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# Unlocking the power of synergy: the joint force of cloud technologies and augmented reality in education

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## Abstract

This is an introductory text to a collection of selected papers from the 10th Workshop on Cloud Technologies in Education (CTE 2021) and 5th International Workshop on Augmented Reality in Education (AREdu 2022) which were held in Kryvyi Rih, Ukraine, on May 23, 2022. It consists of information on events and short summaries of selected papers.

## Keywords

adaptive cloud learning platforms, blended learning, blockchain in education, cloud-based AI education applications, cloud-based e-learning platforms, tools and services, cloud-based learning environments, competency-based education platforms, digital transformation of education, educational data mining, emotion AI, immersive technology applications in education, mobile learning, smart campus technologies, social analytics in education, virtualization of learning: principles, technologies, tools, augmented reality gamification, design and implementation of augmented reality learning environments, augmented reality in science education, augmented reality in professional training and retraining

# 1. Introduction

## 1.1. CTE 2022: 10th Workshop on Cloud Technologies in Education

### 1.1.1. CTE 2022 at a glance

**C**loud **T**echnologies in **E**ducation (CTE) is a peer-reviewed international Computer Science workshop focusing on research advances, applications of cloud technology in education.

The Workshop occupies contributions in all aspects of educational technologies and cloud-based learning tools, platforms, paradigms and models, functioning programmes or papers relevant to modern engineering and technological decisions in the IT age.

CTE topics of interest since 2012 [1, 2, 3, 4, 5, 6, 7, 8, 9]:

- Adaptive Cloud Learning Platforms
- Blended Learning
- Blockchain in Education
- Cloud-based AI Education Applications
- Cloud-based E-learning Platforms, Tools and Services

Figure 1: CTE 2022 logo.

*CTE 2022: 10th Workshop on Cloud Technologies in Education,*
*AREdu 2022: 5th International Workshop on Augmented Reality in Education, May 23, 2022, Kryvyi Rih, Ukraine*
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https://ptpe.edc.uoc.gr/en/staff/32380/82 (S. Papadakis); https://ieeexplore.ieee.org/author/38339185000 (A. E. Kiv); http://www.kspu.edu/About/Faculty/FPhysMathemInformatics/ChairInformatics/Staff/Kravtsov.aspx (H. M. Kravtsov);
https://kubg.edu.ua/prouniversitet/vizytivka/rektorat/dyrektory/1175-osadchyi-viacheslav-volodymyrovych.html (V. V. Osadchyi); https://iitlt.gov.ua/eng/structure/departments/cloud/detail.php?ID=565 (M. V. Marienko); https://iitlt.gov.ua/eng/structure/detail.php?ID=442 (O. P. Pinchuk);
https://iitlt.gov.ua/eng/structure/departments/cloud/detail.php?ID=269 (M. P. Shyshkina);
https://iitlt.gov.ua/eng/structure/detail.php?ID=1139 (O. M. Sokolyuk); https://acnsci.org/mintii (I. S. Mintii);
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CEUR Workshop Proceedings (CEUR-WS.org)

- Cloud-based Learning Environments
- Competency-Based Education Platforms
- Digital Transformation of Education
- Educational Data Mining
- Emotion AI
- Immersive Technology Applications in Education
- Mobile Learning
- Smart Campus Technologies
- Social Analytics in Education

The first part of this volume represents the proceedings of the 10th Workshop on Cloud Technologies in Education (CTE 2022), held in Kryvyi Rih, Ukraine, on May 23, 2022. It comprises 4 contributed papers that were carefully peer-reviewed and selected from 11 submissions. Each submission was reviewed by at least 3 program committee members. The accepted papers present the state-of-the-art overview of successful cases and provides guidelines for future research.

### 1.1.2. CTE 2022 committees

#### Program committee

- *Leon A. Abdillah*, Universitas Bina Darma, Indonesia [10]
- *Fernando Almeida*, University of Porto & INESC TEC, Portugal [11]
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- *Lyudmyla Bilousova*, Independent Researcher, Israel [13]
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- *Vita Hamaniuk*, Kryvyi Rih State Pedagogical University, Ukraine [23]
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- *Hennadiy Kravtsov*, Kherson State University, Ukraine [29]
- *Volodymyr Kukharenko*, Kharkiv National Automobile and Highway University, Ukraine [30]
- *Andrey Kupin*, Kryvyi Rih National University, Ukraine [31]
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- *Liliia Midak*, Vasyl Stefanyk Precarpathian National University, Ukraine [33]
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- *Yuriy Tryus*, Cherkasy State Technological University, Ukraine [50]
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### Organizing committee

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- *Andrii Striuk*, Kryvyi Rih National University, Ukraine [57]

## 1.2. 5th International Workshop on Augmented Reality in Education

### 1.2.1. AREdu 2022 at a glance

**A**ugmented **R**eality in **Edu**cation (AREdu) is a peer-reviewed international Computer Science workshop focusing on research advances, applications of virtual, augmented and mixed reality in education.

AREdu topics of interest since 2018 [58, 59, 60, 61, 62]:

- Virtualization of learning: principles, technologies, tools
- Augmented reality gamification
- Design and implementation of augmented reality learning environments
- Augmented reality in science education
- Augmented reality in professional training and retraining

AREdu 2022

Figure 2: AREdu 2022 logo.

The second part of this volume represents the proceedings of the 5th International Workshop on Augmented Reality in Education (AREdu 2022), held in Kryvyi Rih, Ukraine, on May 23, 2022. It comprises 2 contributed papers that was carefully peer-reviewed and selected from 5 submissions. Each submission was reviewed by at least 3 program committee members. The accepted papers includes a current summary of successful cases as well as directions for future research.

### 1.2.2. AREdu 2022 committees

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- *Olga Bondarenko*, Kryvyi Rih State Pedagogical University, Ukraine [63]
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- *Vita Hamaniuk*, Kryvyi Rih State Pedagogical University, Ukraine [66]
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**Organizing committee**

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## 2. Articles overview

### 2.1. CTE 2022 overview

The research "Economic analysis of factors associated with education and employment" [94] by George Abuselidze (figure 3) and Gia Zoidze aims to analyze the current state of the Georgian economy and labor market, including workforce structure, challenges, and trends, by conducting qualitative and quantitative studies. Market requirements were analyzed, and consultations were held with experts, employers, and representatives from the Center for the Development of Quality Education. The study also examined the compatibility of higher education programs with market demands, practical components in the educational process, and the relationship between higher education institutions and students. The findings suggest that promoting professional education, with the proper involvement of the state, can positively impact the economy and the country's situation. Additionally, the study examined the influence of higher education on employment and income, indicating a discernible return on investment, but also highlighting that human capital developed in the higher education system is not efficiently employed. The

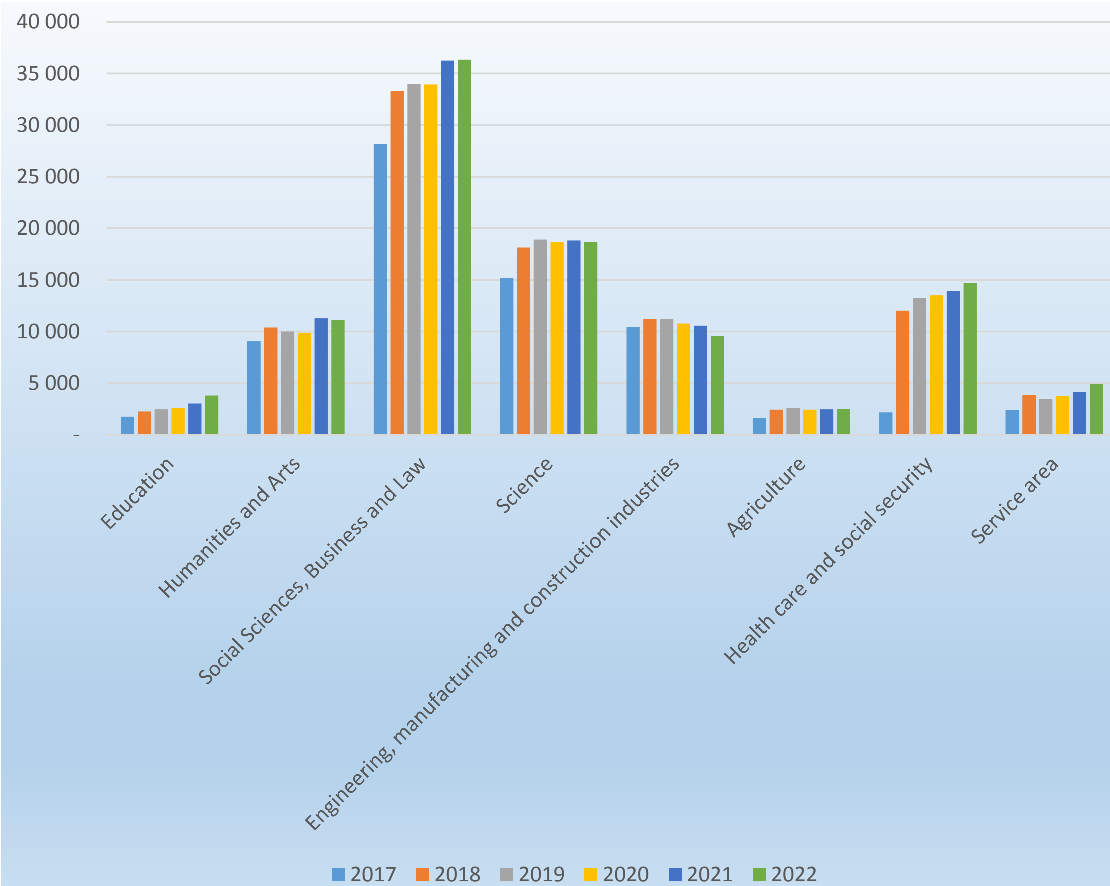


**Figure 3:** Presentation of paper [94].

study concludes with recommendations to address the issues facing the Georgian labor market and envision labor force demand. Overall, this research sheds light on the intersection of education and technology in addressing workforce needs in the Georgian context.

The authors' related works are referenced as [95, 96, 97].

The article "Smart education in the prospective teachers' training" [98] by Natalia Ye. Dmitrenko, Oksana V. Voloshyna, Svitlana S. Kizim (figure 4), Kateryna V. Mnyshenko and Svitlana V. Nahorniak explores the concept of smart education and its potential for developing the professional training of future teachers. The main components of smart education, including smart students, smart pedagogy, and smart environments, are examined, and the principles underlying this approach to education, such as mobile access and the creation of new knowledge, are defined. The features of smart education are also discussed, with a focus on its implementation in the context of the COVID-19 pandemic and military events in Ukraine. The study identifies the functions of the smart system in the pedagogical cycle, including its content, technological components, and facilities for students and teachers. The criteria for evaluating smart complexes, such as automation, sequencing, assessment, data collection, and self-organization, are


**Figure 4:** Presentation of paper [98].

identified. The study also examines distance learning systems for creating smart complexes in the training of prospective teachers, drawing on student surveys to evaluate the advantages and disadvantages of using smart technologies in the educational process. Finally, the article outlines avenues for further research on the integration of smart education into teacher training programs. Overall, this research contributes to the literature on education science by highlighting the potential of smart education for enhancing the professional development of future teachers.

The authors' related works are referenced as [99, 100, 101].

The COVID-19 pandemic led to a public health emergency that required the confinement of populations worldwide, including the suspension of face-to-face classes at all educational levels in the Spain. In response, educational centers and teachers turned to social media as the primary means of communication to continue teaching and socialization processes. The study "Possibilities and limitations of social media in education processes during the pandemic: The

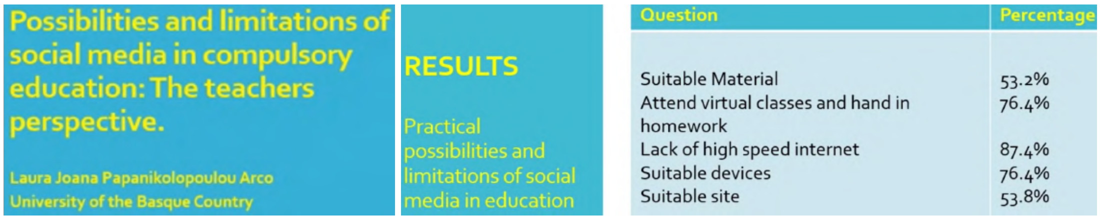


**Figure 5:** Presentation of paper [102].

teachers perspective" [102] by Laura Joana Papanikolopoulou Arco (figure 5) aims to investigate the possibilities and limitations of social media as the sole means of communication in education, from the perspective of teachers. The methodology involves the distribution of an anonymous questionnaire to secondary education centers in the Basque Country and Navarra regions, with data collection conducted electronically. The results reveal the possibilities and limitations of digital media in teaching processes, identifying both surmountable and insurmountable challenges. Overall, this research contributes to the growing body of knowledge on the role of technology in education, with implications for future educational policy and practice.

The author' related works are referenced as [103, 104, 105].

The use of student response systems (SRS) has gained significant attention in recent years as a tool for increasing student engagement and improving the overall learning experience during online lectures. In the study "Interactive surveys during online lectures for IT students" [106], Olena S. Holovnia (figure 6), Natalia O. Shchur, Iryna A. Sverchevska, Yelyzaveta M. Bailiuk and Oleksandra A. Pokotylo provide a comprehensive overview of different SRS platforms such as Mentimeter, AhaSlides, Kahoot!, Wooclap, Socrative, Poll Everywhere, and Slido, and compare their features to determine their suitability for facilitating students' engagement in online lectures.

The authors then present their experience using Mentimeter in the Operating Systems course for second-year IT students of Zhytomyr Polytechnic State University with specializations in Software Engineering, Computer Science, Computer Engineering, and Cybersecurity. The study collects data through observation, surveys, and existing data and uses visual and statistical analyses to analyze the data. The study reports an increase in the number of students' answers within the lectures and highlights IT students' problems and preferences during online lectures.

Holovnia et al. [106] provide recommendations for using SRS during online lectures to improve the interaction between the lecturer and the audience, including increasing the number of questions, reducing the time between questions, and using open-ended questions to encourage critical thinking. This study contributes to the literature on SRS in online learning and provides valuable insights for educators seeking to enhance student engagement and learning outcomes in online lectures.

The authors' related works are referenced as [107, 108, 109].

## 2.2. AREdu 2022 overview

The paper "Using a mobile application to teach students to measure with a micrometer during remote laboratory work" [110] presents the experience of developing and using a mobile

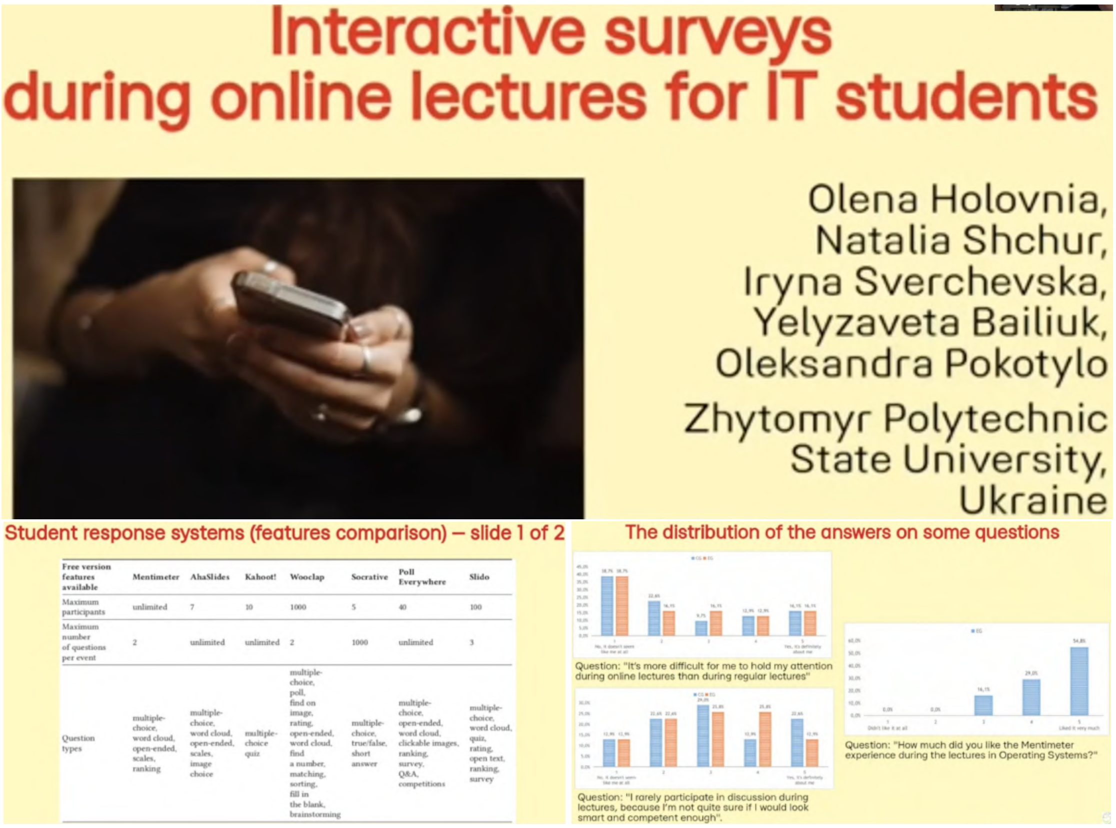


**Figure 6:** Presentation of paper [106].

application for teaching micrometer measurements during remote laboratory work in higher education. The Oleksandr V. Kanivets, Irina M. Kanivets, Tetyana M. Gorda, Oleksandr V. Gorbenko and Anton O. Kelemesh (figure 7) conducted a literature analysis and found that while ICT is widely used in higher education, computer programs and mobile applications are typically developed for secondary school disciplines. To address this gap, the authors developed a mobile application that includes theoretical, educational, and practical components. The application was found to improve students' success rates in laboratory work on the topic of measuring parts with a micrometer during distance learning, with a 7.3% increase in the percentage of qualitative success compared to distance learning without the application. The paper details the process of developing the application, including modeling the micrometer in the CAD system, creating training scenes in the Unity game engine, and writing scripts to fully immerse students in the learning process. Overall, the paper highlights the potential of mobile applications in facilitating laboratory work during distance learning and provides a valuable example for educators looking to incorporate technology into their teaching practice.

