of online courses and self-study materials. As a result, students have the chance to develop their skills in various fields, regardless of the availability of local schools or universities. However, despite these advantages, many people with disabilities face barriers to accessing elearning-based education due to limitations resulting from their disabilities (Calvo et al., 2012). The World Health Organization estimates that over one billion peo-

ple worldwide experience some form of disability, and approximately 93 million children live with disabilities that affect their access to education. People with disabilities have various types and degrees of limitations that may affect their ability to engage with traditional teaching methods. Some of these limitations may stem from difficulties in physical access to buildings, visual or hearing impairments, cognitive disorders, or difficulties in interacting with computers. Many individuals with disabilities experience barriers to accessing education at different stages of life, leading to social exclusion and hindering the acquisition of qualifications and skills needed in the job market.

To mitigate these inequalities and ensure equal access to education for all, there is a need to develop educational tools and e-learning platforms that cater to the needs of people with disabilities (Ulbricht et al., 2011; Maćkowski et al., 2018). One such tool is the e-learning exercise creator, which enables the creation of interactive educational tasks and materials. However, many existing e-learning exercise creators do not meet the accessibility standards for people with disabilities, such as the guidelines specified in WCAG 2.1 (Web Content Accessibility Guidelines) (Germano & Silveira, 2022). WCAG 2.1 is an international standard that defines guidelines for web content accessibility for people with disabilities (Fernandez-Diaz et al., 2019; Sanchez et al., 2022). These guidelines address accessibility issues related to vision, hearing, speech, learning, cognition, mobility, language, and neurological impairments. Disabilities can occur singly or in complex forms, comprising multiple disabilities with varying degrees of severity. Each type of disability requires the application of different techniques to enable access to information on websites. Success criteria are specified for each guideline (Aizpurua et al., 2016; Filipe et al., 2023). This allows for the application of the WCAG standard in developed solutions and the verification of their compliance with the guidelines. The WCAG 2.1 guidelines define three levels of conformance: A (lowest), AA, and AAA (highest). It is important to note that achieving content compliance at the highest level (AAA) does not guarantee accessibility for individuals with all types and degrees of disabilities, especially those with complex disabilities. The design of software and e-learning courses should also take into account the needs of people with disabilities (Romero Mariño et al., 2018; Persson et al., 2015). This standard focuses on ensuring that individuals with different types of disabilities can access online content without any limitations. Adapting e-learning exercise creator tools to incorporate WCAG guidelines aims to enhance accessibility for people with disabilities, allowing them to use these educational tools on an equal basis with able-bodied individuals (Laabidi et al., 2014). Consequently, work is being done to develop new educational tools and e-learning platforms tailored to the needs of people with disabilities, as well as to examine the accessibility of existing ones. The authors of a study (Bocevska et al., 2018) analyzed the accessibility of recent public platforms, such as Moodle, Eliademy, Docebo, Sakai, and ATutor, for people with disabilities. They observed that the considered criteria have varying levels of

compliance with the guidelines for web content accessibility (WCAG) 2.0. The analysis focused on visual, auditory, and motor impairments. Accessibility testing of the Moodle system, specifically for visual impairments, was also conducted in another study (Armano et al., 2018). Four individuals with varying degrees of visual impairment participated in the study. Królak and Zając (Królak & Zając, 2022) conducted an analysis of Massive Open Online Courses (MOOCs) available on the Coursera platform in terms of their accessibility for users with disabilities. MOOCs are courses available to a large number of participants via the internet. The analysis was conducted in accordance with guidelines developed by the World Wide Web in three ways: user testing, heuristic evaluation, and automated auditing using various web tools. Despite the continuous development of the Coursera platform, the introduction of new improvements, and the implementation of accessibility policies, study participants still encountered barriers in terms of digital accessibility. An article by Seale & Cooper (2010) reviewed a range of tools that facilitate the work of teachers in higher education and enable the development of accessible e-learning materials and activities for students with disabilities. Brown et al.(2022) presented the fundamental principles of digital accessibility and the standards by which it is defined, as well as the technologies used by individuals with disabilities to interact with the online world. Reflecting on their own experiences with digital accessibility in the university sector, the authors propose a four-quadrant model of institutional support for accessible online teaching.

The e-learning exercise creator plays a crucial role in the instructional process by providing interactive learning and assessment materials. Adapting this tool to the needs of people with disabilities can improve their educational experiences and ensure equal opportunities for educational advancement. Various adaptations can be considered, such as providing alternative formats for textual and multimedia content, incorporating technologies that assist with navigation and interaction, and implementing user-friendly interfaces that prioritize usability and accessibility (Yang et al., 2023). Adapting the e-learning exercise creator to the needs of people with disabilities is not only important from the perspective of access to education but also a step towards building a more inclusive society. Ensuring equal access to education for all individuals, regardless of their disabilities, contributes to the development of their potential, social integration, and increased opportunities for full participation in society.

Methodology of Research

General Background. Selection of technologies for building the WCAG component

When creating the software and e-learning courses, the WCAG 2.1 guidelines were taken into account, thereby enabling the accessibility of course content for individuals with disabilities, primarily visual impairments. The basis for introducing the WCAG component was the Quizer e-learning platform (Quizer, n.d.), which allows for the creation of interactive multimedia courses. The platform consists of: "Exercise Creator" and "Presenter". The Quizer platform operates on the Oktawave cloud infrastructure, providing consistent platform support across various devices such as PCs, laptops, tablets, and smartphones. The virtual server of the Quizer platform application runs on the Linux-Debian operating system. The development of the platform utilized programming technologies such as Backbone JS, Bootstrap, PHP language, Laravel framework, and MySQL (Dziedzic, 2021). Users can create their individual accounts and gain access to the platform's resources. The "Interactive Exercise Creator" on the Quizer.pl platform enables the creation of presentations and interactive exercises. It allows for the creation of exercises such as pick one, pick many, drag and drop, fill in the blanks, or connect with lines. The "Interactive Exercise Creator" consists of content management modules and an editor for creating courses that facilitate data exchange between the portal and publishing (Dziedzic, Gudków & Wiśniewski, 2020). The diagram of the "Exercise Creator" is shown in Figure 1.

To enable the creation and solution of quizzes in accordance with WCAG guidelines, the following modifications were necessary in the "Exercise Creator" tool:

3. Development of a WCAG component that allows for keyboard and screen reader support in courses, as well as designing courses compliant with WCAG 2.1 guidelines, followed by its implementation into the "Exercise Creator" tool.
4. Addition of a WCAG tab to the Exercise Creator with the ability to enter alternative texts and indicate which elements should be considered by the screen reader. By utilizing an alternative text, non-text elements such as images, decorative graphics, icons, charts, animations, etc., can be processed by the screen reader and provide information about their content.
5. Enabling the screen reader to interpret the HTML code of the exercise and read alternative texts.
6. Allowing for the highlighting of selected elements to visually indicate the currently active element for visually impaired users.
7. Providing the ability to adjust and assess the contrast according to WCAG guidelines for the designed courses.

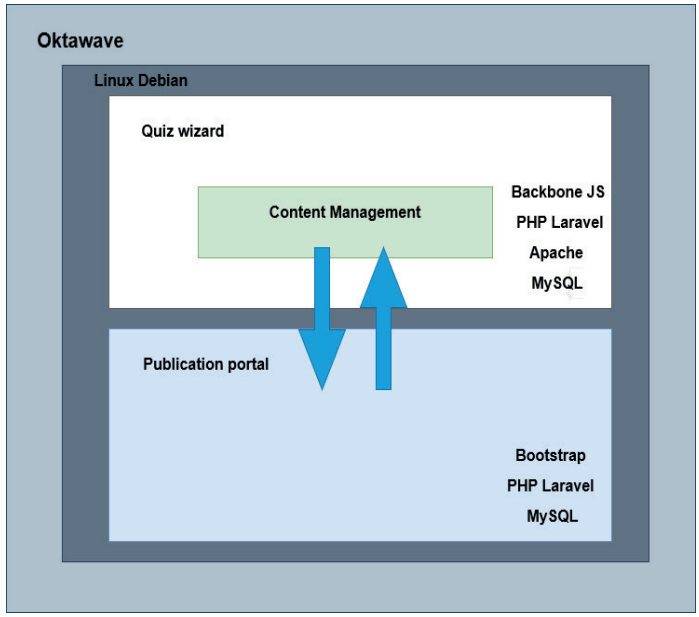

Figure 1. General schematic of the construction of the "Exercise Creator" in the Quizer e-learning platform

S o u r c e: Own work.

The frontend part of the "Exercise Creator" is built using Backbone JS technology. All modifications and new modules were also implemented using Backbone JS to ensure compatibility. Most of the platform's user interface components are programmed in JavaScript. The application incorporates elements such as components, containers, and triggers. A component is a software fragment that can be independently mounted into larger programs, while containers oversee the execution of the component and are implemented by application servers. Triggers are procedures that are automatically executed in response to certain events (Figure 2). Backbone JS is a programming library (framework) that utilizes a model-based data structure. Models are used to perform specific operations, and whenever a user interface action results in a change to a model's attribute, the model triggers a "change" event. All views that display the model's state can be notified of the change, allowing them to react accordingly by re-rendering the model with the updated data. Backbone JS applications follow a structure divided into controllers, views, and models. Backbone JS is event-driven, with events being triggered by changes in data models. All Backbone JS events are described using an event map.

One of the key elements of WCAG guidelines that addresses the needs of individuals with visual impairments is the appropriate contrast of the content presented. This also applies to e-learning courses, where inadequate contrast can limit or prevent the use of the course. In the "Exercise Creator," a component has been

implemented to assess and adjust the contrast of individual elements in relation to each other, ensuring that the designed courses meet specified visibility guidelines. The component is integrated within the "Exercise Creator" and is available upon request for course designers. It was developed in JavaScript, allowing for seamless integration with the Backbone JS framework.

Procedure for designing e-learning quizzes according to WCAG

Tests were conducted using two designed quizzes on the topic of cybersecurity: Types and Identification of Threats in the Network - Phishing. Phishing is currently a very popular method of fraud. The scammer impersonates another person or institution in order to obtain confidential information, infect the computer with malware, or persuade the victim to perform specific actions. The first quiz provided basic information about Phishing. The user's task was to familiarize themselves with or listen to all the information contained in the quiz. The second quiz involved selecting the correct answer to the given questions. The type of quiz used was Pick One (simple choice). To navigate through the courses, appropriate keys and keyboard shortcuts were defined. The following keys and shortcuts were adopted: TAB - to move to the next element on the timeline, SHIFT+TAB - to go back one element, SPACE - to select an answer and confirm the choice. In accordance with the logic of arranging elements in layers on the timeline in the "Quiz Creator" tool, this number of navigation keys is sufficient. As a result, exercising is intuitive for the user, even during their first interaction with the exercise. Additionally, these keys are commonly used for navigating web pages, so users who access online resources navigate through the exercises intuitively and in accordance with familiar procedures. When creating the quiz, all textual, graphical, and auditory elements were added to the stage and arranged on the timeline in layers, planning the TAB navigation path through the elements. The elements that are to be read by a screen reader should be selected and their alternative text should be entered in the WCAG tab. It is also necessary to add user variables to the project, which will store information about which the answer has been selected during the task solving process. Next, triggers were added to each answer checkbox so that specific fields change their state to selected, simultaneously resetting the remaining answers to their initial state. These actions must also include operations on variables that will change along with the user's selection and answer changes. Triggers were added to the button that checks and confirms the user's choice, displaying correct or negative feedback. In the case of the pick one exercise, additional conditions do not need to be applied. The view of the window for the designed quiz with arranged elements on layers on the timeline and adding a trigger is presented in Figure 2. The trigger is supposed to perform the action of showing or hiding objects when a particular object is selected.

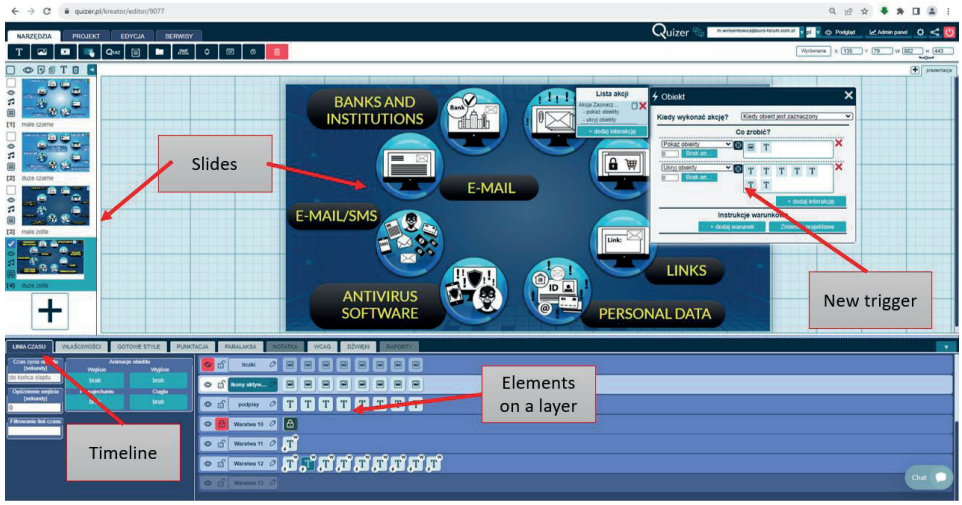

Figure 2. View of arranging textual and graphical elements on layers on the timeline and adding a trigger

S o u r c e: Own work.