The authors' related works are referenced as [111, 112, 113].

The article "Development of the information system for navigation in modern university campus" [114] by Liudmyla E. Gryzun (figure 8), Oleksandr V. Shcherbakov and Bogdan O.

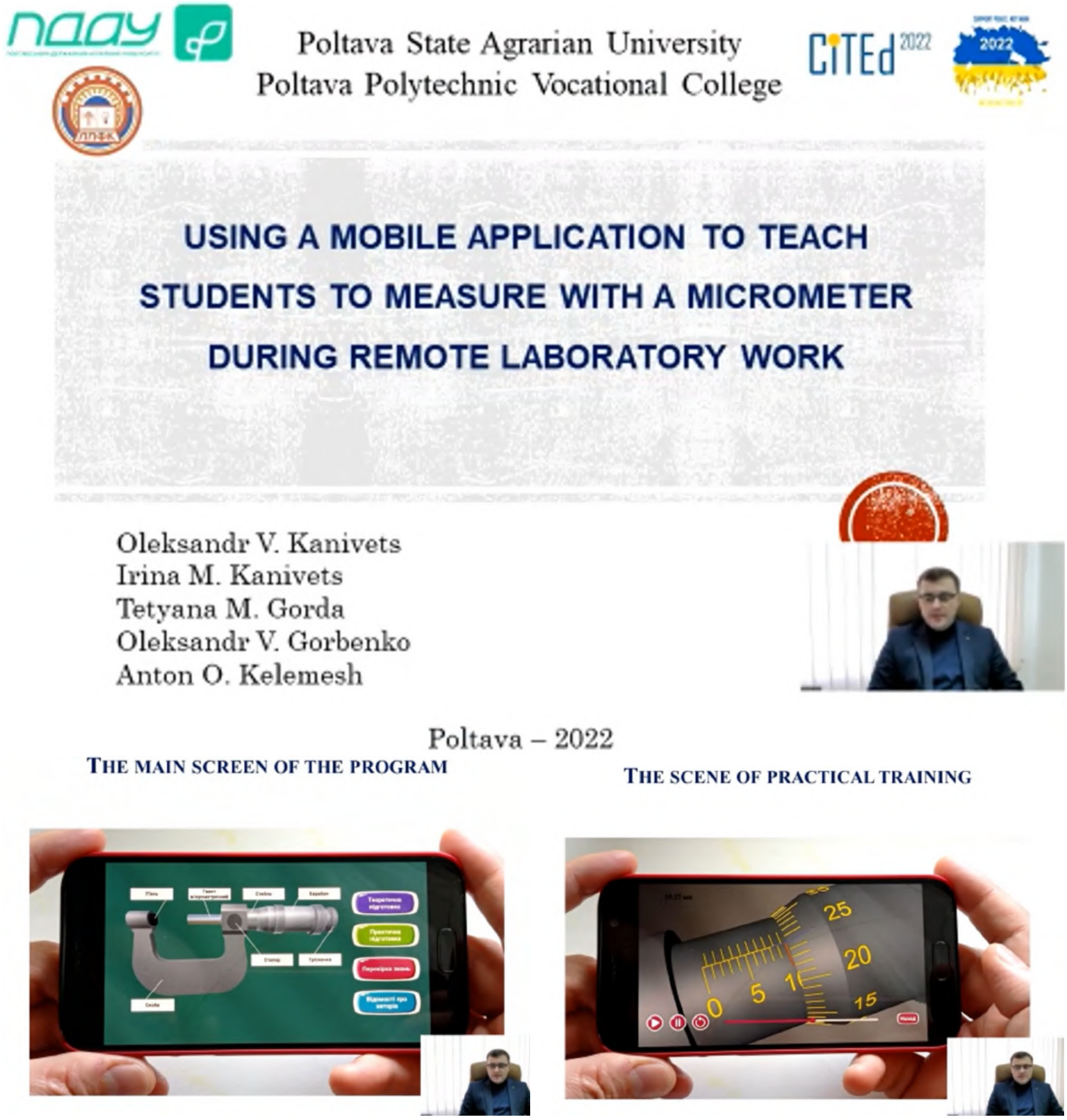


**Figure 7:** Presentation of paper [110].

Bida presents algorithmic, interface, and technological solutions for developing an information system for indoor navigation in university campuses. The scientific and applied problem of indoor navigation is analyzed, and the capabilities of existing navigation systems with similar functionalities are evaluated. The study concludes that the analyzed analogues have certain limitations. The functional and non-functional requirements for the university navigation system are specified, and its architecture is defined as a set of interconnected modules, for which appropriate interface and algorithmic solutions are elaborated. The design and development stages of the university navigation system are highlighted, along with its implemented


**Figure 8:** Presentation of paper [114].

functionality. The study establishes that the main limitations inherent in similar systems implementing indoor navigation can be overcome during the design process. The results of the system implementation in a national university are discussed, and user feedback is presented. The study confirms the feasibility of developing and using an information system for navigation in university campuses. Finally, the prospects for further work in this area are discussed.

The authors' related works are referenced as [115, 116, 117].

## 3. Conclusion

The Academy of Cognitive and Natural Sciences, in partnership with the Institute for Digitalisation of Education of the NAES of Ukraine, Kryvyi Rih State Pedagogical University, Kryvyi Rih National University, Ben-Gurion University of the Negev, and Zhytomyr Polytechnic State University, had the pleasure of hosting the 10th Workshop on Cloud Technologies in Education (CTE 2021) and the 5th International Workshop on Augmented Reality in Education (AREdu 2022).

We extend our sincere gratitude to the authors who submitted their papers and the delegates for their active participation and unwavering interest in our workshops, which have provided a platform for the exchange of ideas and innovation. Our heartfelt appreciation goes to the program committee members for their continuous guidance and to the peer reviewers whose diligent efforts have substantially enhanced the quality of the papers by providing constructive criticisms, improvements, and corrections. We acknowledge and thank the authors for their significant contributions to the success of the conference.

Furthermore, we express our deepest appreciation to the developers and other professional staff of the *Academy of Cognitive and Natural Sciences* (https://acnsci.org) and *Not So Easy Science Education* platform (https://notso.easyscience.education) for providing us with an excellent and comprehensive conference management system that has facilitated every aspect of the conference's organization, from the call for papers and reviewer invitations to paper submissions, author communications, and beyond.

We anticipate excellent presentations and fruitful discussions that will broaden our professional horizons, and we trust that all participants will derive immense satisfaction from these workshops. We look forward to the day when we will be able to meet again in person under more tranquil and peaceful circumstances.

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# Economic analysis of factors associated with education and employment

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**Abstract**

The purpose of the research is to determine and analyze the current situation in the Georgian economy, labor market requirements, existing workforce structure, main challenges and trends. Important studies were conducted, within the framework of which market requirements were analyzed, consultations were held with experts in the field, employers, representatives of the Center for the Development of the Quality of Education; The present situation of supply and demand in the educational market is studied and analyzed. Qualitative and quantitative studies were also conducted, within the framework of which the following were identified: the compatibility of higher education programs with the market requirements, the inclusion of practical components in the educational process, the relationship between higher educational institutions and students, and the processes of interaction between education and the labor market. We think that the promotion of professional education will definitely lead us to the desired results, both from the point of view of the economy of Georgia and the general situation in the country. There is simply a need for more involvement from the state and, accordingly, more properly conducted measures, raising the level of awareness in society and creating all the prerequisites in order to change the attitude towards vocational schools as positively as possible. All this will eventually become a contributing factor for improving the level of education or the economic situation. The study concludes with findings and suggestions, which cover the issues facing the Georgian labor market and the labor force demand vision. The examination of the influence of higher education on employment and income in Georgia demonstrates that the investment in higher education yields a discernible return at this point, but the human capital developed in the higher education system is still not being employed efficiently in the country.

**Keywords**

economic effect of education, labor market, factors associated with education and employment, importance of professional education for the economy, rate of public return of higher education



## 1. Introduction

In general, the countries have been giving more and more importance to education in the recent period, and accordingly they will pay more expenses for the latter as possible. Why is this happening? The answer is that education is a kind of investment in the creation of human capital. Simply put, the state will pay for the education of a specific person today because it will benefit from this person in the future, it may be performing a specific job, participating in technological progress, introducing innovations or any other form that has a positive impact on the economic and general environment of the country.

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To some extent, differences in education levels can also explain differences in income between countries, but not always. The truth is that a high level of education also indicates a high level of economic development and growth of the country. However, since there are many other factors that have a noticeable impact on the economy, a high level of education alone is not enough to maintain its good condition. Even if we ignore the influence of other factors, it is still an issue that deserves our attention. Having the necessary resources (in this case, we mean a high level of education) does not indicate guaranteed good results, it is necessary to give these resources the right direction and use them effectively.

To better understand the relationship between education and economy, here we can briefly talk about the factors that have been identified by researchers over time and which have a direct impact on the country's economy:

- Education increases the potential for innovation, which creates the basis for economic growth;
- Educated workforce is highly productive (easily assimilates technologies) and therefore contributes to the growth and development of the economy;
- By investing in education, a better environment is created for technological development, which naturally has a positive impact on the increase in labor productivity and, accordingly, on the economy.

Here, as an example, we cite the research of Krueger and Lindahl [1], which meant the creation of such a tool that would make it possible to compare school years with economic growth. The result of this was the following: from one additional year of education, more than 10% gains were received. Despite the shortcomings that accompanied such measurement, it is still possible to create a certain idea about the relationship between education and economic growth.

Also, we can consider the method of Hanushek and Woessmann [2], which was about comparing the quality of education and economic growth by countries. TIMSS and PISA tests were used in the method, and the observation finally showed that high results of the tests indicated an appropriate expression of economic growth in percentages of GDP.

The study of the economic effect of education has become particularly noteworthy since the 1980s and 1990s, due to the wage inequality in different countries. According to international studies on the assessment of individual educational outcomes, for each additional year of formal education, the world average of individual financial outcomes increases by 10% [3]. It is significant that the highest coefficient of economic growth is recorded in the case of countries with low and middle income (10.9 and 10.7 respectively). In high-income countries, the coefficient of growth is 7.4.

It is also worth noting that over the last 12 years, the amount of education gaps has decreased by 0.6%, as access to formal education has increased worldwide and, therefore, the average number of years of formal education (especially in countries with strong economies). This circumstance leads to the strengthening of competition in local labor markets based on the supply of human resources in excess of the existing demand, and also to the proliferation of low-income jobs, which, in turn, lowers the individual financial benefits of education [4]. Therefore, finance for human capital is typically considered as an investment aimed at enabling individuals to fully participate in economically productive activities in order to make a livelihood [5, 6, 7, 8, 9, 10, 11, 12, 13]. To do this, the student must be transformed from a passive consumer of knowledge into an active creator of knowledge. Continually enhance ability to apply new information to practical situations in order to advance critical technical, financial, socioeconomic, legal, and management procedures; to increase own and society's capacity for economic activity via social responsibility and collaboration [14].

As a result, the article examines the present trends in employment and unemployment in the country, covering industry and age. The labor market's demand component has been investigated, and the key sectors with especially strong economic activity have been identified, which is one of the required criteria for the expansion of employment in these areas.

## 2. Methods

Important studies were conducted, within the framework of which market requirements were analyzed, consultations were held with experts in the field, employers, representatives of the Center for the Development of the Quality of Education; the present situation of supply and demand in the educational market is studied and analyzed. Qualitative and quantitative studies were also conducted, within the framework of which the following were identified: the compatibility of higher education programs with the market requirements, the inclusion of practical components in the educational process, the relationship between higher educational institutions and students, and the processes of interaction between education and the labor market. Furthermore, our research involves an examination of job searchers and jobs listed on the website of a private recruitment agency.

The topic of the research concerns 3 main issues:

1. Demand/supply analysis for selected higher education programs.
2. Determination of labor market requirements and challenges.
3. The importance of professional education for the economy.

This paper presents a study of the economic benefits of higher education (educational return) in the population of Georgia from a microeconomic perspective, in order to evaluate the personal/individual benefits (monetary benefits) of investment in education in the form of years and the impact of higher education on employment opportunities. As we have already mentioned, individual education gains show how much an individual's income increases (or does not increase) according to the number of years spent on formal education. Mincer's "income equality" is considered one of the most common methods for determining this relationship, and variables such as, first of all, the possibility of employment, as well as professional growth and advancement, job stability, the degree of autonomy in the work process, and so on, are used to determine non-monetary benefits [15]. After that, overall, it affects job satisfaction.

# 3. Results and discussion

## 3.1. The main challenges of the Georgian labor market

In post-communist countries, where economic reforms started relatively late, the restructuring of the labor market took place differently from developed economies, where employment increased in contradictory directions, in particular, requiring high and low qualifications. In Georgia and other post-Soviet countries, the number of medium and low-skilled jobs has increased, and there has been an increase in such activities where there is a high demand for physical skills, for example, construction, the service sector, transportation, wholesale and retail trade. Such transformations of the labor market in post-communist countries led to the devaluation of the quality of education, knowledge and competencies of the largest part of the adult population (credential inflation), considering that post-communist countries (including Georgia) are characterized by a high share of the population with university education [16].

Ultimately, this was reflected in high rates of highly skilled labor force, as the population with higher education diplomas agreed to do low-skilled jobs [17]. At the same time, the workforce of the older generation is not equipped with the knowledge or skills corresponding to the requirements of the modern market, which, in turn, is an expression of the problem of knowledge devaluation. In general, the mentioned part of the labor force remains "downgraded" in the national labor market in workplaces with low productivity, where the possibility of professional development is minimal, and those with lower competences become unemployed [18, 19, 20].

The process of "downgrading" is strengthened by the fact that in post-communist countries the number of university graduates is constantly increasing, which exceeds the country's economic capabilities. As a result, on the one hand, there is an imbalance in the labor market in terms of demand and supply of labor force, and on the other hand, the aging labor force is being replaced by a new generation, which also accepts low-skilled work. As a result, competition in the existing limited market increases and the aging workforce moves into even lower-level jobs or into the unemployed category.

Overall, an aging or young labor force that does not have modern education and skills hinders the adoption of new technologies in the labor market, the development of innovative work areas and the growth of productivity at the macroeconomic level of the country [21]. This is because a strong, educated workforce has the necessary information, abilities, and skills that potential employers are looking for [22].

Employment of young people is one of Georgia's major labor market issues. Young individuals aged 15 to 24 in particular stand out as having a very high proportion of unemployment (figure 1). This is determined by several factors. In Georgia, most young individuals in the work field have a higher education, and after finishing their studies, they confront the following sorts of problems:

1) There is no demand in the labor market for the professions they have learned,
2) The profession they have mastered is a highly competitive profession,
3) And/or their credentials and work experience do not fulfill labor market standards. Furthermore, the percentage of frictional unemployment should be included in this group, because


**Figure 1:** Unemployment rate by age groups, data for 2020 and 2021 [23].

young people require longer time to obtain the desired work, taking into consideration a variety of reasons.

In addition, one of the main challenges of the Georgian labor market is demographic aging, which directly affects the distribution of the labor force in the market and creates the need to assess how capable the existing human capital is now or will be in the future to produce tangible or intangible benefits for the country [24].

An aging workforce is associated with declining health, physical and mental capabilities, as well as reduced adaptive behavior to a changing work environment, devaluation of knowledge, and overall, a decline in productivity [25]. Taking into account all these factors, the productivity of the labor force increases, on average, until the age of 40, and then begins to decline. Despite such a generalized reasoning, the international literature also discusses types of activities that have a positive correlation with the aging of the workforce or are not at all related [26, p. 150-152]. For example, in the case of a doctor and a lawyer, labor productivity increases with age; the labor productivity of bank clerks and electrical engineers does not depend on age, however, the productivity of construction workers decreases with age [21, 27].

In jobs that require problem-solving and fast-acting skills, productivity declines with age, while in jobs that prioritize experience and verbal skills, an older workforce maintains high levels of productivity [28]. Acceptable current economic, technological and organizational innovations are also taken into account, which lead to frequent changes in work requirements and due to which the weights of a number of factors determining the productivity of the workforce (physical abilities, mental abilities, level of education, work experience) also change in the modern labor market [29].

It is difficult to say with certainty what impact the rapidly transforming labor market will have on the workforce of different age groups [30]. However, due to the fact that technological development reduces the demand for physical work in the modern labor market, it is expected that the workforce of the older age group will be able to maintain high productivity under innovative management, which will take care of the targeted updating of the knowledge and skills of the workforce, regardless of its age indicators [31].

### 3.2. Factors associated with education and employment

Also, the results of the OECD 2016 report on economic structures by education field are interesting. Engineering and construction are associated with higher financial benefits; Social Sciences, Business and Law; Exact, natural and computer sciences. The financial benefits of those educated in the above-mentioned fields are, on average, 10% higher than the benefits of other graduates. As for university graduates in pedagogy, education and humanities, as well as language and arts, their financial benefit is 15% less than the average income [19].

In addition, it is important to observe the distribution in the labor market according to their education. The research results reveal that:

- The share of hired employees with higher education is high in the education system (82%), complex office/administrative (81%) and finance/banking/insurance (86%) fields;
- Employees with school education represent the majority in defense and security (82%), production (57%) and construction (61%);
- Employees with professional education dominate in wholesale and retail trade (38%), as well as in individual services (43%).

Along with the factors related to education, the factors associated with the employment market are no less important. This refers to the number and types of vacancies in the market [32, 33].

In 2021, according to the results of the labor market demand component survey conducted in Georgia, trade, repair of cars and household items, restaurants and hotels, metallurgical industry, individual services are the economic activities in which employers experience a shortage of personnel [34]. There is a special demand for teachers and healthcare professions in the regions. However, despite the existing differences, there is a demand for accountants, waiters, sales assistants in all regions of Georgia (including Tbilisi). Therefore, our research also includes the analysis of job seekers and vacancies registered on the website of the private employment agency (hr.ge). According to Hr.ge, more specifically, what positions are in demand, is given in figure 2 [35].

Regarding the labor force recruitment problems, the majority of the employing organizations point out that there is a shortage of specific and necessary personnel in Georgia and that the applicants do not have the relevant skills for the job positions. Sales and marketing managers, confectioners, bank cashiers, teachers, journalists and others are among the deficient professions.

According to the ISCO-08 classification [36], the above-mentioned positions are mostly combined in the service and sales, individual service fields, as well as in the category of artisans/related workers and education professionals. Taking this into account, it is interesting to see what field of study graduates predominate in Georgia today and how professional preferences change over time (figure 3).

According to the 2022 data of the National Statistics Office of Georgia, among the undergraduate graduates of both state and private universities, the majority are graduates of social sciences, business and law. These programs have maintained their leading position since 2011. Educational programs related to the field of service and engineering and construction fields in both state and private universities are characterized by an increasing number of graduates. A downward trend is evident in the case of health and social service programs and agricultural education programs.

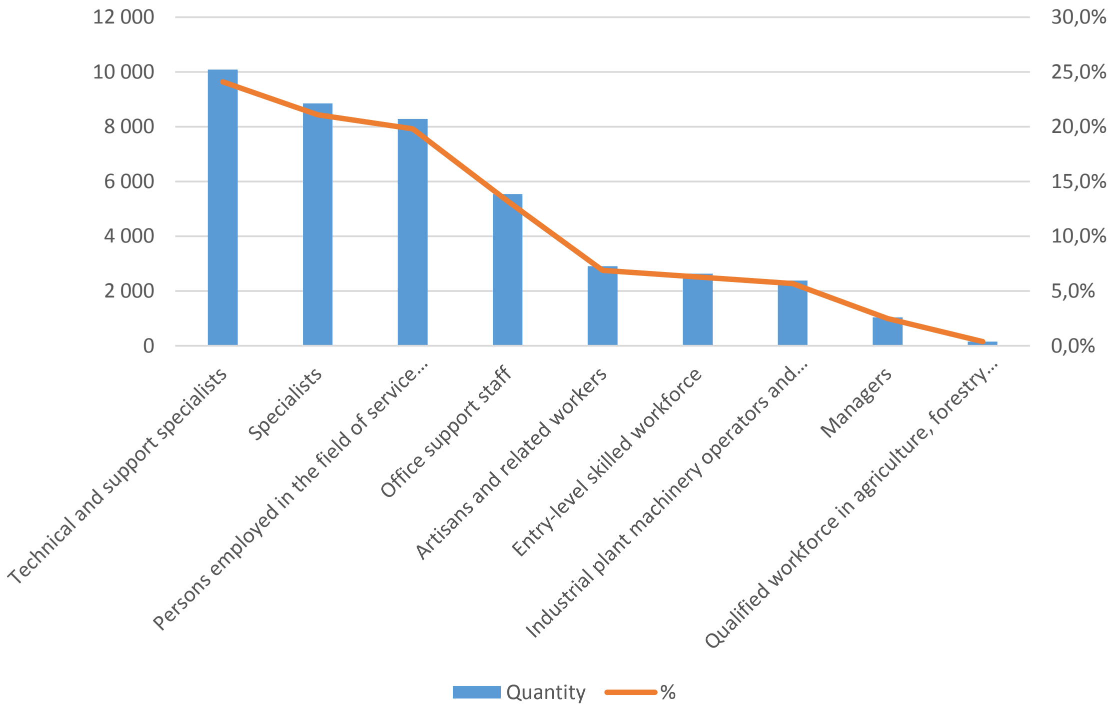


**Figure 2:** Vacancies published on Hr.ge by main professional groups, 2020 [34, 35].

### 3.3. The importance of professional education for the economy

In general, the functioning of the economy is significantly influenced by the level of unemployment. A high level of unemployment can have a very noticeable and negative impact on the economy and, accordingly, on the standard of living of the society [38]. It is associated with low incomes, low incomes in turn indicate deterioration of living standards and reduction of consumption [39, 40]. Reduced consumption naturally also has a negative impact on output: no demand, no supply. The reduced output further increases the ranks of the unemployed, and so endlessly, if it were not for the various measures taken by the state and the fight against the mentioned challenges [41, 42, 43].

Unfortunately, vocational education in Georgia is not in a very good condition, more and more people reach higher education institutions, and less and less people remain in the ranks of those wishing to receive vocational education [22, 44]. This ultimately leads to the fact that we have too many graduates of higher educational institutions in the country, whose employment is physically impossible [45].

What will happen if the number of applicants is properly distributed between professional and higher education institutions? We think that the better the conditions for professional education, the more people will be interested in it, and all this will have a positive effect on the level of unemployment. We are talking about the case when the redistribution of people with higher and professional education will be logical, the demand for vocational schools will increase and there will be a correct match between vacant places and working people [46, 47].

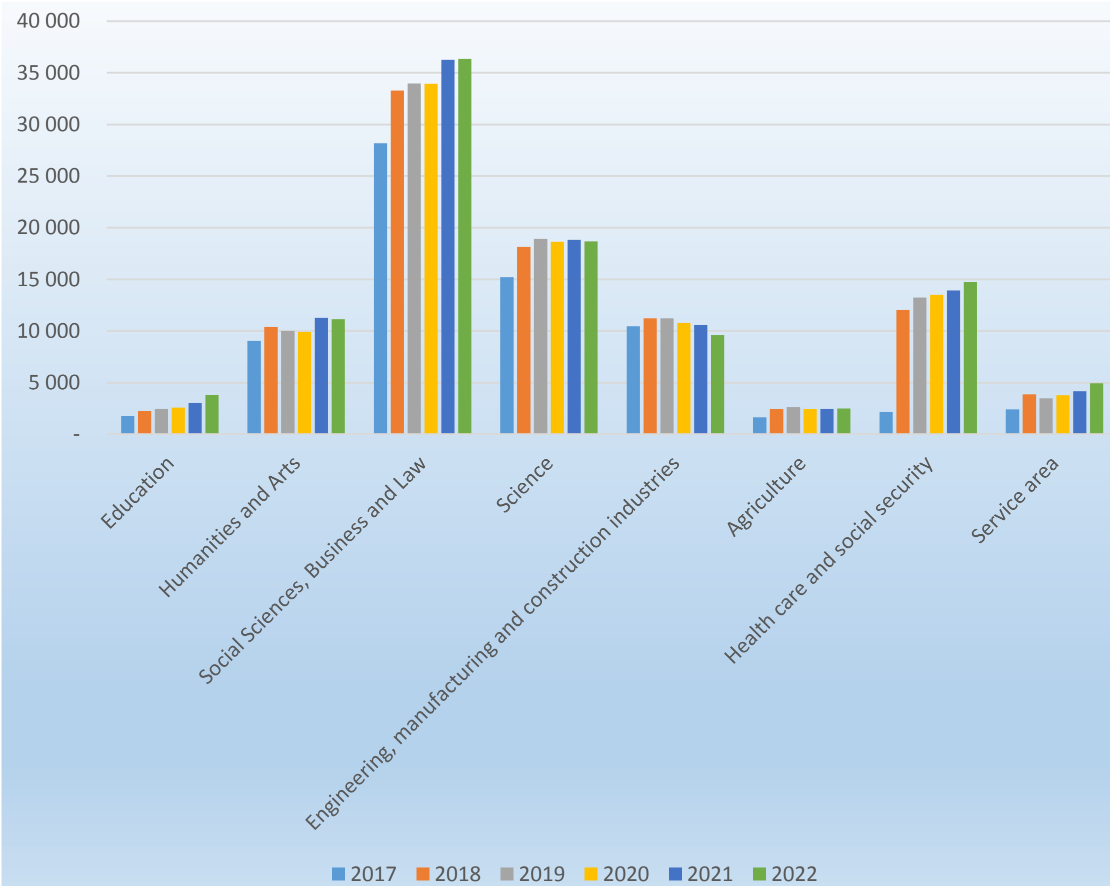


**Figure 3:** Number of students in state higher educational institutions according to programs [37].

However, everything considered is not so simple, since vocational education faces various problems and challenges [48].

If we ignore unemployment (which is quite difficult in the case of Georgia), those professions, which vocational schools provide the opportunity to master, are quite important for the economy. It is good to have higher education, it is good to create the basis of technological progress and to increase the degree of innovation, but all this also requires graduates of vocational education programs.

We can cite a simple example to better understand the role of professional education. We know that the state will spend resources on education, on the other hand, the individual also spends money and time on education, but often the costs incurred are more, and the benefits received are less [49, 50, 51]. This may be due to the education system, less effort of the student himself or some other reason. However, the fact that expenses were spent on education at the initial stage does not change. At this time, we reach a situation where the expenses and time spent are in vain.

Vocational education requires (in most cases) less costs and, most importantly, less time. As for the results, it is entirely possible for a person with a vocational education to have more income, be able to do more work, and therefore benefit the economy and themselves more than a person with a higher education could [52]. Therefore, we believe that professional education plays a very important role in the growth and development of the country's economy, and even more so in the effective distribution of resources (which is naturally accompanied by the improvement of the economy) [53].

Based on the recent (2013-2021) data of the National Statistics Office of Georgia, we can conclude that the number of people enrolled in vocational schools is characterized by a decreasing trend, which is not really good. The number of educational institutions that accepted students for professional programs also decreased. The decrease in the number of students enrolled in vocational schools is shown in figure 4.

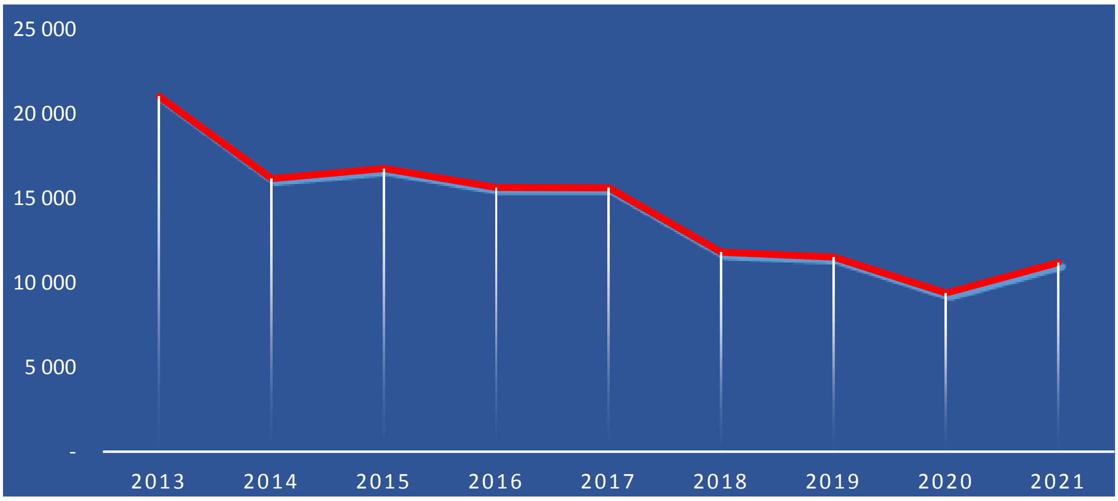


**Figure 4:** Admission of students to professional programs, 2013-2021 [54].

It should be noted that over the years, a large part of the demand for vocational schools of Georgia came from the older population, and this demand from the students was quite small, although recently the situation is changing and by 2021, 60% of the population under the age of 26 will be enrolled in vocational schools. Figure 5 allows us to make the mentioned conclusion, where the data of 2021 on students enrolled in vocational schools, divided by age groups, are presented.

We think that the promotion of professional education will definitely lead us to the desired results, both from the point of view of the economy of Georgia and the general situation in the country. There is simply a need for more involvement from the state and, accordingly, more properly conducted measures, raising the level of awareness in society and creating all the prerequisites in order to change the attitude towards vocational schools as positively as possible. All this will eventually become a contributing factor for improving the level of education or the economic situation [55].

In general, we believe that the promotion of vocational education, especially in the case of Georgia, will be one of the means for reducing the unemployment level and for the effective

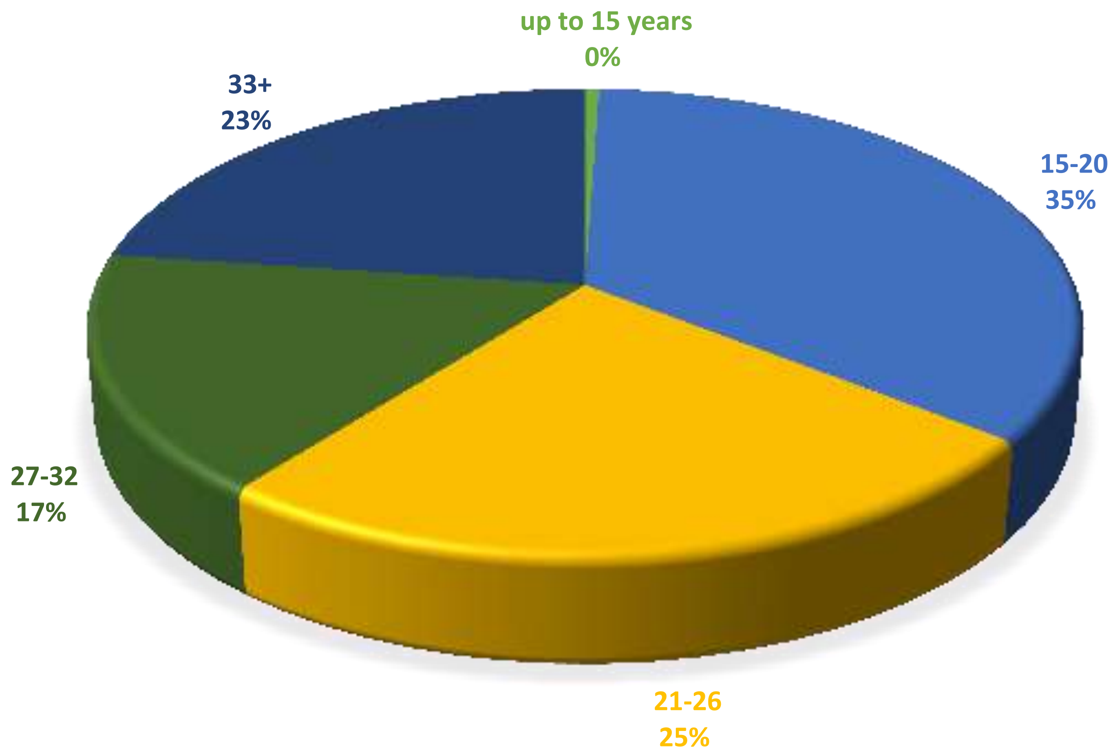


**Figure 5:** Distribution of students in vocational schools by age, 2021 [54].

formation of the labor market. However, despite the fact that professional education is popular in many countries, the attitude towards it in Georgia is quite negative. The majority of students blindly choose higher education without analyzing the situation and the expected results, and in many cases we come to the expenses incurred on education, whether it is monetary resources or students' labor and time, which is wasted, we mean the case when the expenses incurred on education exceed the benefits received.