Another element used during the creation of quizzes was a component that allowed for examining the contrast of the designed content. The component compares the colors of text and background using color codes in the RGB and HEX formats. By comparing the color combinations, the program returns the contrast value for WCAG AA standards for large and normal text, as well as WCAG AAA standards for large and normal text. Achieving an appropriate contrast ratio between the text and the background resulted in feedback in the form of green highlighting for a given standard. If the contrast criteria were not met, the "tile" with that standard would be highlighted in red. Figure 3a illustrates a comparison of yellow text color against a black background. The green tiles shown indicate that the contrast indicators are met for all four text standards. In Figure 3b, a less contrasting color combination of text and background was used (white text on a blue background). In this case, feedback was received about a too low contrast ratio. Only one out of the four standards is met - such a color combination is acceptable only for the WCAG AA standard for large text. By analyzing individual color combinations and adhering to the obtained results, those preparing exercises adapted to the needs of people with disabilities are able to create projects that meet specific WCAG guidelines and allow visually impaired individuals to fully benefit from such prepared resources. According to the WCAG standard, the minimum required contrast ratio (AA level) is 4.5:1 for regular text and 3:1 for text in the form of headings. The recommended contrast ratio for maximum contrast (AAA level) is 7:1 for regular text and 4.5:1 for text with a high level of enlargement. The presented content can be considered visually friendly and accessible if the contrast reaches at least the minimum level

(AA). An important principle applied in the design of web content (including e-learning) is that color should not be the sole means of conveying information. Users should also have the ability to change the font size of displayed information.

When starting the quiz, each user had the option to choose between a standard course or a course designed according to WCAG guidelines. The quiz could be solved using a mouse (basic version), keyboard and screen reader (WCAG version), or in a mixed system. While solving the quiz with a mouse, the user clicks on the answers, which change their state to selected. In case of changing the decision, by clicking on another answer, the previous selection is automatically removed. In the case of a correct answer, the user receives visual and auditory feedback, and user points are added to the course.

When solving the exercise using the keyboard and screen reader, the user receives information at the beginning that the quiz is adapted for people with disabilities and listens to the task instruction. Then, using the TAB key, the user navigates between the answers and selects one by pressing the spacebar. The selection field changes its state, and the user hears the information from the screen reader. In case of changing the decision, the user clicks the spacebar on another answer, which changes its state to selected and removes the previous selection. After providing the correct answer, the user receives visual and auditory feedback and is awarded points. In the case of an incorrect answer, the user also receives visual and auditory feedback indicating an incorrect response.

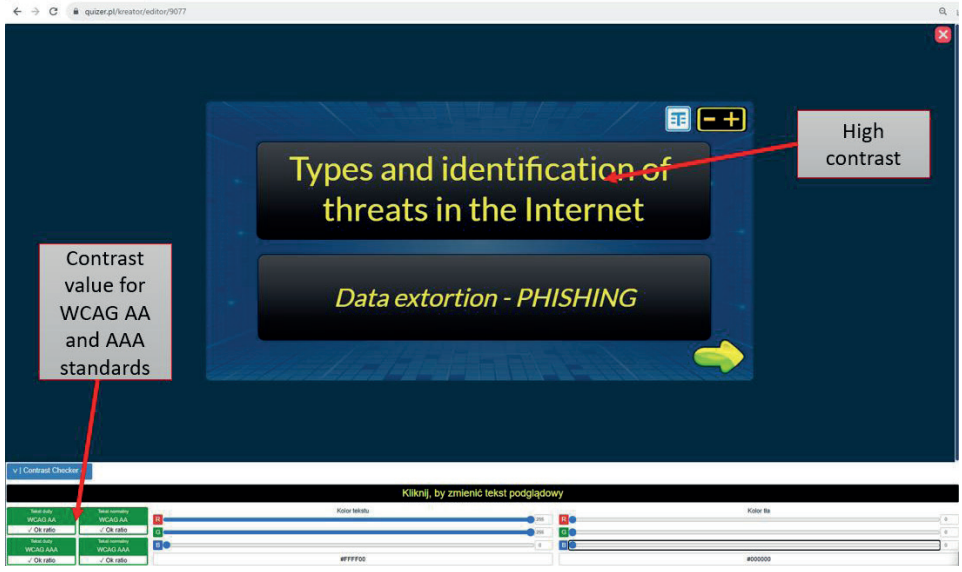

Figure 3a. Example contrast evaluation windows for the designed quiz: high contrast

S o u r c e: Own work.

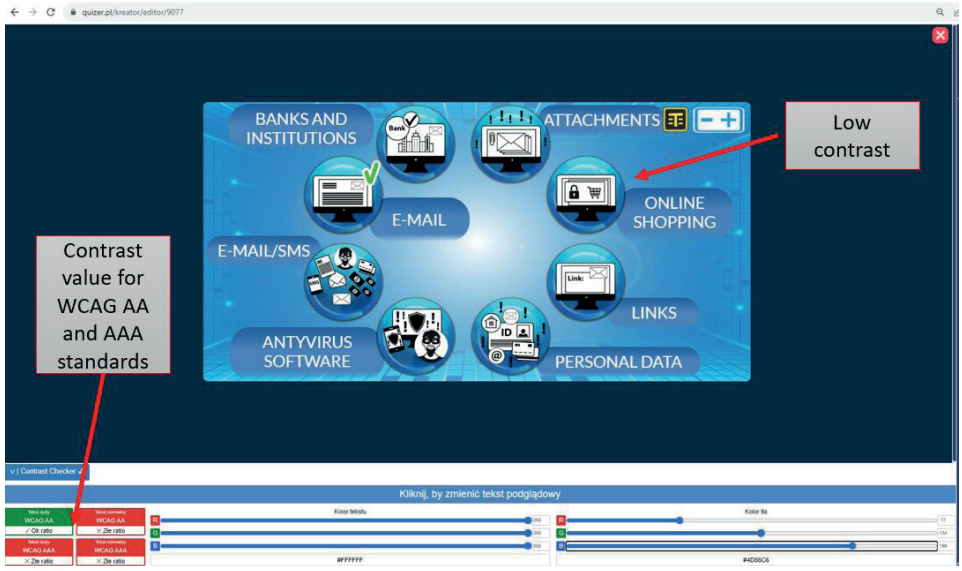

Figure 3b. Example contrast evaluation windows for the designed quiz: low contrast

S o u r c e: Own work.

User Research Methodology for E-Learning Quizzes

The conducted research consisted of verification of the correctness of implementing the WCAG component into the Quizer e-learning platform. The research was carried out in accordance with research ethics principles, involving two groups of individuals: (i) individuals with actual visual impairments and (ii) individuals with simulated visual dysfunction (blind individuals). Simulations of visual impairments were achieved by covering the eyes with a blindfold. The users also utilized headphones to eliminate the influence of the environment on the accurate understanding of the text read by the screen reader. The p articipants were provided with information about the research purpose and the procedure was explained to them. Access to the quizzes (presentation and test) was provided online through a web browser. In the first stage, participants were tasked with familiarizing themselves with the presentation and then completing the test. The test concluded with providing information about the achieved score of correct answers, presented as a percentage. It was assumed that for adult individuals, the time to complete one quiz should not exceed 5 minutes (300 seconds).

After completing the quizzes, the users answered questions in an electronic survey. The survey employed a five-point Likert scale, where: 1-Strongly disagree, 5-Strongly agree. Pilot (survey) studies were conducted with a group of 73 students majoring in Computer Science, aged 20-22, who were all students from Poland. These

students came from both rural and urban backgrounds. The majority of these individuals had already planned to pursue a degree in computer science during their primary school years. While attending university, they utilize an e-learning platform, although it is not compliant with WCAG (Web Content Accessibility Guidelines) standards. The studies were quantitative in nature and conducted in groups of 5 individuals within a dedicated computer laboratory. The tests utilized a standard QWERTY keyboard commonly found in laptops and desktop computers in Poland. The focus was on ensuring that the adaptation of web content for individuals with disabilities had broad applicability and did not require specialized equipment for operation. This solution allows people with disabilities to access online resources regardless of their access to specialized and often costly solutions. The screen reader presented the quiz user with audio feedback based on the acquired information. Screen readers are a form of assistive technology used by individuals who are blind, visually impaired, or have learning difficulties. The NVDA (NonVisual Desktop Access) screen reader was used for the tests. This tool was chosen for its low hardware requirements (minimum 1GHz processor speed, 256 MB RAM, and 90 MB storage space for smooth operation), which do not significantly burden the computer's performance, especially older models. Additionally, this screen reader is freely available, ensuring unlimited access for all users. To facilitate text perception in courses, the ability to change font size was also provided through a dedicated button. At the start of the quiz, users had the option to choose between a version without high contrast and a version with contrast enabled.

In order to compare the final results of quizzes compliant with WCAG (for students with disabilities) with the results of quizzes not adapted to WCAG standards (for students without disabilities), a study was conducted on a group of 73 students using the same quizzes, but without taking into account the WCAG guidelines. Pearson linear correlation coefficient was calculated for the survey data.

Results and discussion

Survey Results

The prepared survey, which was completed by the participants, was divided into two parts. The first part consisted of questions intended only for individuals with simulated visual impairment (blind individuals), while the second part contained questions for individuals with actual visual impairments. In the study with simulated visual impairment, 59 males and 14 females participated, while in the study with actual visual impairments, there were 14 males and 2 females. These individuals had visual impairments ranging from –2 to –6 dioptres and astigmatism. The survey included the questions presented in Table 1.

Table 2
Research Questions Included in the Survey

No.	The content of the question
	Part I
Q1.1	Was the voice information regarding navigation provided in a clear manner upon launching the quiz and throughout its duration?
Q1.2	Does the use of a keyboard enable navigation through the designed e-learning courses?
Q1.3	Does the screen reader recognize and interpret the elements of the e-learning course displayed on the computer monitor?
Q1.4	Does the applied screen reader correctly pronounce the content within the quiz?
Q1.5	Is there any repetitive content causing the screen reader to stutter?
	Part II
Q2.1	Is it clear which element is active during the navigation?
Q2.2	Did the contrast change improve the visibility of displayed content?
Q2.3	Did you notice an improvement in text quality after changing the font size?

The results of the survey, after answering the research questions, are presented in Figures 4–6. Figures 4–5 show the results for the first research group, which includes individuals with simulated visual impairment (blind individuals). Figure 7, on the other hand, represents the second research group consisting of individuals with actual visual impairment.

Figure 4 presents the results of responses to questions Q1.1 and Q1.2. In the case of the response to question Q1.1, over 75% of users expressed a positive opinion regarding the comprehensibility of voice instructions related to quiz navigation. 18% of users had no opinion ("hard to say"), and only 5% responded "probably not." Navigating through the designed e-learning courses using a keyboard (Q1.2) received very high ratings.

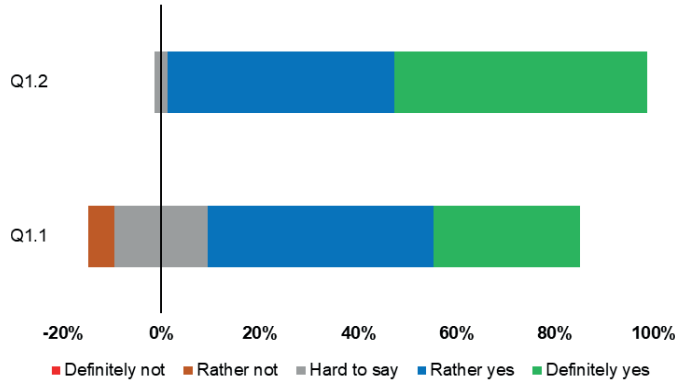

Figure 4. Results of responses to questions Q1.1 and Q1.2

S o u r c e: Own work.

The vast majority, over 97% of the test participants, had no difficulty navigating the quiz using a keyboard. They responded with "definitely yes" (51%) and "probably yes" (46%). Only 2 individuals responded with "hard to say." There were no negative responses. Figure 5 presents the results of the survey regarding the used screen reader (questions Q1.3, Q1.4, Q1.5).

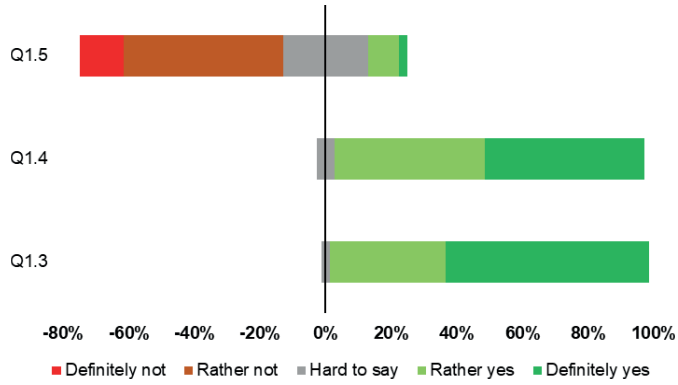

Figure 5. Results of responses to questions Q1.3, Q1.4, and Q1.5

Source: Own work.

The responses to the question "Does the screen reader recognize and interpret the elements of the e-learning course displayed on the computer screen?" (Q1.3) and "Does the applied screen reader pronounce the content in the quiz correctly?" (Q1.4) are very promising as they confirm the adequacy of adapting the e-learning course content to the screen reader used. Over 62% (Q1.3) and 48% (Q1.4) of users responded "definitely yes," while "rather yes" accounted for over 35% (Q1.3) and 45% (Q1.4) of responses. The correlation between the survey questions Q1.1–Q1.4 is moderate (changes from 0.39 to 0.48). In the case of question Q1.5, "rather no" responses were positive, while "rather yes" responses were negative (completely opposite to the previous questions). Over 62% of responses were positive ("definitely no" – over 13%, "rather no" – over 48%). Over 25% of responses were neutral – "hard to say," while only 12% were negative.