## 4. Conclusions

As can be seen from the above data and their analysis, in the modern labor market there is a greater demand and, accordingly, an abundance of vacant positions in the direction of service and sales, as well as individual services. And the number of graduates is the largest in such educational programs, which in the future involve employment as high-ranking professionals rather than starting work in the field of trade, sales and services (ISCO-08).

Therefore, it will not be an exaggeration to say that there is a real imbalance in the modern national labor market in terms of supply and demand of human capital. On the other hand, this circumstance clearly indicates the weak institutional connection between the education policy and the labor market, which is an important factor determining the high degree of vertical and horizontal mismatch between education and employment.

Summarizing the issues discussed above, we can draw the following conclusion. We have seen that education plays a very important role for each country, it is important both for the country's economy and for the state of the country in general. Based on history and examples of countries, it can be said that differences in the level of education often explain differences in income, which once again emphasizes its important role, although not always, since there are many other important factors that also affect the economy of a country.

The analysis of the influence of higher education on employment and income in Georgia demonstrates that the investment in higher education yields a discernible return at this point, but the human capital, which is created in the higher education system, is still not effectively used in the country. As a result, in addition to increasing state investment in higher education, it is critical to implement other measures to raise the rate of public return on higher education. Possible approaches in this direction include:

- Rationalization of state expenditures on higher education based on empirical data;
- Increasing the compatibility of higher education system outcomes with market requirements;
- Increasing overall income from higher education;
- Increasing access to higher education for vulnerable groups;
- Providing relevant statistics for distribution of employment and unemployment levels according to qualifications;
- Further encouragement of cooperation between the private sector and vocational schools to increase the existing scale of transition to work-based learning. Also, increasing the involvement of the private sector in the process of developing vocational education training programs to ensure compliance of vocational education programs with labor market requirements.

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# Smart education in the prospective teachers' training

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### Abstract

The article reveals the features of smart education as a leading concept in the development of professional training of future teachers. The main components of smart education, such as a smart student, smart pedagogy and smart environment were characterized. The main principles of smart education and the ideas that formed the basis of this concept of education (mobile access, formation of new knowledge, creation of a smart environment) were defined. The features of smart education were substantiated. The peculiarities of the implementation of smart education in the conditions of the COVID-19 pandemic and military events in Ukraine were revealed. The functions of the smart system (site management system) in the process of studying the disciplines of the pedagogical cycle, its content and technological components, and facilities of the smart complexes for students and teachers in the process of training future teachers were defined. The criteria of smart complexes (automation, sequencing, assessment, data collection in real time, self-organisation) were singled out. The distance learning systems for creating smart complexes in the process of training prospective teachers were considered. The results of students' survey as for using smart complexes in the educational process were analyzed. Due to the results, the advantages and disadvantages of using smart technologies in educational process were determined. The ways of further research work regarding the introduction of smart education into the educational process were outlined.

### Keywords

smart education, professional training of prospective teachers, fundamentals of smart education, principles of smart education

## 1. Introduction

Wide implementation of information and communication technologies (ICT) and digitization of all fields of social life is considered in the majority of countries of the world as one of the strategic tasks of the progressive development. The use of ICT in society is changing to a

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new quality of communication between consumers and producers, citizens and authorities, students and universities. The education system needs the transformation of educational technologies that are able to ensure rapid adaptation, coordination and strategic orientation to the integration of the domestic education system into the international educational space. Educational technologies are designed not only to accumulate the educational content, but to serve as a vector for the transformation of the content, methods and forms of education in the conditions of the modernization of electronic learning and the accumulation of human capital. Therefore, technologies that were previously based on knowledge and information are being transformed into technologies related to interaction and exchange of experience in off-line and online modes. Such technologies are aimed at creating an effective innovative educational environment by promoting progressive innovations, introducing the most modern teaching methods, professional mobility and rapid adaptation to changes in the socio-cultural sphere, management system and labor organization in the conditions of a market economy. The transformation of educational technologies under such conditions led to the emergence and development of smart education in the system of training students.

Smart education is a concept that involves comprehensive modernization of all educational processes, as well as methods and technologies used in these processes. The concept of "smart" in the context of education is associated with the emergence of such technologies as smart boards, smart screens, and access to the Internet from anywhere. Each of these technologies allows to organize the process of content development and its updating in a new way. For example, learning becomes possible not only in the classroom but also in any other place: public places such as museums, cafes, etc. The main element that connects the educational process is active educational content, on the basis of which unified repositories are created, which allow to remove time and space restrictions, which is gaining relevance in connection with the COVID-19 pandemic and military events in Ukraine [1, 2].

The purpose of the article is the theoretical substantiation and practical implementation of the elements of smart complexes in the educational process of the disciplines of the pedagogical cycle by students in the conditions of the COVID-19 pandemic and military events in Ukraine. The hypothesis of the study is that creating and using the smart complexes in the pedagogical discipline environment will improve the students' level of smart technology using skills and intensify the educational process.

## 2. Theoretical background

According to Iqbal et al. [3], the term "smart education" is a unique pedagogical concept that entitles and facilitates the educational process in the digital age. Hoel and Mason [4] distinguish the essence of smart education as the creation of an intelligent environment using smart technologies to facilitate smart pedagogy and provide personalized learning services and empower students.

Demir [5] defines smart education as an effective way of using ICT in order to reach learning outcomes using a suitable pedagogical approach.

Zhu et al. [6] characterize smart education as learning that includes formal (learning that takes place in an educational organization) and informal learning (learning implemented through informal channels: social networks, the Internet, massive open online courses, game-based learning, etc.), social and collaborative learning, personalized learning, and app and content focused learning.

Jang [7] defines smart education as "an educational system that allows students to learn by using up-to-date technology and it enables students to study with various materials based on their aptitudes and intellectual levels". Shoikova et al. [8] state that smart education represents a new wave of educational systems that involves an effective and efficient interaction of pedagogy and IT and their fusion towards the improvement of educational process.

Alajmi et al. [9] discuss the benefits, challenges, and solutions of smart education implementation in higher education institutions. Aker and Pentón Herrera [10] note the gap between education and the workplace which can be filled in by smart education. The scholars ground that the key scientific and technological advancements with particular reference to the smart educational systems, smart learning devices, and smart pedagogy technologies have facilitated maintaining a healthy and smart learning environment, regardless of the educational level. Such developments in smart learning environments significantly support the students with new approaches, learning technologies, learning processes, and learning strategies [11].

Summarizing the views of scientists on the essence of the concept of "smart education", we can conclude that it is a self-governing, motivated, flexible, resource-enriched, technological educational system that unites smart students, smart pedagogy and smart environment, including both formal, and non-formal learning, as well as a personalized approach to students in order to acquire the required knowledge, skills, abilities and competencies. The main aspects of smart education are 1) the use of current information of the curriculum for solving educational problems; 2) organization of independent cognitive, research, and project activities of students; 3) implementation of the teaching approaches in a multi-aspect educational process environment; interaction of students with the professional community; flexible educational trajectories, individualization of education; multifaceted educational activity.

The main elements of this system are a smart student, smart pedagogy and smart environment. A smart-oriented educational process should be aimed at acquiring the 21st century skills and competencies necessary for effective use at work and in personal life. So that, the goal of smart education is to develop smart learners, and prepare them for functioning in a modern dynamic environment [12]. The smart pedagogy provides students with personalized services that contribute to the expansion of their capabilities, the development of abilities and creative thinking. Zhu et al. [6] observe smart pedagogy in the implementation of four learning strategies: class differentiated learning; group collaborative learning; individual learning based on personal interests; interactive mass generative learning. These strategies are closely related to each other. Each of them in its own way is aimed at providing students with educational services that contribute to their personal development.

Uskov et al. [13] study smart pedagogy from a technological position of using it in the next generation Smart Classroom systems, classify it as practice-based learning, collaborative, project-based, gaming, e-learning, as well as advanced technology-based learning and flipped learning. It should be noted that some researchers consider technological type of smart pedagogy as a smart technology, which confirms the conclusions of Zhu et al. [6] that the conceptual apparatus of the topic has not been clearly formed and systematised yet.

The smart environment is an educational environment supported by various technologies that enable students to use digital resources and interact with learning systems anywhere, anytime, and proactively provide them with the correct learning guidance, aids, and learning offerings in the proper place, time and form [6]. Bajaj and Sharma [14] state that smart environment delivers personalized learning, anytime and anywhere. The smart environment includes applications of the latest smart technologies in collaboration with advanced educational practices, means and techniques [15] for the effective implementation of education services.

The smart learning environment is considered as a technology-oriented learning environment that support the quick adaption of the entire educational process and proper interaction between learners and the environment in a sophisticated manner [3]. The smart educational environment facilitates individual learners' needs, i.e., guidance, feedback, hints, or tools. The learning performance can be determined by analyzing their learning behaviours, performance, and online and real-world contexts [16]. Based on the smart learning environment framework [17], the following aspects should be considered while designing the smart learning environment: (1) smart learning environment and context awareness, (2) smart learning environment with instant adaptive support from different perspectives, i.e., learning performance, learning behaviours, profiles, and personal factors, and (3) overall capabilities of a smart learning environment to adapt the user interface to encounter the personal factors, i.e., learning styles and preferences, and learning status, i.e., learning performance, quality and the outcome of individual learners [18]. The learners should be able to interact with the learning environment through digital devices, such as smartphones, tablets, computers, etc. [18, 15, 19, 17, 20, 21, 22]. The smart environment includes space, place, time, technology, devices, control and interaction. Therefore, it, being one of the main elements of smart education, provides an opportunity for smart learners to interact with personalized educational resources and systems used on the basis of special methods.

Anttila and Jussila [23] shows the development of society diversely through the applications of various smart technologies influence the education. In study of Gomede et al. [24], the educators and institutions are concerned about retaining students to make learning effective, efficient and interesting by means of smart technology. Al-Majeed et al. [25] substantiate the necessity to improve the development of smart technology.

When considering the structure of smart education, most scholars focus on the special position of smart technologies in this system. This is justified by the fact that the effectiveness of the entire educational process largely depends on the set and quality of the used technologies. Smart technologies (computer programs, online resources, learning games and game situations, intelligent educational applications, virtual reality, MOOCs, interactive interfaces, etc. [26, 27, 28, 29]) are adaptive, flexible technologies that contribute to the organization of a personalized training in accordance with the personal differences of students. Such technologies, according to Spector [30], also take into account the context, respond to the interests and characteristics of individual students, and are likely to improve with the use. The smart technology provides communicative interaction between groups of people, makes it possible to simplify the process of obtaining information in various fields, and also makes the material more accessible for perception, leads to the development of personal qualities of students. Smart technologies make it possible to form individual learning trajectories for students (offline, distance and mixed learning), to optimize the use of electronic resources from around the world. Due to such training, students receive new opportunities for: 1) integration of educational institutions into the international educational space; 2) attraction of additional categories of students, including foreign students; 3) stimulating the emergence and development of innovative educational technologies and tools; 4) creation of new guidelines for teachers, training and assessment of knowledge; 5) strengthening of scientific research in certain fields of knowledge; 6) ensuring the development of effective models of administration and management [20].

It should be noted that discussions regarding the prospects for introducing smart technologies into the educational process are constantly being conducted by the professional community. According to Dmitrenko and Voloshyna [31], Karakose et al. [32, 33], Spector [30] the competent application of smart technologies allows:

1) a teacher:
    - increase the effectiveness and efficiency of training;
    - build an individual educational trajectory for each student;
    - develop independence, involvement, and motivation among students;
    - to support the independent research of students;
    - involve students in active joint activities;
    - improve problem-solving, assimilation of information;
    - accelerate the pace of mastering the material, cover a larger number of topics, and content;
    - reduce anxiety among students;
2) students:
    - acquire a greater set of skills;
    - increase motivation, and activity;
    - develop independent learning skills, ingenuity, and strategy;
    - improve learning outcomes etc.

Klichowski et al. [34] demonstrated an attempt to introduce elements of smart education in the educational environment. They believed that the results obtained positively represent the prospects for the further introduction of smart technologies in the content of education. In particular, they describe the experience of using the CyberParks technology, which made it possible to obtain a number of interesting results, namely, the teacher was relieved of the burden of explaining the material and assigned the role of a conductor and assistant, which allowed to motivate students while studying.

The COVID-19 pandemic and military events in Ukraine have led to serious changes in education – the replacement of traditional face-to-face education by remote forms [35, 36, 37]. Such changes contributed to the implementation of smart technologies in the training of prospective teachers. The use of smart technologies does not involve "ready-made" knowledge, but the creation of conditions for the youth to acquire their personal experience and skills. It means, according to the concept of smart education, that the teacher's function is not to transfer ready-made truths, but to provide high-quality content navigation.

Smart complexes make it possible to implement the main trends of the smart education concept. A smart complex is an information and educational system, which is designed to optimize the learning process using digital technologies, as well as the automation of feedback processes, management within the framework of the educational process for the interaction of participants in the educational process and enriching student's personal experience by searching and processing of educational content on the Internet.

In the system of education, with the increase of online services and the possibility of obtaining knowledge remotely, such systems as site management systems (CMS – Content Management System) are rapidly developing, which, at the same time, provide for the development of smart complexes for managing the educational process. Among them: LMS – Learning Management System; CMS – Course Management System; LCMS – Learning Content Management System; MLE – Managed Learning Environment; LSS – Learning Support System; LP – Learning Platform; VLE – Virtual Learning Environments.

The main advantages of smart complexes are 1) immediate response to external changes, openness; 2) expansion due to the integration of new functionality; 3) easy access to educational material; mobility; 4) ensuring compatibility between software for different operating systems; 5) lack of dependence on time and place; 6) continuous updating of the content, the possibility of self-assessment and evaluation of the knowledge of students.

## 3. Methodology

In order to implement smart complexes in the educational process, we determined the facilities of the smart complex for students and teachers in the process of studying the disciplines of the pedagogical cycle using LMS learning management systems (table 1, 2).

**Table 1**
Facilities of the smart complex for organizing the students' educational activities in the process of studying the disciplines of the pedagogical cycle.

| N | Facilities |
|---|---|
| 1. | Log in (registration / password verification) |
| 2. | Ability to view: personal individual educational trajectory of learning; personal success in the student's journal of success; information on changes in one's cognitive abilities (characteristics), necessary for analyzing the success of studying pedagogical disciplines; information about your mode of interaction with the system. |
| 3. | The formation of an individual educational trajectory for the study of pedagogical disciplines and its adjustment, depending on the acquired level of knowledge of the prospective teacher |
| 4. | Obtaining educational material (lectures, assignments, methodological instructions, practical tasks, tests, laboratory works, etc.) by students in accordance with the individual educational trajectory. |
| 5. | System of self-assessment and verification of knowledge acquisition |
| 6. | Communication with other students, teachers, pedagogical community on forums, chats, video conferences, online consultations. |
| 7. | The possibility of independent development of educational material for the discipline to fill or update the content |
| 8. | Obtaining assistance for the processing of educational material |
| 9. | Taking into account the students' state and their capabilities in the process of working with the system |

**Table 2**
Facilities of the smart complex for organizing the activity of a teacher / tutor / coach in the process of organizing the study of the disciplines of the pedagogical cycle.

| N | Facilities |
|---|---|
| 1. | Log in (registration / password verification) |
| 2. | Development. Revision and correction: individual learning trajectories in pedagogical disciplines for students; students' journal of success; characteristics of acquired cognitive skills (characteristics) of prospective teachers; setting parameters for different modes of interaction of students with the system. |
| 3. | Control over: system operation; software settings; training results (information about the state of the training process and the student's activity); as participants in the educational process. |
| 4. | Availability of analytical tools for information analysis in order to optimize the learning process and its personalization (creation of a psychological portrait, identification of possible mistakes during training, etc.) |
| 5. | Management of educational material |
| 6. | Knowledge verification system |
| 7. | Communication with students on forums, chats, video conferences, online consultations, etc. |
| 8. | Protection against unauthorized access |

Based on the analysis of the scientific works, criteria of the smart complex in the educational process were singled out. Among them:

- automation: the possibility of creating automated processes that reduce the number of routine operations during assessment, training and achievement of educational goals;
- sequencing: the possibility of ensuring the consistent progression of the student's competencies, defined in the final goals, in a fixed or non-fixed unit of time;
- assessment: the possibility of applying a number of criteria, diagnostic and formative assessment on the basis of greater immediacy and continuity;
- data collection in real time: the ability to collect, calculate and evaluate data from an array of resources using defined methods in real or approximately real time;
- self-organization: the ability of the system to use the results for the continuous formation of feedback in the educational process.

The interdependence of the criteria can provide a number of functional features of the smart complex in the organization of the educational process by all its participants: wide possibilities of control and management of the educational process; easiness of use; intuitive interface; maximum automation of the educational process; support for SCORM 2004, SCORM 1.2 formats; possibility of integration with other educational resources; the possibility of studying autonomously; low requirements for software and hardware configuration of the server and client terminal [38].

Thus, the main principles of the functioning of smart complexes include: ensuring compatibility between the software of different operating systems; mobility, continuity and free access to any information; autonomy of the teacher and student; definition and application of various motivational models; assessment of changes and competence; change of education due to individual capabilities and interests of the student.

Therefore, in the process of designing and creating the smart complex, it is important that the presented criteria and principles are interdependent, that can adapt the smart complex to the requirements of prospective teachers' professional.

On the basis of literary sources and our personal experience, we consider distance learning systems for creating smart complexes in the process of training students in higher education institutions. The distance learning system Moodle is a system created for distance learning. Moodle is a free and open source system. This allows developers to download, modify, create add-ons, and customize the software to their personal needs.

The Edmodo software product is a Web site that allows you to organize lectures and laboratory classes. The content of which is presented in the form of texts, files, tests, tasks and surveys. The system allows you to import information from various online resources. The distance learning system Google Classroom is a product of one of the leaders of the digital industry. Google Classroom is a free service for educational institutions and non-profit organizations. It is also available to anyone with a personal Google account. The distance learning system iSpring Online is a system for organizing distance learning, provides the possibility of registration, storage and collection of information online. It does not require resources for installation, it works in online format. It is worth noting that such listed systems are appropriate for the creation and design of smart complexes.

We described the peculiarities of the organization of the educational process when studying the disciplines of the pedagogical cycle in the conditions of distance learning. At the department of pedagogy, professional education and management of educational institutions, the content of the disciplines of the pedagogical cycle was successfully tested. A peculiar feature of the organization of teaching of these disciplines was a significant volume of students' independent work. We understood that for the effectiveness and quality of the independent educational activity of prospective teachers, the work had to be carefully thought out, structured and optimized taking into account the main didactic principles: accessibility at the required degree of complexity, consistency and systematicity, clarity, connection between theory and practice, students' activity. We also took into account the knowledge control and assessment mechanism.

To implement these conditions, an electronic educational system was created as part of the general educational environment, which also included a traditional lecture component. The electronic learning environment was created in the form of a website.

The structure and content of the site allowed prospective teachers to get not only access to educational materials, to the educational environment of the discipline, but also full methodological information on its acquisition. The site was designed according to the modular principle: each module included a video recording and a plan of a thematic lecture, a set of educational materials and tasks, the implementation of which involved independent study by students of education, critical analysis and annotation, as well as discussion of the topics studied in practical classes.

### 3.1. Instruments

To achieve the goal, the following methods were used in the study:

- theoretical: systematic analysis and generalization of pedagogical and methodical literature on the problem of implementing smart education; synthesis, abstraction, systematization of theoretical provisions for comparison, comparison of different views regarding the definition of the concepts of "smart education" and "smart complexes");

- empirical: methods of collecting empirical material (questionnaires, testing, conversations, interviews) with the purpose of studying the problem of designing and creating smart complexes in future professional activities in order to test the effectiveness of the developed methodology).

Pedagogical practice took place in the educational process of professional training of future teachers. Students of the specialty 015.39 Vocational education (Digital technologies) were surveyed during their pedagogical practice in order to assess the state of readiness of future teachers for the use of smart complexes in their professional activities.

### 3.2. Participants

In order to obtain experimental data in the process of researching the issue of designing and creating smart complexes based on distance learning systems, a pedagogical experiment took place in the professional training of future teachers. In the process of studying the disciplines of the pedagogical cycle for students of the specialty 015.39 Professional education (Digital technologies) at Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, a questionnaire was conducted regarding the organization of distance learning by students using smart complexes while studying the disciplines of pedagogical cycle. The number of respondents was 18. Questionnaire questions related to the choice of platforms for creating smart complexes, the choice of online tools, educational resources and electronic learning tools for creating the educational content of a smart complex. The participants were informed about the purpose and the structure of the study and assured that students' names would not be used in the study result reports. The participation in the study was voluntary.

## 4. Results and discussion

Currently, there are a lot of educational platforms for organizing and conducting classes in the domestic educational space. The results of the survey show that the Classroom platform is the most popular among prospective teachers for creating smart complexes (17%), the Edmodo platform is used by 6% of respondents, the Meet platform is used by 28% of students, the Zoom platform is used by 17%, combined platforms – by 33% of respondents.

Receiving educational materials and communication between distance learning participants is ensured through the transmission of video, audio, graphic and text information in synchronous or asynchronous mode. Therefore, the question was devoted to online resources that were used by future teachers to visualize educational content in their personal smart complexes, the following resources gained the most percentage: Canva – 11%; Genial.ly – 17%; Prezi – 22%; Venngage – 17%; Infogram – 6%, combined online services – 28% of respondents.

Due to the results, the following online tools were used by future teachers for interaction of participants in their personal smart complexes: ThingLink – 11.11%; Glosster – 16.67%; Jamboard – 22.22%; Padlet – 16.67%; combined interactive services – 33.33%.

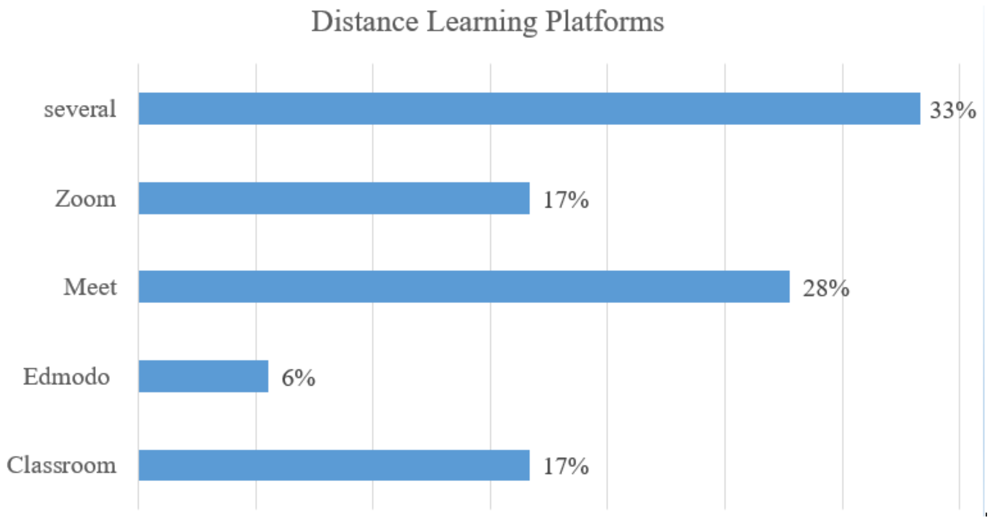


**Figure 1:** The use of distance learning platforms for creation of smart complexes.

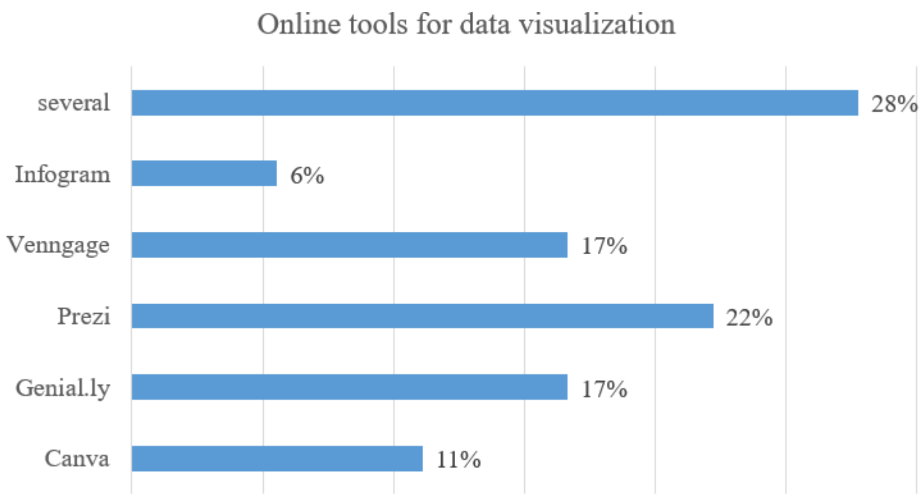


**Figure 2:** The use of online tools for data visualization for creation of smart complexes.

An integral component of the educational process is the monitoring of the knowledge of students. The following services for creating tests scored the most p%; LearningApps – 22.22%; Classtime – 16.67%, Google forms – 16.67%, Quizlet – 5.56%, Quizalize – 5.56%, combined services for creating tests.

The analysis of the survey results showed that the platforms and services mentioned above allow future teachers to create smart complexes of educational disciplines. The smart complex of the educational discipline acts as an individual personalized online program environment (on the website/portal/e-platform), which allows the teacher to accumulate his personal educational digital resources or links to them, provide access to them, and also see the current results of students in real time.

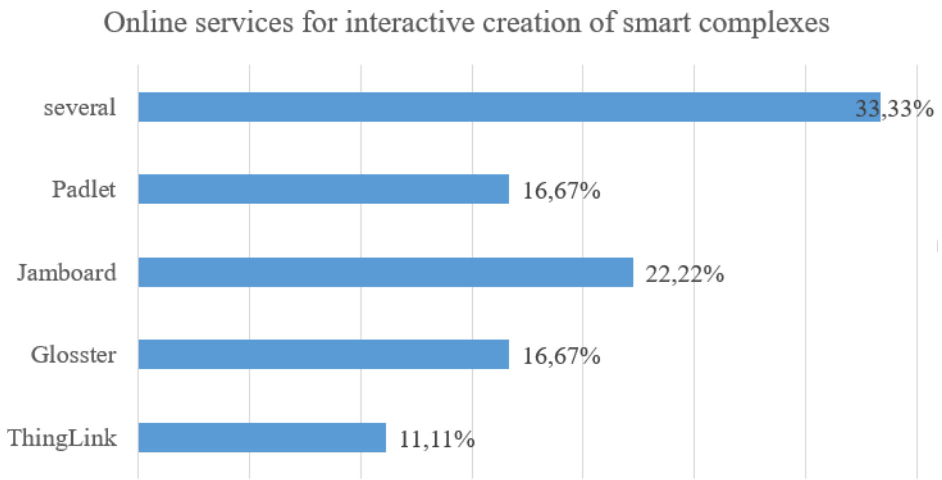


**Figure 3:** The use of online services for interactive creation of smart complexes.

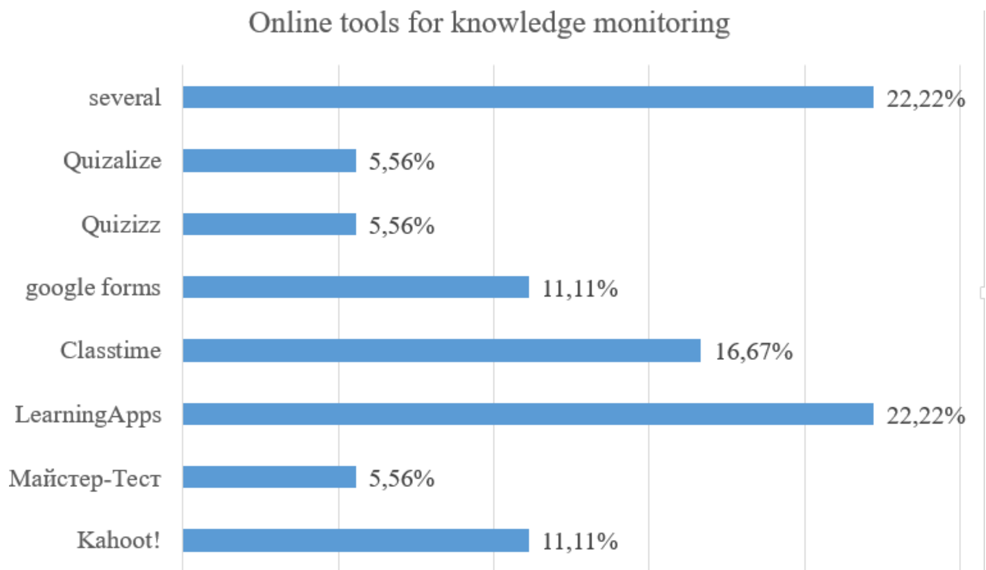


**Figure 4:** The use of online tools for knowledge monitoring in creation of smart complexes.

As the survey results showed, future teachers use platforms and services in combination, strengthening the interactive component of the smart complex of pedagogical disciplines. In the smart complex environment, the teacher can present educational content, communicate with participants in the educational process, visualize data, assign tasks individually, for separate groups or for the entire class at once; instantly receive results after students complete tasks; save and view performance statistics.

In the survey, the students were asked about the problems that they had in the process of creating smart complexes of pedagogical disciplines. The most frequent mentioned problems were:

- lack of experience in methodical organization of training using smart complexes – 11%;
- limited access to the Internet – 6%;
- lack of digital devices – 1%;
- insufficient digital infrastructure of the educational institution – 11%;
- unreliable/slow Internet connection at school – 15%;
- limited/absent technical support of the distance learning organization – 17%;
- teachers and mentors helped solve problems quickly – 22%;
- no problems with the creation of a smart complex – 33%.

The results of the survey made it possible to highlight several advantages and disadvantages of the use of smart technologies in the educational process that can allow intensifying the process of using these technologies.

The respondents also noted a number of advantages of smart technologies that create a certain basement for their further intensive use. Among them we can highlight time saving, visibility, and efficiency of use in distance learning conditions.

For further development students' smart technology skills, it can be recommended to apply some additional courses into the educational process of future teachers, that could allow to eliminate or minimize the identified shortcomings, and to increase the level of students' readiness for the use of smart technologies.

## 5. Conclusions

In general, the research showed that the implementation of smart education was able to ensure a high level of education, which met the goals and objectives of distance learning in the conditions of the COVID-19 pandemic and military events in Ukraine.

The conducted theoretical analysis of the research problem showed that the concept of smart education is a new paradigm of education that can improve the quality of education, focused on contextual, personalized and continuous learning that contributes to the development of the students' intelligence and develops the students' ability to solve problems in a modern "smart environment".

It was concluded that the competent application of smart education allowed the teacher to increase the effectiveness and efficiency of education; to develop an individual educational trajectory for each student; to motivate prospective teachers and support their independent research; to involve in active joint activities; to improve and speed up the rate of assimilation of the material, to cover a larger volume of content; to reduce anxiety among students. For students, smart education allowed to increase motivation and activity; to develop self-study skills, resourcefulness, and improve academic results; to lighten the academic load; to plan time more carefully.

Smart complexes made it possible to introduce the main trends of smart education into the educational process. The smart complex is an information dynamic educational and methodological system with certain smart criteria: automation, sequencing, assessment, data collection in real time, self-organisation.

The facilities of the smart complex for students and teachers in the educational process of the disciplines of the pedagogical cycle using the learning management systems (LMS) were determined. It was stated that the following distance learning systems are appropriate for creating smart complexes: Moodle, Google Classroom, iSpring Online, and Edmodo.

The survey results showed that the smart education system model is being actively implemented at Vinnytsia Mykhailo Kotsiubynskyi Pedagogical University. The respondents noted the advantages of smart education (saving time, visibility, efficiency of use in distance learning conditions), and demonstrated the understanding of the importance of its application in their further professional pedagogical activities.

Further research should be concentrated on the study of the methodology of the organization of smart training, the didactic principles of the creation of smart complexes, the students' activation in the development of electronic educational content of pedagogical disciplines.

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# Possibilities and limitations of social media in education processes during the pandemic: The teachers perspective

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**Abstract**

The health emergency derived from the spread of COVID-19 led to the declaration of confinement for the protection of the population. During this temporary period, the educational centers of the Spanish state were forced to suspend face-to-face classes at all educational levels. To safeguard the teaching processes, educational centers and teachers relied on social media to continue their work. The objective of this study is to understand the possibilities and limitations of social media as the only means of communication in the educational and socialization processes of students from the perspective of teachers. The methodology used is based on the collection of data through a questionnaire distributed in the secondary education centers of the autonomous regions of the Basque Country and Navarra. The questionnaire was distributed electronically, respecting the anonymity of the teaching staff and the center in which they practice. The results reveal that the digital media the possibilities and limitations of these media in the teaching processes, showing that some of these are surmountable and others are not.

**Keywords**

social media, educational inclusion, socialization, COVID-19, professorate

## 1. Introduction

The 2019-2020 academic year was disrupted due to the arrival of the SARS-CoV-2 virus that affected global health. Consequently, the World Health Organization (WHO) declared the COVID-19 disease a pandemic [1, 2]. According to the recommendations of the WHO, the state authorities and the local authorities, the educational centers of the Spanish state, considered contagion points, remained closed during the last quarter of the 2019-2020 school year [3, 4, 5, 6, 7]. This decision made the work of educational centers difficult, especially in states where the closure lasted more than a quarter [8, 9, 10].

Teachers and students were affected by the closure of educational centers and the interruption of face-to-face training. In such a situation, to safeguard the training and socialization processes of the students, the use of digital media and other channels that belong to Information and Communication Technologies (ICT) was chosen [11, 12]. The current customs of the population and the constant use of social media in the lives of citizens of all ages facilitated making this decision [13]. Teachers and students used these tools to be able to maintain a link of interaction

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and continue with the training and socialization processes [6, 10, 14]. In this line, the students connected to virtual classes on the center's own platform, mail or another channel.

Experts from different disciplines recognize in various studies the benefits and advantages of a virtual education even before the pandemic [15]. However, the sudden transformation of educational processes from face-to-face to virtual altered group and learning dynamics. The main problems that teachers faced were the digital divide between students, establishing an approach focused on experiences and not on theoretical content, and stimulating a relationship of trust and sincerity between students and teachers [9, 16, 17, 18, 19, 20, 21].