The results of the survey regarding the second group of test participants (individuals with actual visual impairments) are shown in Figure 6. In the case of question Q2.1 (Can you see which element is active during navigation?), over 56% of responses were positive, and 25% were neutral. Only 2 individuals answered "rather no," and 1 person answered "definitely no." The impact of contrast change on improving the perception of displayed content was also highly rated, with over 68% of users responding positively. Similarly, 2 individuals had no opinion. The negative responses were distributed in the same way as in question Q2.1. Changing the font size has a significant impact on improving the quality of displayed text (Q2.3), as confirmed by 94% of individuals with actual visual impairments.

The correlation between the survey questions Q2.1–Q2.3 is strong (changes from 0.56 to 0.82).

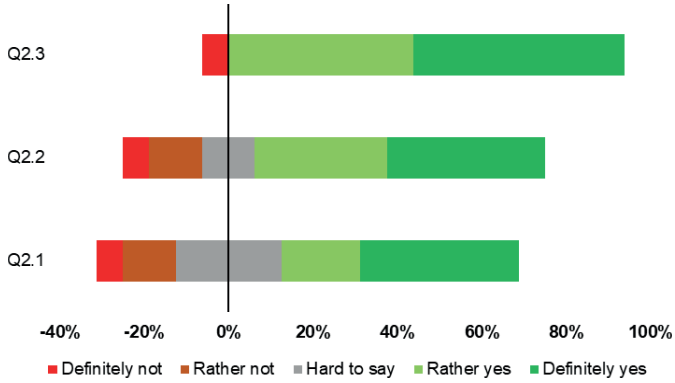

Figure 6. Results of responses to questions Q2.1, Q2.2, and Q2.3

S o u r c e: Own work.

The final results of the quiz prepared according to the WCAG guidelines were compared with the results of people using the standard quiz without WCAG, as shown in Figure 7.

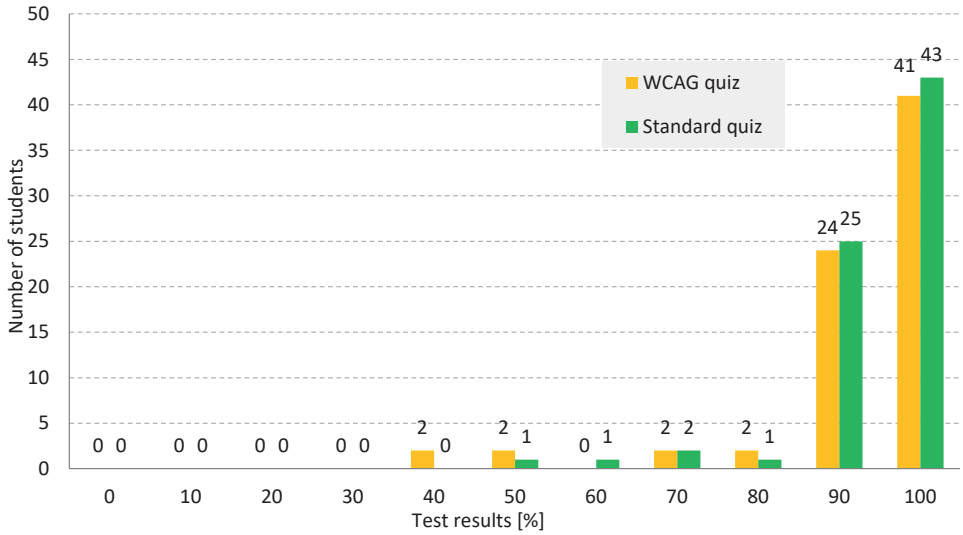

Figure 7. Quiz results

S o u r c e: Own work.

For the quiz with WCAG, the results obtained were quite high, comparable to the results for the standard quiz. This confirms the correct development of the

course and the operation of the WCAG tools used both in the presentation and in the quiz test. More than half of users scored 100% for this type of quiz. Other results are as follows: over thirty percent of users received 90%, 2 people – 80%, 2 people – 70%, 2 people – 50% and 2 people – 40%. All users completed the quizzes within the set time (less than 5 minutes). The average score for the WCAG quiz was 92% and for the standard quiz 94.24%. This is a very similar result, confirming the possibility of equalizing opportunities in access to the quiz and obtaining a positive result for people with disabilities. The correlation between the survey questions and quiz results is weak (below 0.3).

Determination of guidelines for preparing e-learning courses that comply with WCAG standards

Taking into account the specific needs of visually impaired individuals who may have difficulty or limited ability to track mouse movement on a computer screen, it is necessary to implement solutions that can overcome these obstacles. Analyzing the results of the tests, it can be concluded that the use of an e-learning platform, including interactive exercises, with the use of a keyboard and screen reader, is a suitable solution for visually impaired individuals. By employing such a solution, these individuals can navigate and perform specific actions in the course using designated keys and keyboard shortcuts (e.g., the Tab key). Clear highlighting of the active element allows visually impaired individuals to determine their current location within the resource. Additionally, by utilizing screen reader tools, individuals who are completely blind can also access such resources. Keyboard navigation enables logical, pre-planned, and defined movement on the screen, while the screen reader informs these individuals about their current location, available content, and possible actions. Interactive content, where user actions have visual effects (e.g., choosing different paths in an exercise), often presents difficulties or renders the resources completely unusable for individuals with visual impairments. A proper preparation of web resources, including interactive exercises, offers the opportunity to minimize barriers for people with disabilities in accessing these resources. By using keyboard navigation and a screen reader, it is possible to create exercises in which users can follow a planned path, respond to received instructions, or perform required actions. The feedback provided after answering a question or completing a task allows users to proceed to the next stages of the exercise or improve their responses. Through a thoughtful planning and preparation of interactive exercises, barriers to accessing these resources for individuals with disabilities can be significantly reduced without compromising the visual and interactive aspects for able-bodied individuals. In summary, the developed component enables a higher level of compliance with WCAG guidelines for multimedia educational content, strengthening access to education for individuals with disabilities, including visual

and hearing impairments. After conducting the research, general guidelines were formulated for the proper construction and development of e-learning exercises in accordance with WCAG guidelines. It was determined which elements should be visible upon opening the project, what the logical task execution and feedback presentation paths should be, and what actionable options are necessary from the keyboard and screen reader perspective. These guidelines can serve as a framework for designing quizzes for individuals with limited access to digital educational content.

The key assumptions for the WCAG component are as follows:

1. The screen reader only perceives elements that have the visibility option enabled. Other elements are invisible to the screen reader. This allows for planning the user's task execution path by controlling what and in what order the user will see or hear.
2. The screen reader only perceives elements that are active and visible on the timeline. Even elements with the visibility option enabled for the screen reader must remain invisible to the reader until they are shown on the timeline in the Creator tool. This solution enables determining the moment when specific options become available to the user, taking into account the stage of the exercise at which the user is currently.
3. Each element with the visibility option enabled for the screen reader must have an alternative text filled in. The alternative text must not contain words written with spaced-out letters.
4. When a specific element is selected, the screen reader automatically reads its associated alternative text. This event does not require any action from the user.
5. Pressing a designated key allows for moving to the next element. According to the WCAG standard, moving to the next element is done using the TAB key.
6. A designated key combination allows for returning to the previous element with the visibility option enabled for the screen reader. According to the standard, the Shift+TAB key combination is used for this purpose. In accordance with the previous assumptions, the selection will return to the previously visited element unless it has been hidden on the timeline. In such a case, the selection will stop at the first visible element on the timeline.
7. The order of navigating between elements is determined by their arrangement on the timeline: the screen reader cursor moves through marked and visible elements from left to right, from the top layer to the bottom. If there is only one element on consecutive layers, the selection moves through the layers from top to bottom while adhering to the visibility criterion for the screen reader and the timeline.
8. The 'space' or 'enter' key allows for replicating the functionality of clicking the respective element on the screen.
9. Pressing the 'space' or 'enter' key on a selected element enables executable actions, similar to objects operated by the mouse. This allows users with disabilities to access all the executable actions available in the Creator tool, includ-

ing showing objects, hiding objects, displaying layers, hiding layers, moving to the next, previous, or any chosen page, playing, pausing, or stopping audio recordings, changing the value of a score or user variable, altering the style of elements, managing the timer, checking individual exercises, or all exercises in the course, as well as handling video files.

10. Selecting an element visible to the screen reader provides executable actions similar to the event of hovering the mouse over an object. The available actions for the event of selecting an element are the same as those for clicking the mouse button.
11. Upon opening the project, the screen reader selection automatically sets to the first visible element with the WCAG component enabled. This allows screen reader users to orient themselves within the course upon project loading and provides instructions on further steps to solve the exercise.
12. Upon page loading, the screen reader automatically reads the alternative text from the first visible element. This event does not require any user intervention. It provides an opportunity to present the user with the exercise procedure and instruct them on the tasks involved in a specific exercise.
13. Every change on the screen must be initiated by user action. The a utomatic appearance and disappearance of elements should be eliminated. This approach avoids the confusion that could arise when things happen automatically in an exercise for which the user is not prepared. It can also distract the user and make the technical execution of the task more difficult.
14. The elements selected by the screen reader must be clearly marked with borders/highlighting, according to the standard. The visibility of focus should be maintained. This provides additional support for visually impaired individuals when solving the task. The border should be adjusted to the content of the task in terms of contrast.
15. A sufficient contrast must be ensured between the elements present on the page and the background. According to WCAG guidelines, this parameter should be at least 4.5:1. In all cases where the color of an element is defined in the stylesheet, the background color on which it is placed is also defined.
16. The exercise must have a mechanism that allows the view on the page to be enlarged up to 200% while maintaining the visibility of all information.
17. The occurrence of a keyboard trap, where the user is unable to complete the task entirely using the keyboard, must be avoided. Points related to navigating between elements and executing actions on events allow for arranging elements and planning the logic of task solving to avoid such a situation.
18. The exercise and the page on which the exercise is located must not have an automatic refresh mechanism. Such a mechanism prevents the completion of the exercise, leading to loss of focus and the need to start the task-solving process from the beginning. There should also be no mechanism in the exercise or on the page that automatically redirects the user to another address.

Conclusions

The present article raises the key issue of making digital educational content available to people with disabilities, in particular those with a visual impairment. The main objectives of the study were to develop an interactive creator of exercises in accordance with the WCAG 2.1 guidelines and to assess the effectiveness of its implementation on the Quizer e-learning platform. On the basis of tests and user studies, the following final conclusions were formulated:

1. The study showed that a customized e-learning platform successfully enabled people with visual impairments to navigate and interact with a keyboard and a screen reader. The respondents reported clear and understandable voice instructions for navigation, and keyboard interaction provided intuitive navigation paths.
2. It was found that the screen reader used (NVDA) effectively recognizes and interprets elements of e-learning content displayed on a computer screen. It correctly pronounced the content included in the quizzes, increasing the accessibility of educational materials for users with visual impairments.
3. The introduction of the contrast adjustment option had a positive impact on the visibility of the displayed content, thus improving the reception of educational materials by visually impaired users. They noticed improved text quality after changing the font size, further highlighting the importance of customization for accessibility.
4. The study compared the results of quizzes developed according to WCAG guidelines with standard quizzes. The results showed that the WCAG-adapted quizzes achieved a similar success rate to the standard quizzes, highlighting the effectiveness of the adaptation in providing equal educational opportunities for people with disabilities.
5. The obtained results led to the formulation of guidelines for the design and development of accessible e-learning exercises in accordance with the WCAG guidelines. These guidelines emphasize elements such as keyboard navigation, screen reader compatibility, contrast adjustment and logical task paths to ensure accessibility without compromising the interactive aspects.

The results of this study have important implications for the field of inclusive education and e-learning. The successful integration of WCAG guidelines into an e-learning platform, along with positive feedback from users with visual impairments, demonstrates the feasibility of creating digital learning resources that meet a variety of accessibility needs. To sum up, the research has shown that adapting e-learning exercises to the WCAG 2.1 guidelines significantly improves accessibility for people with disabilities, especially those with visual impairments.

The study provides valuable information on the implementation of accessibility features, highlights their positive impact on user experience and educational

outcomes, and establishes guidelines for the design of accessible e-learning materials. By prioritize accessibility, educational institutions and content creators can help create an inclusive learning environment that benefits all students, regardless of their ability.

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References

Aizpurua, A., Harper, S., & Vigo, M. (2016). Exploring the relationship between web accessibility and user experience. *International Journal of Human-Computer Studies*, 91, 13–23. https://doi.org/10.1016/j.ijhcs.2016.03.008.

Alfonso, G. J. & Garcia, P. G. (2015). Open and Distance eLearning: New Dimensions in Teaching, Learning, Research, and Extension for Higher Education Institutions. *International Journal on Open and Distance e-Learning*, 1(1&2), 1–13. https://ijodel.com/index.php/ijodel/article/view/3.

Armano, T., Borsero, M., Capietto, A., Murru, N., Panzarea, A. & Ruighi, A. (2018). On the accessibility of Moodle 2 by visually impaired users, with a focus on mathematical content. *Universal Access In The Information Society*, 17(4), 865–874. https://dx.doi.org/10.1007/s10209-017-0546-8.

Bocevska, A., Savoska, S., Ristevski, B. & Blazheska-Tabakovska, N. (2018). Analysis of Accessibility of the e-Learning Platforms According to the WCAG 2.0 Standard Compliance. In I. Nedelkovski (Ed.), *Proceedings of the 8th International Conference on Applied Internet and Information Technologies*, (pp. 26–31), ISBN 978-9989-870-80-4. https://aiitconference.org/2018/proceedings.