Despite the presence of social media in the daily life of the population, these tools are still not adjusted to the needs of a fully distance secondary education [22]. In the case studied, the lack of a contact channel outside of these media questions the quality of the education and socialization processes of the students, showing their possibilities and limitations [6, 10, 14, 23]. In this article, socialization is considered as the ability of students to adhere to the norms of social behavior.

During the confinement, not all those involved in the education processes had the same practical possibilities. Most of the practical limitations of those involved were related to the lack of technological devices, high-speed Internet access, suitable sites for teleworking and material adapted to new needs [24]. These inequalities encourage the exclusion of the most unfortunate, considering as such exclusion the difficulty of access and participation of all students in the teaching processes [9, 16, 17, 18, 19, 20, 25].

Added to these limitations is the difficulty for teachers to quickly adapt to new technological demands and the lack of prior training in teaching distance learning [10, 26]. A totally virtual education demands different needs than a face-to-face or mixed education. Because of that, the material used so far was not suitable for distance education. Therefore, teachers and educational centers had to adapt the didactic material, the study plans and the way of working to the demands of the new needs, increasing the difficulty of teaching classes and limiting the staff with less technological skills [27, 28, 29]. However, the teachers who suffer the most from the limitations of distance education are those who teach subjects that require the development of experiments, practical examples and, sometimes, access to a laboratory or workshop for their understanding [26].

Along the same lines, part of the students and teachers do not have adequate devices and neither do they have high-speed Internet. These limitations made the transfer process from face-to-face to virtual education difficult and showed the situation of educational centers, teachers, students and the same social media. In addition, these limitations increased the working hours of the teaching staff [30]. However, overcoming the limitations, this forced use of ICT in the education and socialization processes made it possible to reduce the future digital gap of the students, since, after this experience, they increased their digital knowledge [31].

To cover the urgent need for technological devices during confinement, educational centers, local and state authorities and private companies made free devices and Internet access available to those who needed it to enable everyone involved to access classes. However, time was a key element in this situation. The devices did not always arrive on time and in many cases did not arrive; while the collapse of the lines made connections difficult.

Apart from practical limitations and possibilities, social media presented limitations and possibilities for socialization. Such limitations made educational processes difficult [32]. Social media cannot replace, at the desired level, the possibilities of socialization offered by face-to-face classes and direct contact between those involved. In the face-to-face school nucleus, students come into contact with people of the same age, both inside and outside the classroom, learning to live together and socialize. However, this interaction of the students, which is part of the educational processes, was almost impossible to replace through social media.

This limitation of social media hinders the socialization processes of students [18, 33, 34, 35]. The restriction of student movements, such as the loss of physical activity, human contact, online teaching itself, negative emotions due to the pandemic environment, lack of routine, altered the psychological state, attitude, quality of sleep, the weight and performance of the students [18, 36, 37, 38, 39].

That said, this article attempts to understand the possibilities and limitations of using social media as the only contact channels for compulsory secondary education in the Autonomous Community of the Basque Country and the Foral Community of Navarra during confinement from the perspective of the teaching staff Considering as social media all online communication platforms where the content is created by users, in this case by teachers, and facilitate the exchange of information.

## 2. Methodology

The objective of this study is to understand the possibilities and limitations of social media in teaching processes as the only communication channels in compulsory secondary education. During the months of confinement, compulsory secondary education was fully based on the possibilities of digital social media in order to continue with the teaching and socialization processes of the students. Therefore, this time period is significant to understand the current situation and the possibilities and limitations of these tools. For this, in the present work, the experience during the closure of educational centers is studied from the educational and social perspective, carrying out a bibliographic review that will be accompanied by the support of a questionnaire carried out in the teaching staff.

The last three months of the 2020-2021 academic year, a questionnaire was carried out to the teachers of compulsory secondary education, without specifying the courses. The author sent the survey to the educational centers by email and the reception department sent the survey to the participants. The survey was sent to all the educational centers of compulsory secondary education without making a distinction between public, private or subsidized. Specifically, contact was made with 332 centers of the Autonomous Community of the Basque Country present at ikasgunea.euskadi.eus and the 105 centers of the Foral Community of Navarra present at educacion.navarra.eses. Acceptance responses were received from these centers from 150 centers in the Basque Country and 63 centers in Navarra, which in turn facilitated the survey for teachers. The initial purpose of the study was to make a distinction between public, private and subsidized centers. However, the results of the surveys showed that there is no interesting distinction in the possibilities and limitations of the social media used. The problems and advantages mentioned by the teaching staff of the centers were similar.

The questionnaire provided to the centers consists of 30 questions, all of which require a mandatory response, which are divided into two blocks. The first block contains questions related to the practicality of social media and the availability of resources (quality Internet, devices and adequate teaching material). The second block is made up of questions about the impact of the lack of face-to-face classes, the exclusive use of these media and the confinement in social and emotional aspects of the students. All questions are closed in order to obtain accurate data and make it easier for participants to complete the survey, since open questions require more time to answer. However, to safeguard the quality of the study and give the faculty the opportunity to specify an answer or add something relevant, the battery of questions is accompanied by a section for observations. The analysis of the responses to the questionnaire is carried out in table format. Two tables are presented and each table corresponds to a block of questions.

The survey was completed by 186 participants, all of whom were teachers in educational centers in the Autonomous Community of the Basque Country and the Foral Community of Navarra who exercised during the months of confinement. The selection of the teaching staff was carried out by non-probabilistic sampling for the convenience of the centers that were willing to participate. The teachers contributed by contributing their experience and reflecting the reality of the months of confinement. The participants had a time period of 45 days to answer the questions. In order to safeguard the anonymity of educational centers, students and teachers, the questionnaire was based on the guidelines of Organic Law 3/2018. Following this line, the questionnaire was built with the help of the Google Forms application that does not reveal the information of the participants. The implementation of a self-administrative methodology, such as the present one, has several disadvantages. However, we opted for this format that maintains anonymity.

## 3. Results

The sudden transformation of the educational system from face-to-face to virtual created numerous challenges for schools, students and teachers. Without prior notice and without a specific date for the end of the confinement, the face-to-face classes were interrupted, initially for a period of 15 days, although it ended up lasting until the end of the quarter. This event caused the acceleration of the digital transformation in which until then the educational centers were adapting at different speeds.

In order to better understand the results of the survey, the data is presented in two tables. The table 1 deals with the possibilities and limitations of the practical aspects.

**Table 1**
Practical possibilities and limitations of social media in education.

| Issue | Percentage |
|---|---|
| Suitable material | 53.2% |
| Attend virtual classes and hand in homework | 76.4% |
| Lack of high speed internet | 87.4% |
| Suitable devices | 76.4% |
| Suitable site | 53.8% |

The suspension of face-to-face classes forced the search for other forms of training. In this regard, the majority of teachers, when answering the question "Sociodigital media were your main tool to communicate with the center, the teachers, the students, the students' legal guardians, etc. and carry out your duties as a teacher during the pandemic" confirms that he used social media to continue teaching and communicating with the students, the educational center and the rest of the teaching staff. The tools used were social media from the center itself, public or in common use. The selection of the medium used does not show any connection with whether the educational center is private, public or concerted. In this sense, it is understood that the centers had the same possibilities.

The educational processes of the autonomies studied are located in face-to-face environments with certain notions, in some centers, digital. In this aspect, a distinction between private, public and concentrated centers is not perceived either. Each center presents its own speed in the digitization processes, prior to the pandemic. Therefore, the material used in the centers may have certain digital parts, but it is mostly suitable for face-to-face classes. Specifically, 52.9% of teachers affirm that the material used regularly in their classes is not suitable for virtual classes. In this regard, with the sudden interruption of educational processes and the full introduction into the digital environment, teachers faced the shortage of adequate teaching material, creating the need to quickly adapt the material used to the new demands. Despite the efforts of teachers, educational centers and public administrations, in many cases it was not possible to adapt the available material in the required time. To the question about whether the material provided was adequate for online teaching, 53.2% of the teachers were satisfied with the material provided to carry out their teaching work, while almost the other half (46.8%) were not. The times and limitations of many centers and social media made it difficult to share the material. In these cases, teachers had to adapt the material on their own and create material from scratch, excluding content and increasing working hours.

Likewise, the technological devices to continue with the training processes were not adequate in all cases. The sudden suspension of face-to-face education did not make it possible for educational centers and students to have the appropriate devices. In addition, the confinement situation affected sectors other than education, as a consequence many mothers and fathers were teleworking at home. Therefore, the devices were not always enough for all family members trying to best manage their resources. Answering the question "Did all your students have the appropriate devices to attend classes and tutorials during confinement and distance learning?" only 76.4% of the students had these. This means that 23.6% of the students did not have devices to access the material and join the virtual classes. Along the same lines, mass teleworking on an unprepared system caused more problems than organizing devices. Teleworking from different sectors loaded Internet lines, complicating the continuation of work with an adequate connection. In this regard, 87.4% of the students did not have high-speed Internet at home, making it difficult for them to connect in virtual classes and to hand in their homework. In addition, due to the sudden teleworking of various family members, not all students had an adequate study environment. 53.8% say they did, but the rest either did not have a friendly environment or the teachers were unaware of it.

However, despite the practical limitations, most of the students made an effort to attend class and hand in their homework, although in many cases with setbacks. Specifically, 76.4% of teachers say they are satisfied with the attendance of students in virtual classrooms and the delivery of homework.

Next, the table 2 is presented, which includes the possibilities and social and emotional limitations of students and teachers due to the exclusive use of digital social media for communication. These aspects affect the emotional and social development of students.

**Table 2**
Social possibilities and limitations of social media in education.

| Issue | Percentage |
|---|---|
| Tutor activities and tasks | 58.1% |
| Increased stress | 80.3% |
| Coordination between teachers | 84.1% |
| Fluid communication between teachers | 67.3% |
| Difficulty perceiving problems and emotions | 68.6% |
| Decreased socialization | 93.7% |
| Increase in working hours | 98.1% |
| Decreased performance | 80.3% |
| Commitment | 56.4% |

The period of confinement affected the social life and emotional state of students and teachers. Without prior notice, both had to isolate themselves in their homes and limit human contact, while they continued with the training processes in a new and unknown system. The lack of face-to-face contact and the constant stay at home increased isolation, making it difficult for the school to contribute to the emotional and social development of the students. During this temporary period, digital social media were the only means of contact and socialization, clearly showing the possibilities and social limitations of these tools as the only means of education.

In this aspect, the teachers were present and accompanied the students in the transition. During this process, the teachers assure that social media made it possible to maintain contact, reducing isolation, but the lack of attendance had negative effects on emotional and social development. The new demands and the need to help students to adapt to this new system increased the working hours of the teaching staff. In this line, in order to minimize social damage and events of social exclusion during virtual classes, teachers continued and, in many cases increased, group and individual tutorials. 58.1% of the teaching staff indicated that it was possible to continue with their tutoring tasks without much difficulty, but that they required more hours of attention. In order to compensate for the lack of attendance, 39.5% of teachers confess that they interacted more than five times, 15.3% five times, 10.2% four times, while 21.7% three times a week. In this aspect, social media made it possible to maintain contact with students, but its limitations increased the working hours of teachers without being able to match the results of social development with face-to-face classes. Specifically, 98.1% of teachers say they had to work more hours than before and increase contact with students.

In order to achieve good coordination, maintain a common line of teaching and deal with emotional and social aspects of students, teachers, and especially tutors, need suitable communication. In order to coordinate, the teachers used social media, since, like the students, they were teleworking. Specifically, 67.3% of the teachers were satisfied with the communication devices and ensure that they had fluid communication with the rest of the teachers. To respond to practical demands and social and emotional needs, teachers had to achieve greater coordination with their peers. Specifically, 84.1% of teachers confirm that it was possible to coordinate with their peers through social media, although this increased working hours even more.

Despite the communication and coordination of the teaching staff and the possibilities offered by social media, virtual classes could not provide the social and emotional contributions that face-to-face classes offer. The students showed a certain commitment by attending class and handing in their homework. Specifically, 56.4% of the teaching staff are satisfied with the commitment shown by the students, especially taking into account that academic performance during confinement would not be taken into account to pass the course. However, the commitment shown by the students was not enough to maintain the desired academic level. 80.3% of the teaching staff observe a decrease in the academic performance of the students that can be perceived even at the beginning of the following academic year. In addition, 93.7% of the teachers affirm that they saw the participation of the students decrease and perceived greater difficulty in ensuring the social inclusion of all the students.

The lack of participation on the part of the students and the physical distance made it difficult for the teachers to prevent emotional discomfort and socialization problems. Specifically, 68.6% of teachers say they had difficulties perceiving tense situations and emotional problems in class.

These difficulties and limitations presented by the exclusive use of social media increased stress in both students and teachers. The hours of dedication to classes and the study of students and teachers increased. The adaptation and work with a new material, the communication difficulties due to the collapse of the lines and the lack of devices, the need for coordination, etc., were just a few of the aspects that increased the stress experienced. In addition, the confinement situation made it difficult for the students to relieve themselves, generating problems with sleep, concentration, eating, etc. Specifically, 80.3% of teachers claim to feel more stress than usual.

## 4. Conclusions

The educational centers provide students with practical knowledge and social and emotional skills that help them function in society. Based on this premise, the health emergency affected the teaching and socialization processes of students at all educational levels. Specifically, an educational crisis was generated that affected the academic and social development of the students. However, social media helped mitigate the impact by offering opportunities to maintain contact, albeit limited, between students and teachers.

In this sense, despite the difficulties, the situation generated by the confinement was an opportunity to identify the possibilities and limitations of social media in the teaching and socialization processes of compulsory secondary education students. Starting with the possibilities, these means present practical, emotional and social facilities. The main contribution was the possibility of establishing contact at a distance, which, although limited, was able to reduce the feeling of isolation and made it possible to continue the training of the students.

The students were able to maintain contact with their classmates and teachers by participating in video calls. In this way, the emotional impact could be reduced. In addition, the continuation of the classes made possible the minimum continuation of the teaching processes, which, although the students could not participate and acquire knowledge as in the face-to-face classes, did maintain a certain contact. Similarly, the ability of students with technology increased.

Regarding the limitations of social media as unique tools for student socialization and education, many of these come from the tools themselves and others from preparing the environment for this change. In order to continue with the teaching processes, it is necessary to have a quality Internet connection, suitable devices and adequate material for distance learning. On many occasions it was not possible to provide adequate resources to continue with the teaching processes in this format, increasing inequalities between different centers, students and teachers.

The lack of a fast and quality Internet connection, of sufficient devices and of material adapted to the needs of a fully distance education are limitations presented by the selection of social media as the main educational tool. As a result, part of the students attended class with inadequate devices, a poor quality connection and inadequate material. This had a negative impact on the education and socialization processes, since practical difficulties limited access to video calls. In addition, these digital barriers increased inequality among students.

Added to the practical limitations are the emotional and social problems derived from distance education. The impact and reduction of the socialization of the students during the months of confinement was perceived by the teachers. On the one hand, most of the students decreased their intervention in the classroom. On the other hand, it was a challenge for the teachers to detect the difficulties and emotions of the students during this time, a fact that if it lasts for a long period of time, it can have negative consequences on the development of the students. In addition, the teachers perceived an increase in stress in both students and teachers. The demands of a fully virtual system without prior preparation, apart from increasing working hours, had important consequences on stress levels and the emotional state of students and teachers.

The result of this study concludes that the possibilities of social media made it possible to continue the processes of education and socialization of the students. Without the contribution of these tools it would be impossible to continue and the impact on students would be even greater. However, the education sector was not prepared for this radical change. During the period of confinement, teachers perceive a negative impact on both academic performance and the emotional state of the students. Without diminishing the value and contribution of social media and ICT during this time, it is concluded that these tools, educational centers, teachers and students are not prepared for full distance education. In addition, even if the devices and material were suitable, it would still be pending to satisfy the socialization needs of the students, since secondary school students need face-to-face contact with their classmates and teachers.

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# Interactive surveys during online lectures for IT students

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**Abstract**

The article investigates student response systems (SRS), and how to apply them to facilitate students' engagement and to improve the overall students' experience during online lectures. The authors give an overview of different student response systems (Mentimeter, AhaSlides, Kahoot!, Wooclap, Socrative, Poll Everywhere, and Slido) and make a comparison of their features. The work describes the experience of using the Mentimeter student response system at online lectures in the Operating Systems course for second-year students IT students of Zhytomyr Polytechnic State University (Software Engineering, Computer Science, Computer Engineering, and Cybersecurity specializations). The data is collected using observation, surveys and taking existing data. Data analysis methods include visual analysis (box plots, Q-Q plots, histograms) and statistical analysis (descriptive statistics, Shapiro-Wilk normality test, F-test, Kruskal-Wallis rank sum test). The study provides experimental results showing an increase in the number of students' answers within the lectures. It also highlights IT students' problems and preferences during online lectures. The authors give recommendations on using SRS during online lectures, aimed at improving the lecturer's interaction with the audience.