Brain, S. & Mariani, R. (2023). Reviews of education for students with disability in Australia. *International Encyclopedia of Education (Fourth Edition)*, 376–385. https://doi.org/10.1016/B978-0-12-818630-5.12023-8.

Brown, J., Permvattana, R., Hollier, S. & McKee, J. (2022). Online Learning & COVID-19: Exploring Digital Accessibility. *Journal on Technology and Persons with Disabilities*, 10, 82–96. https://doi.org/10.1145/3430263.3452445.

Burgstahler, S., Corrigan, B. & McCarter, J. (2004). Making distance learning courses accessible to students and instructors with disabilities: A case study. *The Internet and Higher Education*, 7, 233–246. https://doi.org/10.1016/j.iheduc.2004.06.004.

Calvo, R., Iglesias, A. & Moreno, L. (2012). Is Moodle Accessible for Visually Impaired People? In J. Filipe & J. Cordeiro (Eds.), *Web Information Systems and Technologies. WEBIST 2011. Lecture Notes in Business Information Processing,* 101, (pp. 207–220). https://doi.org/10.1007/978-3-642-28082-5_15.

Chatzoglou, E., Fishstrom, S., Payne, S. B., Andress, T. T. & Vaughn, S. (2023). The footprint of the COVID-19 pandemic in reading performance of students in the U.S. with and without disabilities. *Research in Developmental Disabilities*, 140, 104585. https://doi.org/10.1016/j.ridd.2023.104585.

Contreras, M. I., Duryea, S. & Martínez, A. C. (2023). The effect of the pandemic on the transition to tertiary education in Chile: A focus on students with disabilities. *International Journal of Educational Development*, 100, 102779. https://doi.org/10.1016/j.ijedudev.2023.102779.

Dziedzic, K. (2021). Measuring Student Involvement When Taking Tests in E-learning Courses. *IJREL*, 7, 1–17. http://doi.org/10.31261/IJREL.2021.7.1.09.

Dziedzic, K., Gudków, M. & Wiśniewski, T. (2020). The "Quizer" e-learning platform as a tool for creating interactive quizzes with multiplayer functionality. *JCSI*, 15, 196–201. https://doi.org/10.35784/jcsi.1610.

Fernandez-Diaz, E., Maldonado, M. C. J. & Sanchez, P. P. I. (2019). Web Accessibility. The new era of WCAG 2.1, the transition to future WCAG 3.0. *Gecontec-Revista Internacional De Gestion Del Conocimiento Y La Tecnologia*, 7(2), 42–65. https://www.upo.es/revistas/index.php/gecontec/article/view/4069.

Fernández-Gutiérrez, M., Gimenez, G. & Calero, J. (2020). Is the use of ICT in education leading to higher student outcomes? Analysis from the Spanish Autonomous Communities. *Computers & Education*, 157, 103969. https://doi.org/10.1016/j.compedu.2020.103969.

Filipe, F., Pires, I. M. & Gouveia, A. J. (2023). Why Web Accessibility Is Important for Your Institution. *Procedia Computer Science*, 219, 20–27. https://doi.org/10.1016/j.procs.2023.01.259.

Germano, R. S. & Silveira, I. F. (2022). WCAG-Easy Tool A tool based in the WCAG to learn web accessibility. In A. Rocha, B. Bordel, F. G. Penalvo & R. Goncalves (Eds.), *17th Iberian Conference on Information Systems and Technologies (CISTI)*, (pp. 1–6). https://doi.org/10.23919/CISTI54924.2022.9820012.

Kabyshev, M. V. & Kovalchuk, S. V. (2019). Development of personalized mobile assistant for chronic disease patients: diabetes mellitus case study. *Procedia Computer Science*, 156, 123–133. https://doi.org/10.1016/j.procs.2019.08.187.

Królak, A. & Zając, P. (2022). Analysis of the accessibility of selected massive open online courses (MOOCs) for users with disabilities. In C. Stephanidis & M. Antona (Eds.), *Universal Access in the Information Society*, (pp. 1–13). https://doi.org/10.1007/s10209-022-00927-2.

Laabidi, M., Jemni, M., Jemni Ben Ayed, L., Ben Brahim, H. & Ben Jemaa, A. (2014). Learning technologies for people with disabilities. *Journal of King Saud University - Computer and Information Sciences*, 26, 29–45. https://doi.org/10.1016/j.jksuci.2013.10.005.

Lee, Y. (2023). ICT use, internal communication satisfaction, and engagement of working-from-home employees: The moderating role of affiliative tendency. *Computers in Human Behavior*, 138, 107472. https://doi.org/10.1016/j.chb.2022.107472.

Maćkowski, M. S., Brzoza, P. F. & Spinczyk, D. R. (2018). Tutoring math platform accessible for visually impaired people. *Computers in Biology and Medicine*, 95, 298–306. https://doi.org/10.1016/j.compbiomed.2017.06.003.

Madhesh, A. (2023). Quality of life of higher education students with disabilities at Shaqra University. *Research in Developmental Disabilities,* 138, 104520. https://doi.org/10.1016/j.ridd.2023.104520.

Mon, A. & René Del Giorgio, H. (2021). Evaluation of Information and Communication Technologies towards Industry 4.0. *Procedia Computer Science*, 180, 639–648. https://doi.org/10.1016/j.procs.2021.01.286.

Persson, H., Åhman, H., Yngling, A. A. & Gulliksen, J. (2015). Universal design, inclusive design, accessible design, design for all: different concepts-one goal? On the concept of accessibility-historical, methodological and philosophical aspects. In C. Stephanidis & M. Antona (Eds.), *Universal Access in the Information Society,* 14, (pp. 505–526). https://doi.org/10.1007/s10209-014-0358-z.

Petrovic, V. V., Milsevic, H. & Gavrilovic, S. (2014). E-learning using software moodle. In J. Beseda & Z. Machat (Eds*.), Disco 2014: Media Literacy Education From Pupil To Lifelong Learning*, (pp. 297–304), ISBN 978-80-86302-45-4.

Quizer. (n.d.). Quizer Platforma e-learningowa dla firm: Strona Główna. https://quizer.pl/ (accessed 03.11.2023).

Rizk, J. & Hillier, C. (2022). Digital technology and increasing engagement among students with disabilities: Interaction rituals and digital capital. *Computers and Education Open,* 3, 100099. https://doi.org/10.1016/j.caeo.2022.100099.

Romero Mariño, B. D., Rodriguez-Fortiz, M. J., Hurtado Torres, M. V. & Haddad, H. M. (2018). Accessibility and activity-centered design for ICT users: ACCESIBILITIC ontology. *IEEE Access*, 6, 60655–60665. https://doi.org/10.1109/ACCESS.2018.2875869.

Rosa, D. & Obillos, J. P. (2016). Experiences, perceptions and attitudes on ICT integration: A case study among novice and experienced language teachers in the Philippines. *International Journal of Education and Development using Information and Communication Technology*, 12(3), 37–57, ISSN: ISSN-1814-0556. https://api.semanticscholar.org/CorpusID:63769927.

Sanchez, L. A. V., Idrobo, D. I. G., (...) & Gomez-Jaramillo, S. (2022). Guide for Website Design for Higher Education Institutions Based on the WCAG 2.1 Standard Applied to Visual Disabilities. *Academia Y Virtualidad*, 15(1), 105–118. https://doi.org/10.18359/ravi.5601.

Seale, J. K. & Cooper, M. (2010). E-Learning and accessibility: An exploration of the potential role of generic pedagogical tools. *Computers & Education*, 54(4), 1107–1116. https://doi.org/10.1016/j.compedu.2009.10.017.

Stofkova, J., Stofko, S. & Loucanova, E. (2017). Possibilities of using e-learning system of education at universities. In *INTED2017 Proceedings*, 11th International Conference on Technology, Education and Development (INTED), 6965–6972. https://doi.org/10.21125/inted.2017.1618.

Ulbricht, V., Flores, A. R. B., (...) & Ribas, A. (2011). The Visually Impaired and Distance Education. *Revista Educaonline*, 5(3), 1–18, ISSN 1983-2664.

Val, J.-H., Rashid, A. T. & Elder, L. (2010). Using mobile phones to improve educational outcomes: An analysis of evidence from Asia. *International Review of Research in Open and Distributed Learning*, 11(1), 117–140. https://doi.org/10.19173/irrodl.v11i1.794.

Yang, M., Lowell, V., Long, Y. & Farmer, T. (2023). Designing for Accessibility in Online Learning: A Design Case. *Journal of Postsecondary Education and Disability*, 36(1), 75–87. https://digitalcommons.odu.edu/stemps_fac_pubs/240.

Krzysztof Dziedzic, Marcin Barszcz, Tomasz Wiśniewski

Dostosowanie kreatora ćwiczeń e-learningowych do potrzeb osób z niepełnosprawnościami utrudniającymi dostęp do edukacji

S t r e s z c z e n i e

Niniejszy artykuł dotyczy implementacji wytycznych WCAG 2.1 w kursach elearningowych. Bazą do wprowadzenia komponentu WCAG była platforma elearningowa Quizer, umożliwiająca tworzenie interaktywnych kursów multimedialnych. W skład platformy wchodzą dwa podstawowe narzędzia: kreator ćwiczeń i prezenter ćwiczeń.

Po przeprowadzeniu analizy kreatora ćwiczeń na platformie Quizer, opracowano koncepcję kursów i zaimplementowano komponent umożliwiający tworzenie kursów e-learningowych zgodnych z wytycznymi WCAG 2.1 i przeznaczonych dla osób z niepełnosprawnościami. Zaprezentowano również technologię wykonania tego komponentu. Omówiono także funkcję i zasadność poruszania się po kursach z wykorzystaniem klawiatury oraz przedstawiono zastosowanie czytników ekranu.

Badania dotyczące poprawności implementacji standardu WCAG 2.1 w kursach elearningowych były przeprowadzane z użyciem quizów z zakresu cyberbezpieczeństwa. Porównano również wyniki końcowe quizów przygotowanych według wytycznych WCAG i bez WCAG. W badaniach wzięli udział studenci kierunku informatyka Politechnik Lubelskiej. Wyniki badań wskazują na zasadność stosowania wytycznych WCAG w projektowaniu treści edukacyjnych dla studentów z niepełnosprawnościami w celu wyrównania ich szans edukacyjnych.

S ł o w a k l u c z o w e: e-learning, kreator ćwiczeń, kursy multimedialne, WCAG 2.1

Krzysztof Dziedzic, Marcin Barszcz, Tomasz Wisniewski

Adaptar el creador de los ejercicios e-learning a las necesidades de las personas con discapacidad con difícil acceso a la educación

R e s u m e n

Este artículo se refiere a la implementación de las pautas WCAG (Web Content Accessibility Guidelines) 2.1 en los cursos de aprendizaje electrónico. La base para la introducción del componente WCAG fue la plataforma de e-learning Quizer que permite la creación de cursos multimedia interactivos. La plataforma consta de dos herramientas básicas: creador de ejercicios y presentador de ejercicios.

Después de analizar el creador de ejercicios en la plataforma Quizer, se desarrolló un concepto y se implementó un componente para permitir la creación de cursos de aprendizaje electrónico de acuerdo con las pautas de WCAG y dedicados a las personas con discapacidad. También se presentó la tecnología de creación de este componente. Igualmente se discutió la función y la conveniencia de navegar por los cursos usando el teclado así que el uso de lectores de pantalla.

La investigación sobre la corrección de la implementación del estándar WCAG en los cursos de aprendizaje electrónico se llevó a cabo con el uso de pruebas de ciberseguridad. Los estudiantes de Informática de la Universidad Tecnológica de Lublin participaron en el estudio. Los resultados de la investigación indican la conveniencia del uso de las pautas WCAG en el diseño del contenido educativo para los estudiantes con discapacidades y el igualamiento de las oportunidades educativas.

P a l a b r a s c l a v e: e-learning, creador de ejercicios, cursos multimedia, WCAG

Кшиштоф Дзедзис, Марцин Барщ, Томаш Вишневски

Адаптация креатора упражнений электронного обучения к потребностям людей с ограниченными возможностями с затрудненным доступом к образованию

Аннотация

Эта статья касается реализации рекомендаций WCAG (Web Content Accessibility Guidelines) 2.1 в курсах электронного обучения. Основой для внедрения компонента WCAG стала платформа электронного обучения Quizer, позволяющая создавать интерактивные мультимедийные курсы. Платформа состоит из двух основных инструментов: создания упражнений и представления упражнений.

После анализа Конструктора упражнений на платформе Quizer была разработана концепция и реализован компонент, позволяющий создавать курсы электронного обучения в соответствии с рекомендациями WCAG и предназначенные для людей с ограниченными возможностями. Также была представлена технология изготовления этого компонента. Также обсуждаются функции и правомерность навигации по курсам с помощью клавиатуры и использования программ чтения с экрана.

Исследование правильности реализации стандарта WCAG в электронных учебных курсах проводилось с использованием разработанных тестов в области кибербезопасности. Были сравнены также окончательные результаты тестов, приготовленных в соответствии с рекомендациями WCAG и без WCAG. В исследовании приняли участие студенты факультета информатики Люблинского политехнического университета. Результаты исследования свидетельствуют о правомерности использования рекомендаций WCAG при разработке образовательного контента для студентов.

Ключевые слова: электронное обучение, создание упражнений, мультимедийные курсы, WCAG

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Tetiana A. Vakaliuk
Zhytomyr Polytechnic State University, Ukraine
https://orcid.org/0000-0001-6825-4697

Oleksii V. Chyzhmotria
Zhytomyr Polytechnic State University, Ukraine
https://orcid.org/0000-0002-5515-6550

Svitlana O. Didkivska
Krakow University of Economics, Poland
https://orcid.org/0000-0002-4004-6631

Illia Linevych
Zhytomyr Polytechnic State University, Ukraine
https://orcid.org/0000-0002-8189-4856

Development of a Web Service for Creating Tests Based on Text Analysis Using Natural Language Processing Technologies

Abstract

The purpose of the work is to analyze models, natural language processing methods, and select modern technologies for training these models, as well as to develop a web service for creating tests based on text analysis using natural language processing technologies. The study considers methods and algorithms for intelligent data analysis to generate questions and correct and incorrect answers from the text. The authors justify the choice of a neural network for generating tests based on English and Ukrainian text, and characterize data sources for training. The study also describes the activity of the proposed model, which will serve as a basis for creating a web service. After a detailed review of these datasets, the necessary data for the experiment were extracted and transformed into a convenient format for use. The training algorithm for 6 models was designed and implemented, and

valuable metrics were obtained after their training. Additionally, a server-side and web interface were developed to interact with each other.

K e y w o r d s: text analysis, natural language, natural language processing technologies, NLP, model

Introduction

To assess students' knowledge and skills at the end of a semester or upon completion of any topic, instructors often conduct a summative assessment. While preparing for this process, the instructor needs to analyze the covered educational material and, based on it, creates various questions with corresponding answers. It is also essential not to forget about the subsequent test review, which involves calculating the results for each student. The entire process is very monotonous, consuming a lot of energy and time, especially if the instructor has a large number of students. A similar chain of events also occurs during the evaluation of a company's employee professionalism or, conversely, during their internship.

Therefore, the relevance of the topic is determined by the need to automate the process of creating tests from textual material using natural language processing technologies. Further research is required on the issue of properly training neural models for generating questions, correct and incorrect answers based on an English and Ukrainian text.

Tests are one of the primary forms of consolidating knowledge. The more accurately they are selected, the more effectively the learning process can be implemented. An automated system for creating questions could improve their quality and increase their number, thereby covering more details and topics for the learning program. With this system, instructors or employers could generate questions based on covered material to assess the knowledge and skills of their students and workers.

At present, there are numerous languages and nationalities, complicating this task. To efficiently generate tests from a text in various languages, it is necessary to consider the lexical, grammatical, and other features of each language. That is, a separate implementation plan must be developed for each language to achieve the best results. Therefore, to simplify the work, this project will focus on generating questions, correct and incorrect answer options from an English text, as it is one of the most widespread languages globally. Additionally, based on the conducted research, algorithms will be adapted for Ukrainian texts.

In general, all types of questions can be divided into two groups: objective and subjective. When answering objective questions, users are asked to choose

the correct answer from the provided options. The most popular of this type are multiple-choice tasks, matching, true or false, filling in blanks in a sentence, and more. At the same time, when answering subjective questions, students need to write the answer independently. Tasks of this type may require a short response (from a few words to several sentences) or a long one (for example, an essay). Therefore, for a successful generation, one needs to have such a data pair: a text passage (minimum 2–3 sentences); a predetermined answer or a set of answers, based on which questions will be asked and incorrect options will be generated.

To avoid doing this manually, there are numerous methods for extracting so-called "keywords" from the text that can become potential answers, as well as algorithms that can generate false options based on these words. Using this, a comprehensive test can be created. One such interesting approach is Named Entity Recognition (NER). Named Entity Recognition is a subtask of information extraction that attempts to find and classify named entities in an unstructured text into predefined categories, such as names of people, organizations, places, time, quantities, monetary values, percentages, and more. That is, some named entities can be used as answers, and some of them, which match a category, can be used as incorrect options.

As for the generation of the questions themselves, this task is much more complex. Unfortunately, most static methods do not show very high efficiency and work well only with a few languages, such as English, while they cannot form a long, consistently correct chain of words for Ukrainian. Therefore, nowadays, artificial intelligence is increasingly replacing these algorithms, as this development allows for obtaining more accurate results, similar to the ones obtained by human. Considering this, further research was conducted in this area.

The **purpose** of the work is to analyze models, natural language processing methods, and select modern technologies for training these models, as well as to develop a web service for creating tests based on text analysis using natural language processing technologies.

Methodology of Research

To achieve this goal, the following main **tasks** need to be solved:

- define the basic requirements and desired end results;
- research existing neural models of natural language processing that are suitable for achieving the selected goals;
- select suitable models and methods of their training;
- make a reasonable choice of tools for model training;
- create an API to interact with models (server side);

- create a web interface for testing and general use of models (client side).

To solve these tasks, a number of methods were used: analysis, synthesis, and generalization to study neural models of natural language processing and to select tools for training models; and methods for training neural models using programming languages.

Theoretical Background

Data mining methods and algorithms for generating questions, correct and incorrect answers from the text

To implement the given task, natural language processing technologies can be used. Natural Language Processing (NLP) is the ability of a computer program to understand a human language. NLP is a branch of artificial intelligence that deals with the interaction between computers and humans using a natural language. The ultimate goal of NLP is to teach a neural network to read, decode, understand, and determine the meaning of human language in a valuable way. Most NLP techniques rely on various machine learning methods to derive meaning from a text (Education Ecosystem, 2022).

NLP is used in various development areas, namely: in language translation programs such as Google Translate; in text processors like Microsoft Word and Grammarly for checking the grammatical accuracy of texts; in interactive voice response programs; in personal assistants such as Google, Siri, Cortana, Alexa, and more.

There are two main stages of natural language processing: preprocessing of data and the development of the necessary algorithm to solve the given problem. Preprocessing of data includes preparing and "cleaning" text data for machines to be able to analyze it. Preprocessing presents the data in a workable form and highlights specific words in the text that the algorithm can work with. This stage may include the following processes (Lutkevich, 2022):

- tokenization – the text is broken down into smaller, separate units for processing;
- removal of stop words – common, frequently repeated words and parts of speech are removed from the text, leaving only unique ones that provide the most information about the text;
- lemmatization and stemming – words are reduced to their root forms for processing;
- part-of-speech tagging – words are marked with the part of speech they correspond to, such as nouns, verbs, and adjectives.

After preprocessing the data, the development of the text processing algorithm begins. There are many different natural language processing algorithms, but usually, two main types are used: rule-based systems – these systems use carefully pre-developed linguistic rules; machine learning-based systems – machine learning algorithms are used to train neural networks. They learn to perform tasks based on the training data provided to them and adjust their methods as they process more data (Lutkevich, 2022). The second approach will be used in this study.

Effective question generation is an open scientific problem that still lacks a universal, easy approach to its solution. The question generation itself consists of two fairly complex processes: analysis of the lexical and syntactic context of input sentences, and construction of new sentences based on the processed information, following all the rules of the current language. Therefore, after analyzing various sources, several works were found on the autogeneration of questions from a text in Turkish (Akyon et al., 2022), Arabic (Nagoudi et al., 2022), and English languages (Vachev et al., 2022).

In each of these works, special transformer models for natural language processing based on machine learning were used. A transformer (neural network) is a deep learning model. It uses an "attention" mechanism that takes into account the relationship between all the words in a sentence. The transformer creates differential coefficients that indicate the elements in the sentence that are most important for a more accurate interpretation of the meaning of problematic words. Thus, the computer can quickly and efficiently understand ambiguous phrases (Negri, 2022). Other scholars (Mellah et al., 2021; Affolter et al., 2019, Guo et al., 2019; Xavier et al., 2022) have also considered various aspects of the issue in their works.

Transformers can differ in the type of input and output data. For example, they can accept data in a text, visual, or audio format and return results of the same type. To solve the problem of generating tests, transformers that can work with text data and return a textual result will be considered. They are also called seq2seq models (sequence to sequence).

Seq2Seq models consist of two parts: an encoder and a decoder. The encoder and decoder can be thought of as translators who can speak only two languages. Each of them has its own native language; for example, one can say that the encoder is a native speaker of Chinese, and the decoder is a native speaker of English. Both have a second common language; let us say Japanese. To translate Chinese to English, the encoder converts the Chinese sentence into Japanese. This Japanese sentence is then passed as a context to the decoder. Since the decoder understands Japanese and can read in this language, it can now translate the given Japanese passage into English.

Another key component of the transformer architecture is a mechanism called "attention." This technique mimics cognitive attention. Cognitive attention reflects how our brain focuses on the meaningful parts of a sentence, helping us understand its overall meaning. For example, when you read this sentence, you are

always focused on the word you are reading, but at the same time, your memory stores the most important keywords you have already read to ensure understanding of the context.

The attention mechanism examines the input text sequence in parts, and at each step, it decides which other parts of the sequence are important. This helps the transformer filter out noise and focus on what is relevant, connecting related words that, by themselves, do not contain any obvious markers pointing to one another.

Selecting a neural network for generating tests based on English and Ukrainian text

At present, there are many ready-made natural language processing models, each of which has been pre-configured on large datasets to be able to perform basic NLP tasks. During this initial training, transformers learn various language constructs and basic functions, which are sufficient to avoid having to train them from scratch. Thus, they begin to "understand" a human language. Datasets represent a large "repository" of records that are stored in a special format. By receiving these records as input, transformers learn to perform specific tasks. Pre-trained models are most often used in the implementation of NLP tasks because they are easier to adjust, have high accuracy, and require much less time and computational resources for additional training compared to custom transformers built from scratch (neural networks). Although most pre-trained transformers can perform a range of simple tasks, none of them can initially generate questions, correct or incorrect answers based on the analyzed text. Therefore, it is necessary to choose an NLP model for each task and train them separately. There are countless neural networks that can work with texts, but the choice of the best is limited by a number of factors, namely:

1. The ability of the neural network to work with texts in different languages.
2. The amount of computational resources needed for training and operation of the neural network.
3. The availability of the neural network on the Internet.

After analyzing several natural language processing models, the most optimal option was found to be the Text-To-Text Transfer Transformer (T5) developed by Google (Roberts, 2022). In T5, all NLP tasks are transformed into a unified text format in which the input and output data are always text strings, unlike models like BERT (Devlin, 2019), which accept a text as an input but return results as quantitative estimates.

The T5 transformer was pre-trained on a large dataset, the Colossal Clean Crawled Corpus (C4) (Dodge et al., 2021), so that it understands a human language and can perform a range of tasks, such as data classification or text translation. An important component for further training of neural networks for more specific

tasks is the unlabeled dataset used for pre-training. To enhance the pre-training effect, a dataset is needed that will not only be high-quality and diverse, but also massive. Existing datasets for pre-training do not meet all three of these criteria – for example, a collection of articles from Wikipedia is of high quality but is unified in style and relatively small in size, while the Common Crawl dataset (Common crawl) is huge and very diverse but has a relatively low quality.

So, to satisfy all requirements, Google developed the Colossal Clean Crawled Corpus (C4), a cleaned version of Common Crawl, which is two orders of magnitude larger than the collection of Wikipedia articles. The cleaning process involved deduplication, discarding incomplete sentences, and removing offensive or noisy content. This filtering led to better initial training results for the T5 model. As for the language, the T5 model works only with English, but there is its multilingual version (mT5), which can be used for Ukrainian. This model also has different versions (dimensions), which allows it to be used even on ordinary machines with a single graphics processor. It is worth noting that the smaller the size of the neural network, the less accurate the results it produces, but their quality remains satisfactory. Such models work much faster and are more accessible to ordinary users.

To train the T5 model for generating questions, correct and incorrect answers, special datasets need to be used. Also, in training the transformer, the optimization function plays an important role, helping to reduce the error of future calculations. Mathematical optimization (sometimes referred to as optimization) or mathematical programming in mathematics, computer science, and operations research refers to the selection of the best element (according to a certain criterion) from a set of available alternatives. In the simplest case, the optimization task consists of finding the extremum (minimum or maximum) of a real function by systematically selecting input values from the allowed set and calculating the function's value. The optimization function to be used is the AdamW function (Graetz, 2022), which is an improved version of the Adam method.

Comparison of available software products

The use of artificial intelligence is achieving great success in the field of education. A striking example of such development is the increase in the number of online platforms and mobile applications for teaching. Machine learning, deep learning, and natural language processing are used to assist teachers in their work and help students increase their productivity.

Let us consider software products with the ability to auto-generate questions and determine the features of each of them: PrepAI, Quillionz, and Questgen. For better perception, we will divide the analysis into certain evaluation criteria:

1. Data submission methods, input formats, and sources

The first factor is the data input method. PrepAI allows multiple input formats. It can read data from plain text, files (.pdf, .docx), video files or YouTube videos, as well as Wikipedia articles. Quillionz also supports multiple input data formats: plain text, ".pdf" files, and YouTube videos. In addition, Quillionz allows you to choose a topic before generating questions, which helps the algorithm perform better. Questgen, on the other hand, can only work with a text. Unfortunately, each of the services supports only the English language, which is a significant drawback and emphasizes the relevance of conducting research on test generation for the Ukrainian language as well.

2. Types of questions and their generation

Generation in all applications is relatively fast. The process mainly takes from a few seconds to a minute, but this number depends on the amount of input data.

3. Output data and storage

After the questions have been generated, they can be edited and saved. PrepAI and Quillionz allow for editing and deleting questions with answers, while Questgen, in addition, provides the ability to change their order. Unfortunately, none of the services allows adding your own questions to the final result. In PrepAI, you can export the created test in ".pdf", ".docx", or ".xlsx" format. Quillionz allows for exporting data in ".txt", ".pdf", and ".docx" format. As for Questgen, it does not allow for exporting the resulting test, but it can be copied as a text, saved to a personal account, and printed in the prepared format. From the analysis, it can be said that PrepAI mainly wins in terms of functionality, but Questgen showed the best results in terms of the quality of generated questions.