**Keywords**

student response systems, Mentimeter, online lectures, blended learning, online learning

## 1. Introduction

From the spring of 2020, due to the COVID-19 pandemic, students of Zhytomyr Polytechnic State University (Zhytomyr, Ukraine) were attending lectures online. The importance of online learning only increased in 2022, during the war [1]. Although giving lectures through online conference applications, like Google Meet, Zoom or BlueButton, was a novel experience for most of the teaching staff, gradually, we have adapted to working in new conditions [2, 3]. However, certain difficulties remain.

Particularly, most lecturers experience a leak of communication with students (no eye contact, no confirmation if students are listening, and hard to estimate students' understanding and engagement). The lecturer may demand that students keep their web cameras on during the lecture. However, this approach may reduce connection stability and cause low-quality video and audio then the bandwidth is not high enough. Furthermore, some students do not have

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web cameras on devices with a stable network connection. Conversely, students face another kind of challenge when attending online lectures. Given less control, they may be distracted more often and, thus, listen less carefully. For the same reason, asking students questions online could be less effective. Similarly, students have limited ability to show their misunderstanding or disengagement without speaking up or writing a message directly to the lecturer, and the latter may be uncomfortable for some of them.

Student response systems (SRS) are often used to capture and hold students' attention, facilitate students' experience during classes, promote their engagement, to make online lectures more person-oriented. SRSs have also been used in universities before the COVID-19 pandemic, but new restrictions force educators to pay more attention to these tools. While numerous researchers report a positive effect of using SRSs, especially when first introduced to students, it is also crucial to investigate ways of using the above-mentioned tools thoughtfully and efficiently.

The *purpose of the article* is to investigate student response systems and their application to facilitating students' engagement as well as overall students' experience during online lectures, to formulate recommendations for more effective usage of these systems.

## 2. Related work

SRS are known by various names, including audience response systems (ARS), personal response systems (PRS), electronic voting systems (EVS), polling systems, and clicker systems.

Many researchers explore the benefits, challenges and implications of using SRS as a learning tool. The publications review demonstrates that the most popular systems are Kahoot! [4], Socrative [5] and Mentimeter [6].

Wang [7] has noted that the game-based student response system Kahoot! managed to boost students' engagement, motivation and learning after using it repeatedly for five months. Roman et al. [8] offer to use Socrative as an effective instrument that allows for minimizing learning disruptions as a consequence of the recent COVID-19 outbreak is also. Quiroz Canlas et al. [9] describe their experience using the Mentimeter online platform in the Computer Science lecture classes.

Furthermore, recent reports suggest [10, 11, 12, 13, 14, 15], that personal response systems help to engage students in active and self-regulated learning, and enhance their collective efficacy, satisfaction and learning achievements.

Despite the wide range of demonstrated benefits, many authors note that student response systems have some disadvantages. For example, Barnett [16] found that SRS use faces financial, pedagogical, and technical limitations. Kay and Lesage [17] chose to group the types of SRS limitations into student-based, teacher-based, and technology-based categories. Ault and Horn [18] provide guidelines for teachers when planning, implementing and monitoring the use of student response systems.

Tkachuk et al. [19, 20, 21] developed methods of applying mobile technologies to university students' training during the COVID-19 lockdown and showed how to use Plickers audience response system for that purpose.

# 3. Methodology

## 3.1. Research settings and methods

The study investigated different SRS and, particularly, Mentimeter in the terms of their application to facilitating students' engagement and overall students' experience during online lectures. The research used quantitative analysis (for most of the data) and, partially, qualitative analysis (for the literature review).

The experimental part of the study was conducted at Zhytomyr Polytechnic State University during one semester in 2021 and involved second-year IT students. We investigated their participation in the lectures on Operating Systems. Also, the research included the further implementation of Mentimeter SRS at the lectures, subsequent analysis and formulating the recommendations for using SRS for this purpose.

## 3.2. Participants

At the time the research began (February 2021), there were four academic groups on Software Engineering specialization and two academic groups on Computer Science specialization (126 students), and also one academic group on Computer Engineering and two academic groups on Cybersecurity (62 students). All the mentioned above students have had very similar training during the previous three semesters. Meanwhile, the Software Engineering and Computer Science students had lectures in Operation Systems separately from the Computer Engineering and Cybersecurity students. Considering this, the Software Engineering and Computer Science students comprised the control group (CG), whereas the Computer Engineering and Cybersecurity students comprised the experimental group (EG).

## 3.3. Data collection tools

The data collection involved taking existing data, observation and survey. We used several tools for data collection, including the following.

- Paper and electronic document management systems of Zhytomyr Polytechnic State University for the scores gained by CG and EG students on their previous exams (existing data).
- Rating lists of the Operating Systems course for the data about attending the lectures (observation).
- Mentimeter automatic answers counters for the data about students' answers during the lectures (observation).
- Google Meet video recording of Operating Systems lectures for the data about students' answers during the lectures (observation).
- The text versions of Google Meet chats of Operating Systems lectures for the data about students' answers during the lectures (observation).
- Google Forms for the data about students' experience during online lectures (survey).

### 3.4. Data analysis methods

The methods used to define the homogeneity of the sample included visual and statistical analysis of students' average scores on previous sessions. The visual analysis involved box plots, Q-Q plots, and histograms. The statistical analysis included descriptive statistics (median, mean, standard deviation) and inferential statistics (Shapiro-Wilk normality test, Kruskal-Wallis rank sum test). General patterns shown by the survey were explored through visual analysis (histograms). Statistical differences between CG and EG were tested using visual analysis (histograms, Q-Q plots) and statistical analysis (Shapiro-Wilk test, F-test, Kruskal-Wallis test).

### 3.5. Implementation

At the beginning, the comparison of different SRS has been done, and the Mentimeter SRS has been chosen. The CG and EG have been formed. The homogeneity of the sample has been defined based on a statistical analysis of the average scores of students on previous sessions.

We were using Mentimeter SRS at online lectures in the Operating Systems course for CG and EG for one semester (from February 2021 until May 2021) to gain the experimental data. Course in operating systems is a normative discipline in the curriculum of Software Engineering, Computer Science, Computer Engineering and Cybersecurity at Zhytomyr Polytechnic State University and contains 32 academic hours of lectures on this course. In 2021 the lectures were organized separately for Software Engineering, Computer Science students (CG) and students of Computer Engineering and Cybersecurity specializations (EG). The lectures were given by the same lecturer (Olena Holovnia), on the same topics and simultaneously (within a few hours of one another or one day of one another, depending on the university timetable). The other tools used to present the material to students include Google Meet (within Google Workspace for Education) and electronic presentations (WPS Presentations) with similar content.

Mentimeter was introduced to the EG students during their online lectures in Operating Systems, whereas the CG students attended regular online lectures with questions asked through text chat or using microphones.

Figure 1 presents the example of Menimeter slides used for lectures in EG. It demonstrates the Mentimeter leaderboard as the results of a graded quiz are summing up. The student at the top of the diagram (nicknamed "Bahogabaguguwongas") is going to be the winner as he or she just gave the most precise and quick answer. Students may use both nicknames or their true names within leaderboard quizzes.

After 13 lectures (26 academic hours) an anonymous online survey for both CG and EG has been conducted. The survey contained questions about students' experiences during the lectures on Operating Systems. The general patterns shown by the survey have been analysed.

To investigate differences between the CG and EG we compared self-reported levels of students' engagement (based on the data from the survey) and conducted a statistical analysis of the number of students' answers during the lectures (based on the data collected within the lectures). A statistically-significant difference in the number of answers per student in CG and EG has been found. We also analysed the EG students' experience with Mentimeter (also gained from the anonymous survey).

The further implementation of Mentimeter (February 2022, April 2022 – June 2022, September

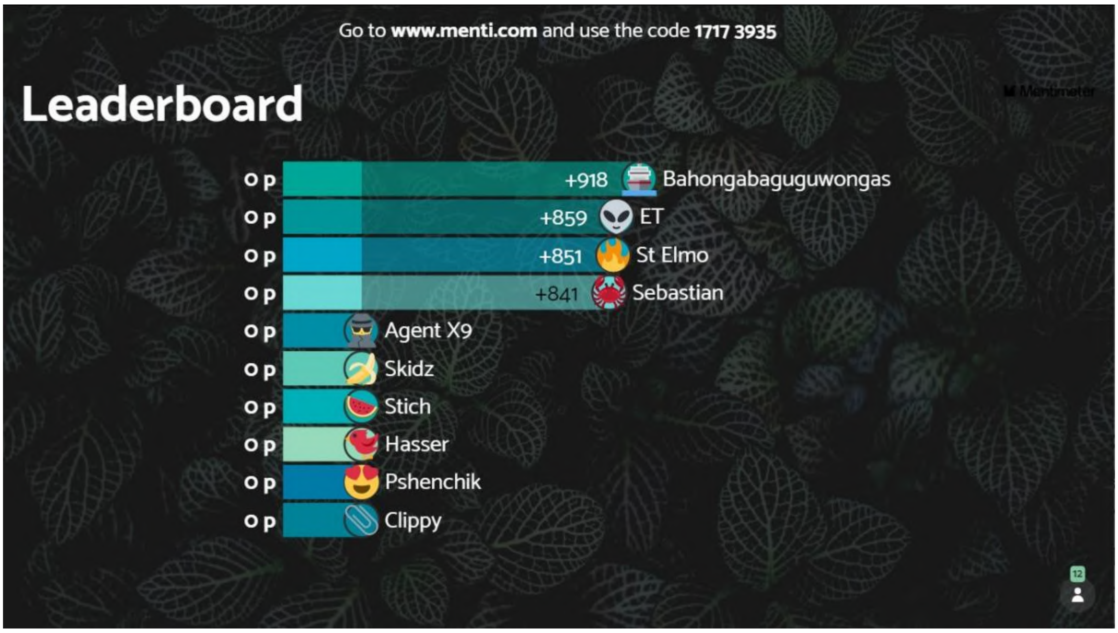


**Figure 1:** Students' results on the Mentimeter leaderboard during the online lecture about scheduling and dispatching.

2022 – November 2022) allowed us to continue accumulating experience and formulate practical recommendations for more efficient usage of SRS at online lections.

The details about the research along with the results obtained are covered in section 4.

# 4. Results

## 4.1. An overview of student response systems available for free

The main functions of such services as Mentimeter, AhaSlides, Kahoot!, Poll Everywhere, Slido, Wooclap, Socrative and their ability to involve the student audience in the educational process through polling were considered (table 1).

A more detailed comparison of the products' features available for free is shown in table 2.

Mentimeter is a simple and convenient online service for creating polls and voting in real-time. The basic features of the platform are provided for free. However, the free plan has several limitations: the number of questions is no greater than 2, and it is impossible to customize the appearance of the questionnaire and export it to other services.

Most of the features of AhaSlides are immediately available for free, there is no limit to the number of questions that can be used in the presentation. However, a significant drawback is the maximum number of participants – only 7 people can simultaneously join the presentation. Paid access to the platform provides much wider opportunities. They are manifested, in particular, in the number of students who can be involved in the survey, and the ability to export an extended report on the survey results.

**Table 1**
Student response systems (product comparison).

| Product details | Website | Founded | Located | Starting price | Platforms supported |
|---|---|---|---|---|---|
| Mentimeter | mentimeter.com | 2014 | Sweden | $9.99 per month, free version available, free trial available | cloud, SaaS, web-based, Android, iOS |
| AhaSlides | ahaslides.com | 2019 | Australia | $4.95 per month, free version available, free trial available | cloud, SaaS, web-based |
| Kahoot! | kahoot.com | 2013 | Norway | €5.00 per month, free version available, free trial available | cloud, SaaS, web-based, Android, iOS |
| Wooclap | wooclap.com | 2014 | Belgium | $6.99 per month, free version available, free trial available | cloud, SaaS, web-based |
| Socrative | socrative.com | 2010 | Canada | $59.99 per year, free version available | cloud, SaaS, web-based, Android, iOS |
| Poll Everywhere | polleverywhere.com | 2007 | USA | $13.99 per month, free version available | cloud, SaaS, web-based, Android, iOS |
| Slido | slido.com | 2012 | Slovakia | €10.00 per month, free version available | cloud, SaaS, web-based, Android, iOS |

Kahoot! is primarily a game-based learning platform for creating educational tests, games and quizzes. The gameplay is simple – all players simultaneously answer questions on their devices and gain points for each correct answer. At the end of the competition, the number of points of all participants is displayed on the screen. Free access allows you to create only two types of questions: quiz, i.e. questions with "multiple-choice" and "true or false".

Another survey tool that is widely used in western schools (particularly in the United States) is the Socrative educational platform. Socrative service is designed to organize and use a voting system using any gadgets, computers, tablets, or mobile devices that can display surveys. However, the number of participants should not exceed 50 people.

Poll Everywhere is an online service for creating polls with different types of questions. A feature of this tool is the ability to create polls that involve answering questions for a long time. An interesting feature is a graphical way of displaying users' answers to open questions (in the form of a text wall, word cloud, quotes or a moving line). In the free version of Poll Everywhere, the maximum audience size is 40 users, but there are no restrictions on the number of questions in the survey.

Slido is an easy-to-use tool for audience engagement. This tool is often used in large events.

**Table 2**
Student response systems (features comparison).

| Free version features available | Mentimeter | AhaSlides | Kahoot! | Wooclap | Socrative | Poll Everywhere | Slido |
|---|---|---|---|---|---|---|---|
| Maximum participants | unlimited | 7 | 10 | 1000 | 5 | 40 | 100 |
| Maximum number of questions per event | 2 | unlimited | unlimited | 2 | 1000 | unlimited | 3 |
| Question types | multiple-choice, word cloud, open-ended, scales, ranking | multiple-choice, word cloud, open-ended, scales, image choice | multiple-choice quiz | multiple-choice, poll, find on image, rating, open-ended, word cloud, find a number, matching, sorting, fill in the blank, brainstorming | multiple-choice, true/false, short answer | multiple-choice, open-ended, word cloud, clickable images, ranking, survey, Q&A, competitions | multiple-choice, word cloud, quiz, rating, open text, ranking, survey |
| Q&A | Yes | Yes | Yes | Yes | No | Yes | Yes |
| Quiz | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Real-time vote | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Anonymous voting | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| PowerPoint integration | Yes | Yes | No | Yes | No | Yes | Yes |
| Google Slides integration | No | Yes | No | Yes | No | Yes | Yes |
| Microsoft Teams integration | Yes | No | No | Yes | No | Yes | Yes |
| Screen sharing | Yes | No | Yes | Yes | Yes | Yes | Yes |
| Data analysis tools | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Reporting, export results | Yes | No | Yes | No | Yes | No | No |
| Design | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Security and Privacy | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Support | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

With its help, participants of conferences, trainings, seminars, and public lectures can ask questions to the speaker, as well as vote for the best questions, so that speakers can answer exactly those that are interesting to the majority. The number of events in the free version is unlimited, but there is a limit on the number of participants – up to 100 per event. Also, the free version has the ability to conduct 3 polls during 1 event, including 1 quiz and 1 brainstorming session.

Unlike the platforms discussed above, the Wooclap service provides the ability to create a survey with different types of questions and allows users to attract a large audience (up to 1000 people). However, the maximum number of questions in the free version is 2.

In general, all the services under consideration have similar functionality. For further research, the Mentimeter platform was chosen. It has a convenient and intuitive interface and supports multiple-choice, word cloud, and open-ended types of questions, along with questions with scales and ranking. The Free Mentimeter plan allows an unlimited number of students to participate, so it can be used at lectures for a large audience, which is not unusual at Zhytomyr Polytechnic University. The service has a limited number of questions per event, but this could be enough when combined with traditional questions through a web meeting chat or students' microphones.

## 4.2. The homogeneity of the sample

To research the homogeneity of the sample, the average score on previous sessions for CG and EG students has been compared. The descriptive statistics for the average score of students are shown in table 3.

**Table 3**
The descriptive statistics parameters for the average score (control and experimental group).

| Group | Median | Mean | Standard deviation |
|---|---|---|---|
| Control group | 75,25 | 76,18 | 14,42 |
| Experimental group | 75,35 | 74,74 | 15,12 |

The box plot for average students' scores in CG and EG is presented in figure 2. It shows that these two samples are visually similar, and there are no visible outliers.

The results of visual analysis and Shapiro-Wilk normality test (`shapiro.test( )` function in R) for the student's average score in CG and EG showed visual differences between the normal distribution and distributions in CG and EG (figure 3), along with p-values 0,0001616 and 0,02458 respectively, which is less than the significance level 0,05.

So, we can conclude that the data significantly deviate from a normal distribution. The residuals analysis also showed a significant deviation from a normal distribution visually (figure 4) and through the Shapiro-Wilk normality test (p-value = 0,00004022, which is considerably less than the significance level 0,05).