Results

The server-side implementation, data processing, and training will be conducted using the Python programming language, as it contains numerous built-in methods and libraries that greatly simplify the development process. The model training will take place in the Google Colaboratory cloud development environment (Google Colaboratory, 2022). A single-page application (SPA) type of website is chosen for a web interface development. The web application developed following this scheme uses a single page and allows for dynamically changing content without reloading, providing the user with an experience similar to using a native application. The web interface will be written using the TypeScript programming language and the React library.

Characteristics of data sources for training

For the task of generating questions, the Stanford Question Answering Dataset (SQuAD) can be utilized. SquAD is a reading comprehension dataset consisting of questions posed on English Wikipedia articles. The answer to each question is a word or text snippet from the corresponding passage or the question can be unanswerable. Generally, SquAD was created for the opposite task – generating answers to questions, but it is well-suited for the current task.

There are two versions of this dataset: SquAD 1.1 – the previous version of the SquAD dataset, containing approximately 100,000 question-answer pairs based on 500+ articles; SquAD 2.0 – combines questions from SquAD 1.1 with unanswerable questions written by crowdworkers to resemble answerable ones. SquAD 2.0 will be used for training since this dataset contains two types of questions, allowing the model to learn to generate questions based on both predefined answers and without them.

Now let us take a closer look at the structure of the selected dataset. Figure 1 shows several entries.

id (string)	title (string)	context (string)	question (string)	answers (json)
56bf6b0f3aeaaa14008c9602	Beyoncé	Beyoncé Giselle Knowles-Carter (/bi…	In which decade did Beyonce becom…	{ "text": ["late 1990s"],…
56bf6b0f3aeaaa14008c9603	Beyoncé	Beyoncé Giselle Knowles-Carter (/bi…	In what R&B group was she the lead…	{ "text": ["Destiny's Child"]…
56bf6b0f3aeaaa14008c9604	Beyoncé	Beyoncé Giselle Knowles-Carter (/bi…	What album made her a worldwide…	{ "text": ["Dangerously in…

Figure 1. SquAD 2.0 structure

S o u r c e: Own work.

In fact, the dataset is split into two files: train and dev. This is done for convenience. The first file is used for model training, while the second is used for validation after each training epoch. The SquAD 2.0 translation into Ukrainian has already been carried out in a fellow researcher's work (Huggingface.co, 2022), where the dataset was used for generating answers to questions. For the task at hand, it is sufficient to have only a context, question, and answer. Moreover, the data is stored in the less convenient JSON format rather than CSV. So let us modify the dataset to meet our needs. For entries without an answer, the answer column will contain a special token "[MASK]" to train the model to generate questions based only on the context. Figures 2 and 3 show the result of the data transformation.

```
squad_train_df = load_pandas_df()
print(squad_train_df.shape)

squad_train_df.head()
```

```
File ./train-v2.0.json already downloaded
(130319, 3)
```

	context	question	answer
0	Beyoncé Giselle Knowles-Carter (/biːˈjɒnseɪ/ b...	When did Beyonce start becoming popular?	in the late 1990s
1	Beyoncé Giselle Knowles-Carter (/biːˈjɒnseɪ/ b...	What areas did Beyonce compete in when she was...	singing and dancing
2	Beyoncé Giselle Knowles-Carter (/biːˈjɒnseɪ/ b...	When did Beyonce leave Destiny's Child and bec...	2003
3	Beyoncé Giselle Knowles-Carter (/biːˈjɒnseɪ/ b...	In what city and state did Beyonce grow up?	Houston, Texas
4	Beyoncé Giselle Knowles-Carter (/biːˈjɒnseɪ/ b...	In which decade did Beyonce become famous?	late 1990s

Figure 2. Modified training set for generating questions

S o u r c e: Own work.

```
squad_val_df = load_pandas_df(file_split='val')
print(squad_val_df.shape)

squad_val_df.head()
```

```
File ./dev-v2.0.json already downloaded
(11873, 3)
```

	context	question	answer
0	The Normans (Norman: Nourmands; French: Norman...	In what country is Normandy located?	France
1	The Normans (Norman: Nourmands; French: Norman...	When were the Normans in Normandy?	10th and 11th centuries
2	The Normans (Norman: Nourmands; French: Norman...	From which countries did the Norse originate?	Denmark, Iceland and Norway
3	The Normans (Norman: Nourmands; French: Norman...	Who was the Norse leader?	Rollo
4	The Normans (Norman: Nourmands; French: Norman...	What century did the Normans first gain their ...	10th century

Figure 3. Modified validation set for generating questions

S o u r c e: Own work.

Now, let us set aside a few percent of the training dataset for the test set, which will be used for checking the results after training. Figure 4 shows the result.

```
test_df, train_df = split_dataset(13)
val_df = squad_val_df.copy()

print(train_df.shape, 'train_df')
print(val_df.shape, 'val_df')
print(test_df.shape, 'test_df')

test_df.head()
```

```
(113377, 3) train_df
(11873, 3) val_df
(16942, 3) test_df
```

	context	question	answer
1778	Though the iPod was released in 2001, its pric...	How large was the hard drive on the original i...	5 GB
12433	There are diverse interpretations of Christian...	While many, the perceptions of Christianity ca...	conflict
13663	On January 25, 1918, at the third meeting of t...	Which unofficial name was Russia given at the ...	[MASK]
4280	Lee had lost her mother, who suffered from men...	What profession did Harper Lee's father hold?	lawyer
12876	In 2011–2012, Sony Music Inc. expressed suppor...	Which acts did not stir up any controversy?	[MASK]

Figure 4. Creating a test data set for question generation

S o u r c e: Own work.

For the task of extracting answers from the text, the SQuAD dataset will also be used, but we will transform the data so that each entry contains the context and a list of potential answers found within it. Splitting into three separate datasets followed a similar principle as in the previous example.

To perform the task of generating incorrect answers, the ReAding Comprehension dataset from Examinations (RACE) can be used. RACE is a dataset containing more than 28,000 paragraphs and approximately 100,000 questions. This dataset is based on English language exams designed for middle and high school students in China. Unlike the SQuAD dataset, which contains only questions and answers, RACE also includes a list of incorrect answer options for each question-answer pair. Now, let us take a closer look at the structure of the chosen dataset. Figure 5 shows several entries.

The dataset is already divided into three files: train, dev, and test. The translation of RACE into Ukrainian was carried out independently. Figure 6 shows the transformed datasets in a convenient format for training.

example_id (string)	article (string)	answer (string)	question (string)	options (sequence)
"high19432.txt"	"The rain had continued for a week…	"C"	"What did Nancy try to do before she fel…	["Measure the depth of the river", "Look for a…
"high19432.txt"	"The rain had continued for a week…	"D"	"The following are true according to th…	["It took Lizzie and Nancy about 20 minutes to…
"high19432.txt"	"The rain had continued for a week…	"A"	"What did the local people do to help…	["They put up shelter for them in a school.", "They…

Figure 5. RACE structure

S o u r c e: Own work.

```
train_df = pd.read_csv(f'data/train_df_{GENERATION_LANGUAGE}.csv', converters={'incorrect_options': literal_eval})
val_df = pd.read_csv(f'data/val_df_{GENERATION_LANGUAGE}.csv', converters={'incorrect_options': literal_eval})
test_df = pd.read_csv(f'data/test_df_{GENERATION_LANGUAGE}.csv', converters={'incorrect_options': literal_eval})

print(train_df.shape)
print(val_df.shape)
print(test_df.shape)

train_df.head()
```

```
(87849, 4)
(4887, 4)
(4934, 4)
```

	context	question	correct_option	incorrect_options
0	«Культура складається з усіх спільних продукті…	У спілкуванні не буде труднощів, якщо _ .	люди з різних країн можуть знати мови та культ…	[люди з різних країн можуть говорити мовами од…
1	«Обідати поза домом» або «їсти поза домом» — ц…	Згідно з уривком, яке з наступних тверджень є …	Ваше замовлення в ресторані з виносом можна ві…	[існують великі відмінності правил у різних ре…
2	«Обідати поза домом» або «їсти поза домом» — ц…	Про що в основному йдеться в уривку?	Ресторанна культура в Британії	[Манери за столом у Великобританії, Різні рест…
3	«Мрії можуть бути важливішими за сон. Нам усім…	Спати може бути менш важливо, ніж _ .	сон	[думаю, працювати, дослідження]
4	«Мрії можуть бути важливішими за сон. Нам усім…	Сни та фільми зазвичай _ .	в кольорі	[дуже довго, про роботу, дуже сумно]

Figure 6. Modified datasets for generation of incorrect answer choices

S o u r c e: Own work.

Model training and practical implementation

For each of the three identified tasks, a separate model for both English and Ukrainian languages needs to be trained. Therefore, a total of 6 transformers will be trained. In each of the three cases, the overall training process is similar and differs in terms of some details. So, let us consider only the common methods.

We will start training the T5 model. It is best to conduct training on a graphics processor because it is a complex computational process that can take a lot of time, especially if using a regular CPU, which has far fewer cores. Google Colaboratory offers the opportunity to use powerful graphics processors for free but limits their continuous usage to 6 hours, which is also important to consider since sometimes training models can take much longer, so it has to be done in parts. To ensure that the training is performed on a GPU, go to Edit -> Notebook settings -> Hardware accelerator and select GPU. Check the information about the GPU chip to which the current notebook has an access (Figure 7).

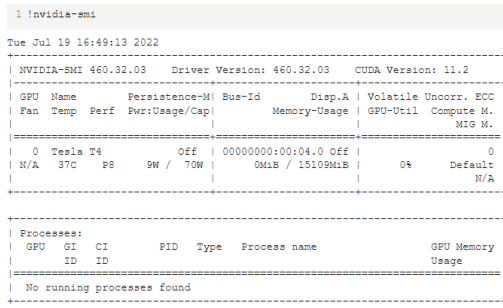


Figure 7. GPU information

Source: Own work.

Next, we choose the language for which we want to perform training and connect Google Drive to the runtime environment so that we can write and read files from it. Now, we set up Google Drive as the working directory for storing all checkpoints and logs.

The "transformers" library contains various NLP models for solving a wide range of tasks. In this work, we export the T5 model from it. The "pytorch-lightning" library contains many useful classes that simplify the training process and reduce the amount of a written code. The "tokenizers" library contains special tokenizers that prepare the text input for the model. We import the required methods and classes.

Next, we need to prepare the dataset for use. After that, appropriate classes with methods for training are created. For each task, the classes were developed separately, but their operating principle is quite similar. The following is an example of classes for generating questions. We inherit a special Dataset class, which manipulates the dataset. We also add another special token "SEP" to separate parts of input and output sequences. Now we create a DataModule class. DataModule is responsible for creating Datasets (for training, validation, and testing) and for creating appropriate DataLoaders for iterating over them. In the end, we create a Trainer, which will carry out the training, and a ModelCheckpoint that will save the model after each epoch. This way, the best model can be used later on. Figure 8 shows the training process.

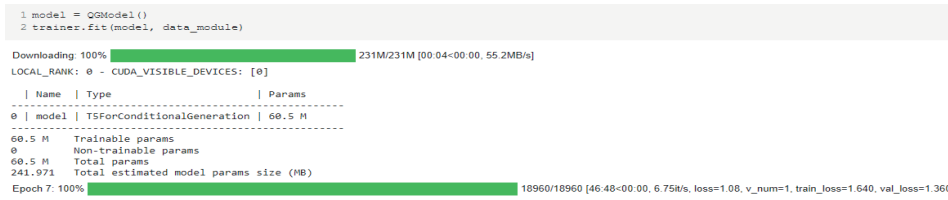


Figure 8. Training model

S o u r c e: Own work.

Now we can move on to the time metrics. Due to Google Colaboratory limitations, the training of some models took place in two or even three stages. However, the pytorch-lightning library can save logs and the state of the model being trained at the time of urgent and emergency disconnections from the runtime environment. For the question generation task, the process of training the English model took approximately 6 hours (8 epochs). Training the Ukrainian model took approximately 9 hours (12 epochs). For the potential answer extraction task, the process of training the English model took approximately 2 hours (6 epochs). Training the Ukrainian model took slightly over 2 hours (8 epochs). For the incorrect answer generation task, the process of training the English model took approximately 6 hours (10 epochs). Training the Ukrainian model took approximately 8 hours (8 epochs).

Results of the training

We load the trained models and test them on the test dataset. Now we install the “tensorboard” extension to display graphs with metrics and specify the path to the directory where logs were stored.

Below, in Figures 9–11, the main loss minimization graphs during training and validation for the English models are presented.

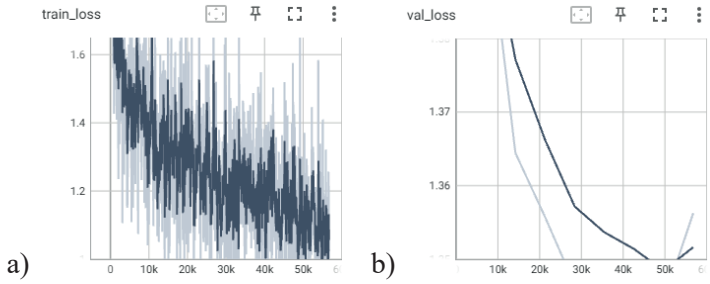
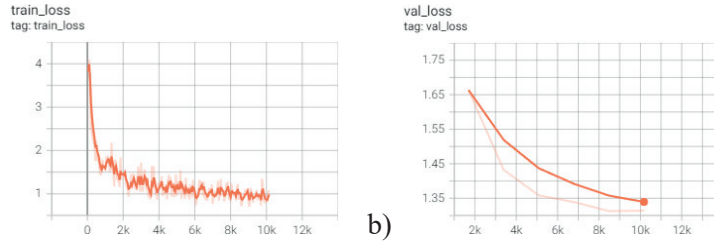


Figure 9. Graph of loss changes during a) training / b) validation for the task of generating questions

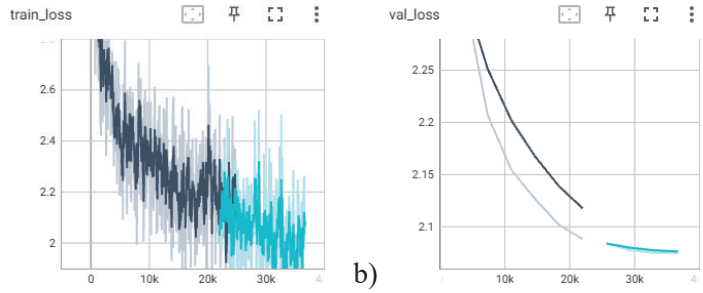
S o u r c e: Own work.



a) b)

Figure 10. a) Graph of loss changes during training for the task of extracting potential responses. b) Graph of loss changes during validation for the task of extracting potential answers

S o u r c e: Own work.

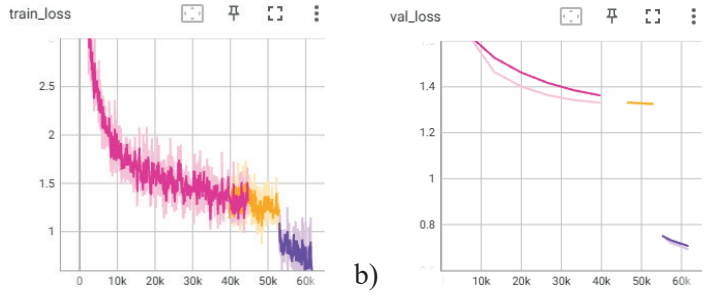


a) b)

Figure 11. a) Graph of loss changes during training for the task of generating incorrect answers. b) Graph of loss changes during validation for generating incorrect answers

S o u r c e: Own work.

Now, in Figures 12–14, the main loss minimization graphs during training and validation for the Ukrainian models are presented.



a) b)

Figure 12. Ukrainian models graph of loss changes during a) training / b) validation for the task of generating questions

S o u r c e: Own work.

As can be seen from the figures, with each training epoch, the neural models provided more and more accurate results. Now we can move on to the demonstration of their use.

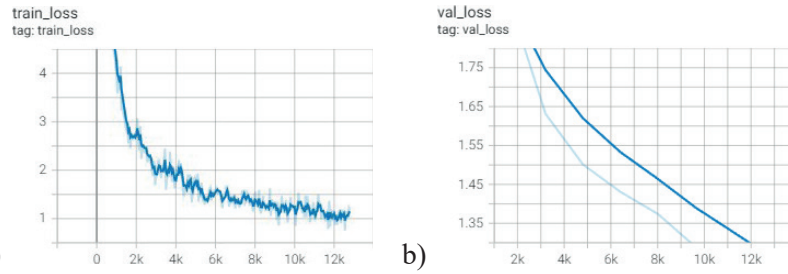


Figure 13. Ukrainian models a) Graph of loss changes during training for the task of extracting potential responses. b) Graph of loss changes during validation for the task of extracting potential answers

S o u r c e: Own work.

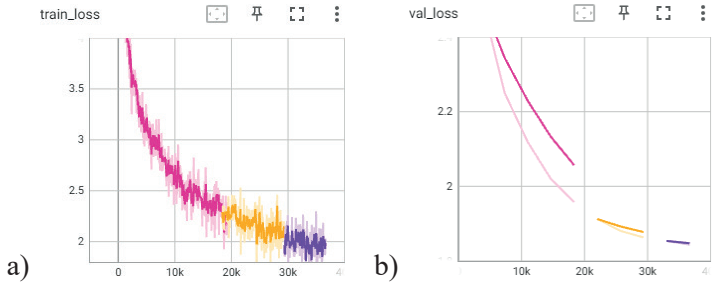


Figure 14. Ukrainian models a) Graph of loss changes during training for the task of extracting potential responses. b) Graph of loss changes during validation for the task of extracting potential answers

S o u r c e: Own work.

Development of the server API

After training, the models were saved to separate files, and a special API for their use was written using the Python programming language and the Flask library. Figure 16 shows the main endpoints.

```python
from flask import Flask, render_template, request, jsonify, abort
from test_generation.test_generator import TestGenerator
from helpers import validate_generate_test_input

app = Flask(__name__)
test_generator = TestGenerator()


@app.route('/')
def index():
  return render_template('index.html')


@app.route('/test-generator/generate', methods=['POST'])
def generate_test():
  try:
    input = request.get_json()
    validate_generate_test_input(input)
  except Exception as e:
    return jsonify({'error': str(e)}), 400

  try:
    test = test_generator.generate(input['language'], input['text'], input['desired_questions_count'], input['generate_distractors'])

    return jsonify(test)
  except Exception as e:
    return jsonify({'error': f'{e.__class__.__name__}: {str(e)}'}), 500
```

Figure 15. API endpoints

Source: Own work.

The first endpoint contains a description of the usage, and the second provides the access to the trained models, with which a complete test generation can be performed.

Let us look at the parameters accepted by the second server API endpoint in more detail:

- language – the input text language. Possible values: “ENG”, “UKR”;
- text – a paragraph of the text from which tests will be generated. A minimum paragraph character counts: 50;
- desired_questions_count – the desired number of questions to be generated. Possible values: from 1 to 20. Can be “null” if the “predefined_answers” parameter is specified;
- predefined_answers – answers chosen by the user. Possible values: str[], 1 to 20. Can be “null” if the “desired_questions_count” parameter is specified;
- generate_distractors – determines whether to generate incorrect answers. Possible values: “True”, “False”.

After sending a request for generation, the parameters undergo validation. If the validation is successful, the data enters the main class responsible for test generation and connects the previously trained models. First, the text is cleared of noise. Next, the filtered text is broken down into smaller parts. The spaCy library is responsible for this. It uses numerous natural language processing methods and is able to work with many languages. After this, one of the neural networks must find potential answers, the number of which should correspond to the desired number of generated questions. If the user enters potential answers themselves, this step is ignored. The next step is creating questions. Based on the found answers and the text snippets they relate to, another neural network generates questions. Finally, if the “generate_distractors” parameter contains the “True” value, the third neural model will begin generating incorrect answer options for each question.

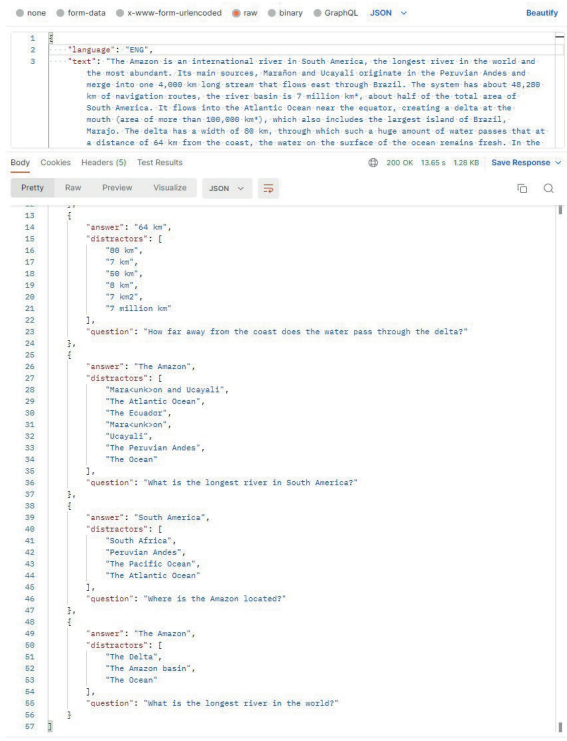


Figure 16. Generating questions based on the text in English

S o u r c e: Own work.

This model takes into account the text snippet on which the question was based, and adjacent ones to increase result diversity. In the final stage, the generated questions, correct, and incorrect answer options are formatted and combined into a single JSON object that is returned to the client. At this point, test generation can be considered complete. The test creation time varies greatly and depends on the desired number of questions and the need to generate correct (the user can specify them independently) or incorrect answers. On average, generating a test with 15–20 questions takes about two minutes. Figure 16 shows the testing of the server API and the generation of five questions from a paragraph of a text. All requests were executed using the Postman program.

Web interface

As mentioned earlier, a web application was developed for using the server API using the TypeScript programming language and the React library. Let us consider its structure and capabilities. Figure 17 shows the main page with instructions for

use. The application supports two interface languages: English and Ukrainian. To change it, click on the selector in the upper right corner and choose the desired option.

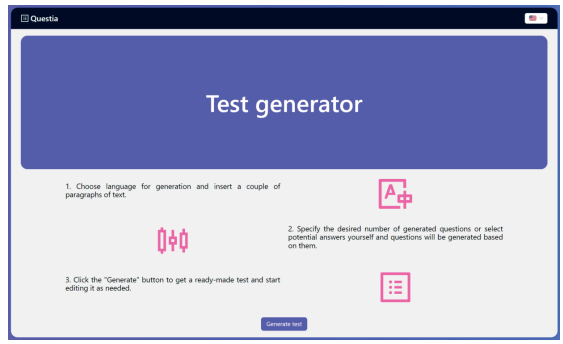
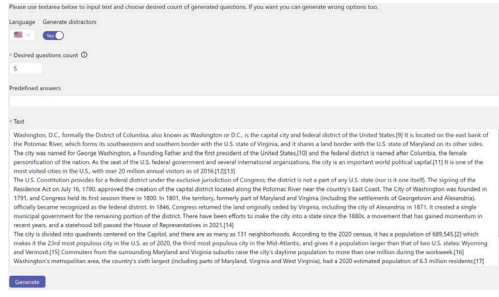


Figure 17. Web application home page

S o u r c e: Own work.

All further instructions will be executed for the English interface. To start creating a test, click the "Generate test" button. After that, you will be redirected to the generation form page. This form contains fields that correspond to the server API parameters: Language – the language of the text; Generate distractors – a checkbox indicating whether to generate incorrect answer options; Desired questions count – the desired number of generated questions. This is a required field, but if potential answers (Predefined answers) are specified manually, this field is ignored; Predefined answers – desired answers specified manually, based on which questions will be generated. Answers must be separated by a semicolon ";"; Text – the text from which the test will be generated. Fill in the form and try to generate a test with 5 questions (Figure 18, a). Click the "Generate" button to get the result. Now you can start editing the test in a special text editor (Figure 18, b). The answers are highlighted in a bold format.

a)



b)

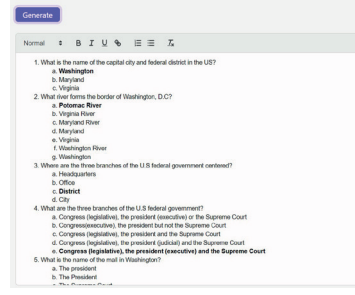


Figure 18. a) Generation of a five-question test; b) Generated test from English text

S o u r c e: Own work.

Discussion

The problem of auto-generating questions and correct and incorrect answers based on a particular text is relevant and widespread for the research. This will make it easier for teachers to create questions and answer options in the future. The proposed approach can be easily adapted to other languages, not just English.

In the future, teachers should be encouraged to try using such an application for educational purposes and analyze its advantages and disadvantages according to various criteria and indicators. Developing such criteria and indicators involves using the expert research method, which will be the next stage of the study.

Conclusions

In this study, the problem of autogeneration of questions, correct and incorrect answers based on the English text was identified. Based on this, several scientific works on this topic were researched and analyzed. As a result, it was decided to create a proprietary algorithm that would perform this task, i.e., generate questions, correct and incorrect answers from an English text. Special SQuAD and RACE datasets were chosen for training. After a detailed review of these datasets, the necessary data for the experiment were extracted and transformed into a convenient format for use. The training algorithm for 6 models was designed and implemented, and useful metrics were obtained after their training. Additionally, a server-side and web interface were developed for interaction with them.

In conclusion, the models were configured correctly, and now they fully perform the assigned task. Overall, the conducted research and work can be considered successful, as the web application requires a minimal amount of user actions.

The prospects for further research include studying the possibility and feasibility of using this software tool for educational purposes.

References

Affolter, K., Stockinger, K. & Bernstein, A. (2019). A comparative survey of recent natural language interfaces for databases. *The VLDB Journal*, 28(5), 793-819. https://doi.org/10.1007/s00778-019-00567-8.

Akyon, F., Cavusoglu, D., Cengiz, C., Altinuc, S. & Temizel, A. (2022) Automated question generation and question answering from Turkish texts using text-to-text transformers. *Turkish Journal of Electrical Engineering and Computer Sciences* (30:5), article 17. https://doi.org/10.55730/1300-0632.3914.

Colab.research.google.com. (2022) Google Colaboratory. Retrieved: https://colab.research.google.com/notebooks/welcome.ipynb?hl=ua.

Common crawl. https://commoncrawl.org/.

Devlin, J., Chang, M., Lee, K. & Toutanova, K. (2019). BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding. In J. Burstein, C. Doran & T. Solorio (Eds.). Proceedings of NAACL-HLT 2019, (pp. 4171–4186). https://aclanthology.org/N19-1423.pdf.

Dodge, J. et al. (2021) Documenting large Webtext corpora: A case study on the Colossal Clean Crawled Corpus, Proceedings of the 2021 Conference on Empirical Methods in Natural Language Processing, (pp. 1286–1305). https://aclanthology.org/2021.emnlp-main.98.pdf.

Education Ecosystem (LEDU). (2022) A Simple Introduction to Natural Language Processing, Becoming Human: Artificial Intelligence Magazine. https://becominghuman.ai/a-simple-introduction-to-natural-language-processing-ea66a1747b32.

Graetz, F. M. (2022). Why AdamW matters, Towards Data Science. https://towardsdatascience.com/why-adamw-matters-736223f31b5d.

Guo, J., Zhan, Z., Gao, Y., Xiao, Y., Lou, J. G. & Liu, T. (2019). Towards complex text-to-SQL in cross-domain database with intermediate representation. In 57th Annual Meeting of the Association for Computational Linguistics, (pp. 4524–4535), Association for Computational Linguistics, Florence, Italy. https://doi.org/10.18653/v1/P19-1444.

Huggingface.co. (2022) squad_v2 · Datasets at Hugging Face. https://huggingface.co/datasets/squad_v2.

Lutkevich, B. (2022) What is Natural Language Processing? An Introduction to NLP. https://www.techtarget.com/searchenterpriseai/definition/natural-language-processing-NLP.

Mellah, Y., Rhouati, A., Ettifouri, E. H., Bouchentouf, T. & Belkasmi, M. G. (2021). SQL Generation from Natural Language: A Sequence-to-Sequence Model Powered by the Transformers Architecture and Association Rules. *Journal of Computer Science*, 17(5), 480–489. https://doi.org/10.3844/jcssp.2021.480.489.

Nagoudi, E., Elmadany, A. & Abdul-Mageed, M. (2022) AraT5: Text-to-Text Transformers for Arabic Language Understanding and Generation. In S. Muresan, P. Nakov, & A. Villavicencio (Eds.). Proceedings of the 60th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers), (pp. 628–647). http://dx.doi.org/10.18653/v1/2022.acl-long.47.

Negri, D. (2022). Transformer NLP explained & natural language processing examples, Eidosmedia. https://www.eidosmedia.com/blog/technology/machine-learning-size-isn-t-everything.

Roberts, A. (2022). Exploring Transfer Learning with T5: the Text-To-Text Transfer Transformer. Google Research. https://ai.googleblog.com/2020/02/exploring-transfer-learn ing-with-t5.html.

Vachev, K., Hardalov, M., Karadzhov, G., Georgiev, G., Koychev, I. & Nakov, P. (2022). Leaf: Multiple-Choice Question Generation. Advances in Information Retrieval. ECIR 2022. Lecture *Notes in Computer Science* (13186). Springer, Cham, (pp. 321–328). https://doi.org/10.1007/978-3-030-99739-7_41.

Xavier, B. A. & Chen, P. H. (2022) Natural Language Processing for Imaging Protocol Assignment: Machine Learning for Multiclass Classification of Abdominal CT Protocols Using Indication Text Data. *Journal of Digital Imaging* 35, 1120–1130. https://doi.org/10.1007/s10278-022-00633-8.

Tetiana A. Vakaliuk, Oleksii V. Chyzhmotria, Svitlana O. Didkivska, Illia Linevych

Opracowanie usługi internetowej do tworzenia testów opartych na analizie tekstu z wykorzystaniem technologii przetwarzania języka naturalnego

S t r e s z c z e n i e

W artykule przeanalizowano modele i metody przetwarzania języka naturalnego oraz wybrano nowoczesne technologie szkolenia modeli w celu opracowania usługi internetowej do tworzenia testów opartych na analizie tekstu z wykorzystaniem technologii przetwarzania języka naturalnego. Badanie uwzględnia metody i algorytmy inteligentnej analizy danych w celu generowania pytań oraz poprawnych i niepoprawnych odpowiedzi z tekstu. Autorzy uzasadniają wybór sieci neuronowej do generowania testów na podstawie tekstu w języku angielskim i ukraińskim oraz charakteryzują źródła danych do szkolenia. Badanie opisuje również działanie proponowanego modelu, który posłuży jako podstawa do stworzenia usługi internetowej. Niezbędne dane do eksperymentu zostały wyodrębnione i przekształcone w wygodny do użycia format po szczegółowym przeglądzie tych zbiorów danych. Zaprojektowano i zaimplementowano algorytm treningowy dla 6 modeli, a po ich wytrenowaniu uzyskano wartościowe metryki. Dodatkowo opracowano interfejs po stronie serwera i interfejs sieciowy do interakcji z nimi.

S ł o w a k l u c z o w e: analiza tekstu, język naturalny, technologie przetwarzania języka naturalnego, NLP, model

Tetiana A. Vakaliuk, Oleksii V. Chyzhmotria, Svitlana O. Didkivska, Illia Linevych

Desarrollo de un servicio web para la creación de pruebas basado en el análisis de textos mediante tecnologías de procesamiento del lenguaje natural

R e s u m e n

El artículo analiza modelos y métodos de procesamiento del lenguaje natural, y selecciona tecnologías modernas para el entrenamiento de modelos con el fin de desarrollar un servicio web para la creación de tests basados en el análisis de textos utilizando tecnologías de procesamiento del lenguaje natural. El estudio considera métodos y algoritmos de análisis inteligente de datos para generar preguntas y respuestas correctas e incorrectas a partir del texto. Los autores justifican la elección de una red neuronal para generar tests basados en textos en inglés y ucraniano y caracterizan las fuentes de datos para el entrenamiento. El estudio también describe la actividad del modelo propuesto, que servirá de base para crear un servicio web. Tras un examen detallado de estos conjuntos de datos, se extrajeron los datos necesarios para el experimento y se transformaron a un formato conveniente para su uso. Se diseñó e implementó el algoritmo de entrenamiento de 6 modelos y se obtuvieron valiosas métricas tras su entrenamiento. Además, se desarrolló una interfaz web y de servidor para interactuar con ellos.

P a l a b r a s c l a v e: análisis de texto, lenguaje natural, tecnologías de procesamiento del lenguaje natural, PLN, modelo

Tetiana A. Vakaliuk, Oleksii V. Chyzhmotria, Svitlana O. Didkivska, Illia Linevych

Татьяна Вакалюк, Алексей Чижмотря, Светлана Дидковская, Илья Линевич

Разработка веб-сервиса для создания тестов на основе анализа текста с использованием технологий обработки естественного языка

Аннотация

В статье проанализированы модели и методы обработки естественного языка и выбраны современные технологии обучения моделей с целью разработки веб-сервиса для создания тестов на основе анализа текста с использованием технологий обработки естественного языка. В исследовании используются интеллектуальные методы анализа данных и алгоритмы для генерации вопросов, а также правильных и неправильных ответов из текста. Авторы обосновывают выбор нейронной сети для генерации тестов на основе текста на английском и украинском языках и характеризуют источники данных для обучения. В исследовании также описана работа предложенной модели, которая послужит основой для создания веб-сервиса. Необходимые для эксперимента данные были извлечены и преобразованы в удобный для использования формат после детального рассмотрения этих наборов данных. Был разработан и реализован алгоритм обучения для 6 моделей, после их обучения были получены ценные метрики. Дополнительно были разработаны серверный интерфейс и веб-интерфейс для взаимодействия с ними.

Ключевые слова: анализ текста, естественный язык, технологии обработки естественного языка, НЛП, модель

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Contributors

Marcin Barszcz, PhD, Lublin University of Technology, Poland, email: m.barszcz@pollub.pl
Ainur Bazarbayeva, PhD student, Kazakh National Women's Teacher Training University, Institute of Physics, Mathematics and Digital Technologies, Kazakhstan, email: aynur555a@gmail.com
Kornel Chromiński, PhD, University of Silesia in Katowice, Institute of Computer Science, Poland, email: kornel.chrominski@us.edu.pl
Aleksandra Cząstkiewicz, BA, Maria Curie-Sklodowska University, Department of Philosophy and Sociology, Poland, email: aleksandra.czastkiewicz@gmail.com
Oleksii V. Chyzhmotria, PhD student, Senior Lecturer, Zhytomyr Polytechnic State University, Department of Software Engineering Ukraine, email: 4ov.ztu@gmail.com
Svitlana O. Didkivska, PhD student, Krakow University of Economics, Poland, email: d2023@student.uek.krakow.pl
Krzysztof Dziedzic, PhD hab., Associate Prof., Lublin University of Technology, Poland, email: k.dziedzic@pollub.pl
Kazeem Olaiya Fabunmi, Ph.D, University of Ilorin, Department of Educational Technology, Nigeria, email: olaolaoluwa21@gmail.com
Natalia Frys, BA student, Jagiellonian University, Department of Polish studies, Poland, email: nataliafrys457@gmail.com
Marta Jokiel, PhD hab., Associate Prof Poznan University of Medical Sciences, Department of Traumatology, Orthopedics and Hand Surgery, Physiotherapy Department, Poland, email: marta.jokiel@ump.edu.pl
Maurycy Jankowski, Prof., PhD hab., Poznan University of Medical Sciences, Department of Computer Science and Statistics, Poland, email: mjankowski@ump.edu.pl
Agnieszka Karbownik, PhD hab., Associate Prof., Poznan University of Medical Sciences, Department of Clinical Pharmacy and Biopharmacy, Poland, email: akarbownik@ump.edu.pl
Piet Kommers, Prof., PhD, University of Twente, Netherlands, email: pkommers@gmail.com
Illia Linevych, PhD student, Zhytomyr Polytechnic State University, Ukraine, email: illia.linevych@gmail.com
Nataliia Morze, Prof., PhD hab., Borys Grinchenko Kyiv University, Faculty of Information Technologies and Mathematics, Ukraine, email: n.morze@kubg.edu.ua
Olha Naboka, Prof., PhD hab., Donbas State Pedagogical University, Ukraine, email: olganaboka911@gmail.com
Volodymyr Proshkin, Prof., PhD hab., Borys Grinchenko Kyiv University, Ukraine, email: v.proshkin@kubg.edu.ua
Małgorzata Przybyła-Kasperek, PhD hab., Professor of the University, University of Silesia in Katowice, Institute of Computer Science, Poland, email: malgorzata.przybyla-kasperek@us.edu.pl

Barbara Purandare, PhD hab., Associate Prof., Poznan University of Medical Sciences, Department of Occupational, email: barbarap@ump.edu.pl

Magdalena Roszak, PhD hab., Associate Prof., Poznan University of Medical Sciences, Department of Computer Science and Statistics, Head of Department od Statistic and Mathematic, Poland, email: mmr@ump.edu.pl

Zofia Samsel, BA, Université Paris Cité, Learning Planet Institute, France, email: zosiasamsel@gmail.com

Olena Semenikhina, Prof., PhD hab., Sumy State Pedagogical University named after A. S. Makarenko, Ukraine, email: e.semenikhina@fizmatsspu.sumy.ua

Volodymyr Shamonia, PhD, Sumy State Pedagogical University named after A. S. Makarenko, Ukraine, email: shamonawg@gmail.com

Anna Smelkowska, PhD, Poznan University of Medical Sciences, Department of Neurological Nursing, email: asmelk@ump.edu.pl

Eugenia Smyrnova-Trybulska, PhD hab., Professor of the University, University of Silesia in Katowice, Faculty of Arts and Educational Science, Poland, email: esmyrnova@us.edu.pl

Yakubu Ibrahim Umar, Prof., Ph.D, Federal University of Technology Minna, Department of Industrial and Technology Education, Minna, NIGER State, Nigeria, email: umaryakubu@futminna.edu.ng or yakumaite2002@yahoo.co.uk

Tetiana A. Vakaliuk, Prof., PhD hab., Zhytomyr Polytechnic State University, Ukraine, email: tetianavakaliuk@gmail.com

Jan Waligórski, PhD, AGH University of Krakow, EduVRLab, Poland, email: jan.bruno.waligorski@gmail.com

Tomasz Wiśniewski, Mgr inż. Euro-Forum, ul. Graniczna 4/7,8, 20-010 Lublin, Poland, email: t.wisniewski@rapsody.com.pl

Artem Yurchenko, Prof., PhD hab., Sumy State Pedagogical University named after A. S. Makarenko, Ukraine, email: a.yurchenko@fizmatsspu.sumy.ua

Katarzyna Zaorska, PhD hab., Associate Prof., Poznan University of Medical Sciences, Department of Histology and Embryology, email: kzaorska@ump.edu.pl

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2. *Zastosowanie systemów CMS w tworzeniu przestrzeni informacyjno-edukacyjnej w Internecie*. Podręcznik akademicki. Ed. E. Smyrnova-Trybulska, S. Stach. Authors: E. Smyrnova-Trybulska, S. Stach, B. Fuklin, D. Staniek. Katowice: Wydawnictwo Uniwersytetu Śląskiego, Studio Noa, 2012, 194p. ISBN 978-83-60071-55-7 (http://www.wydawnictwo.us.edu.pl/node/3731).

Monograph

1. Smyrnova-Trybulska, E. (2018). *Technologie informacyjno-komunikacyjne i e-learning we współczesnej edukacji*. [*Information and communication technologies and e-learning in modern education*]. Katowice: Wydawnictwo Uniwersytetu Śląskiego. ISSN 0208-6336, ISBN 978-83-226-3070-9 (print edition), ISBN 978-83-226-3071-6 (digital edition).

Contact
International Journal of Research in E-learning
University of Silesia in Katowice
Faculty of Arts and Educational Sciences
Bielska 62, 43-400 Cieszyn, Poland
phone: +48 33 854 61 12
fax: +48 33 854 61 01
email: esmyrnova@us.edu.pl

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Marzena Wysocka-Narewska

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