Given the mutual independence of the samples and also the deviation from normality for both samples, the Kruskal-Wallis rank sum test was used to compare the two samples. The Kruskal-Wallis test is a statistical test to determine whether two or more population means are different

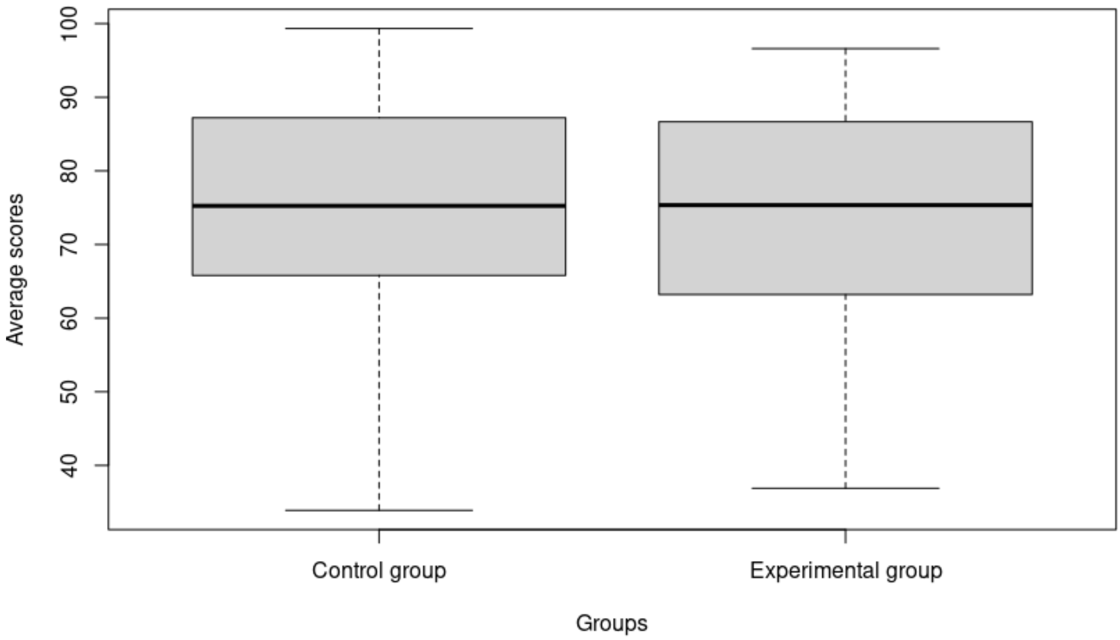


**Figure 2:** The boxplot diagram for the student's average score in CG and EG.

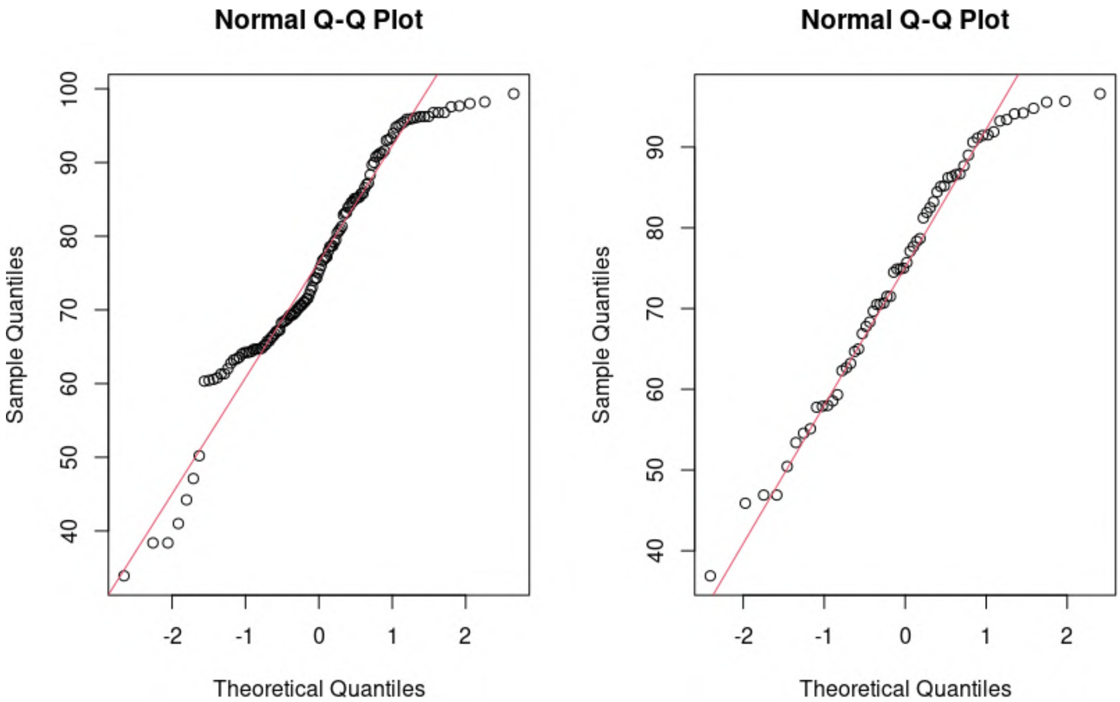


**Figure 3:** The normal Q-Q plots for the student's average score distribution in CG and EG.

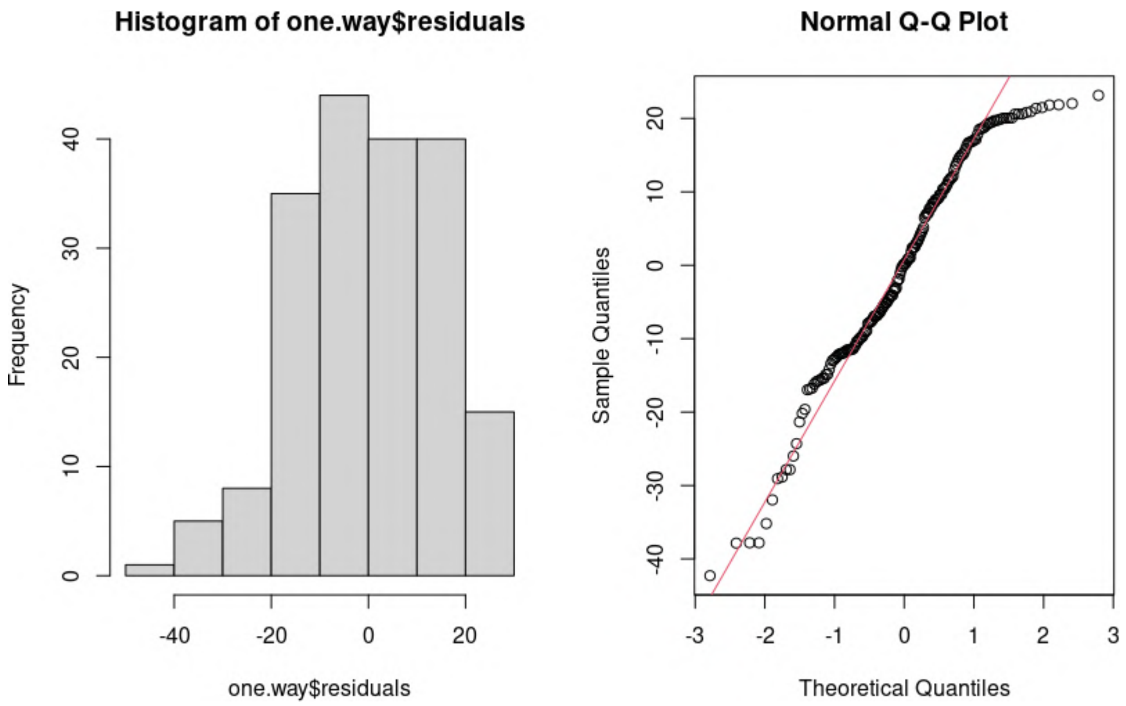


**Figure 4:** The histogram and the normal Q-Q plot for the student's average score distribution residuals.

and does not require the assumptions of normality [22, p. 115-120]. The `kruskal.test( )` function in R has been used. The test showed p-value = 0,5589, which is more than the significance level 0,05, showing no statistically significant difference between the medians of CG and EG.

Taking into account all mentioned above, we can consider the samples as homogeneous.

### 4.3. General patterns shown by the survey

After 13 lectures students were given an online survey using Google Forms. The survey was anonymous and contained an identical set of questions, except the Computer Engineering and Cybersecurity students (EG) were been also asked questions about their experience on Mentimeter.

Despite the total number of Software Engineering and Computer Science students differs from the total number of Computer Engineering and Cybersecurity students, the number of students taking the survey was 31 persons in each case. Given the significantly different sizes of CG and EG, this observation forms a specific interest, which, however, goes beyond the scope of this research.

As expected, students in both the CG and EG reported some degree of difficulty during online lectures. When asked the question about holding their attention within lecture ("It's more difficult for me to hold my attention during online lecture than during regular lectures"), more than 61% in each group choose the answers 2-5 on the scale from 1 ("No, it doesn't seem like me at all”) to 5 (“Yes, it’s definitely about me”), of which almost a half chose the answers 4 or 5 (figure 5).

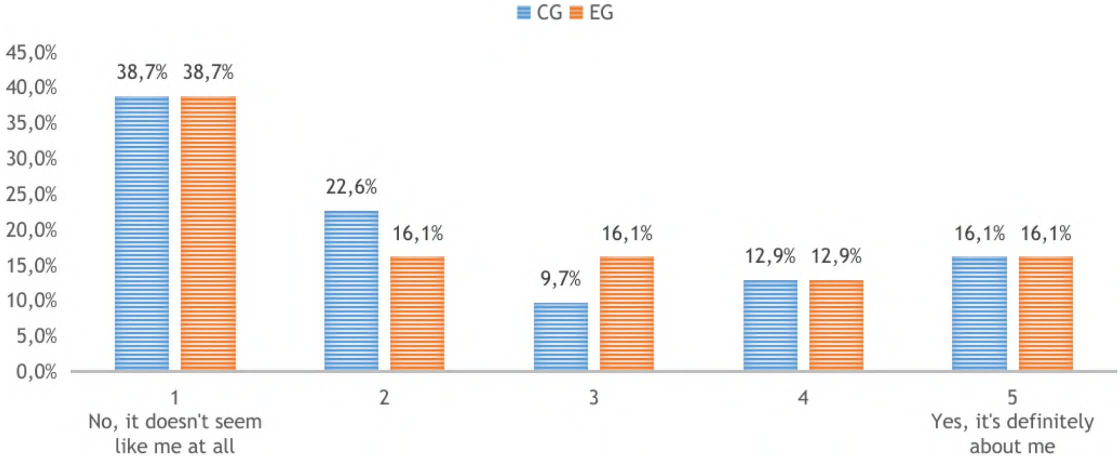


**Figure 5:** The distribution of the survey answers. Question: “It’s more difficult for me to hold my attention during online lectures than during regular lectures”.

The majority of respondents admitted they may distract during online lectures. About 20% of students in both groups do it quite often or very often (figure 6).

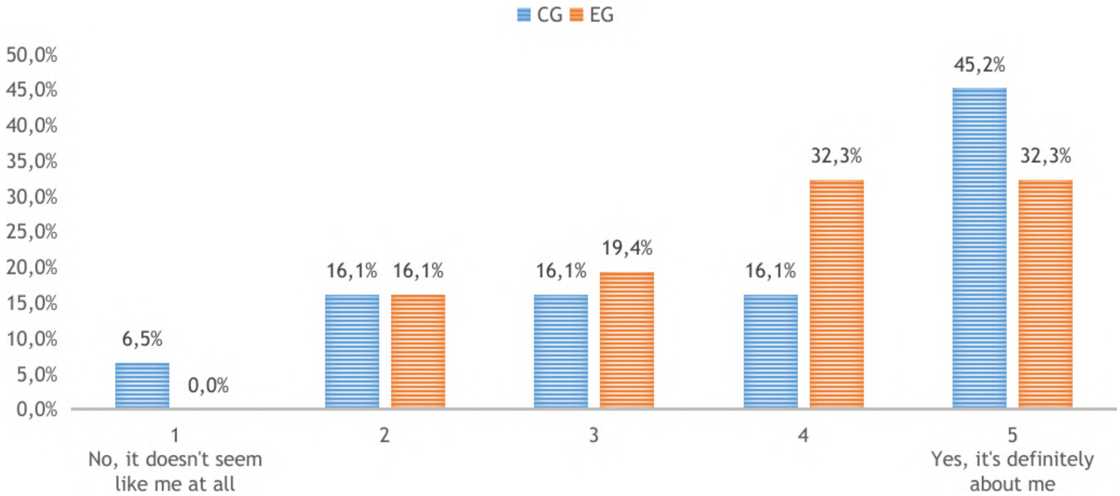


**Figure 6:** The distribution of the survey answers. Question: “There is a temptation to do other things when attending online lectures. It happens that I do that”.

Approximately a quarter of respondents stated the importance to them (4 or 5 on 1..5 scale) if the lecturer knows, that it is he or she the one who answered the question or made a comment within the class (figure 7). Also, a quarter of students reported they agree or mostly agree (4-5 on 1..5 scale) with a statement: “I rarely participate in discussion during lecture, because I’m not quite sure if I would look smart and competent enough”), as shown in figure 8. This information should be taken into consideration when choosing the type of the questions during the lecture.

It may indicate that some students need anonymous quizzes during the lectures whereas other students may want to be identified by the lecturer when they answer. Therefore, the online quizzes have to contain both anonymous and non-anonymous tasks.

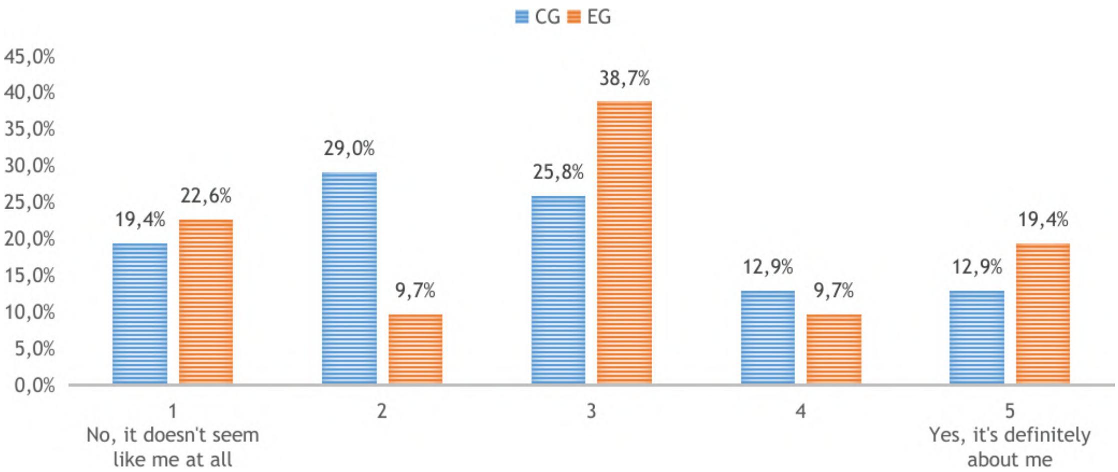


**Figure 7:** The distribution of the survey answers. Question: "It is important to me if the lecturer knows that it was me the one who answered the question or made a comment within the class".

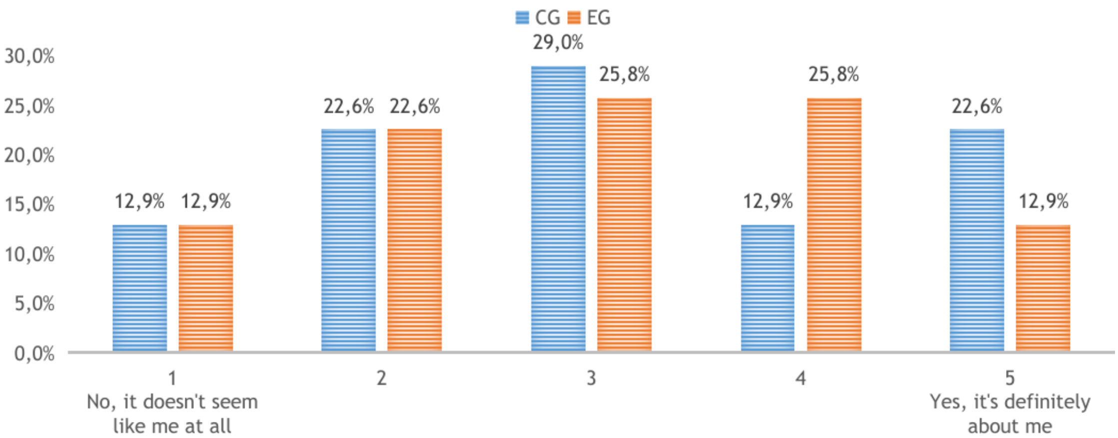


**Figure 8:** The distribution of the survey answers. Question: "I rarely participate in discussion during lectures, because I'm not quite sure if I would look smart and competent enough".

As well, students in both groups are predictably interested in gaining extra points for correct answers within lectures (figure 9). However, about half of respondents showed less interest in such a way of getting extra points and, therefore, may be better motivated by other factors.

The students of EG also were proposed to answer the questions about their Mentimeter experience.

Most of the respondents enjoyed the Mentimeter online surveys. When asked to estimate how much they liked the surveys, 83,9% of the students chose 4 or 5 points out of 5. The rest of the students (16,1%) reported a more neutral attitude, choosing 3 points out of 5 (figure 10).

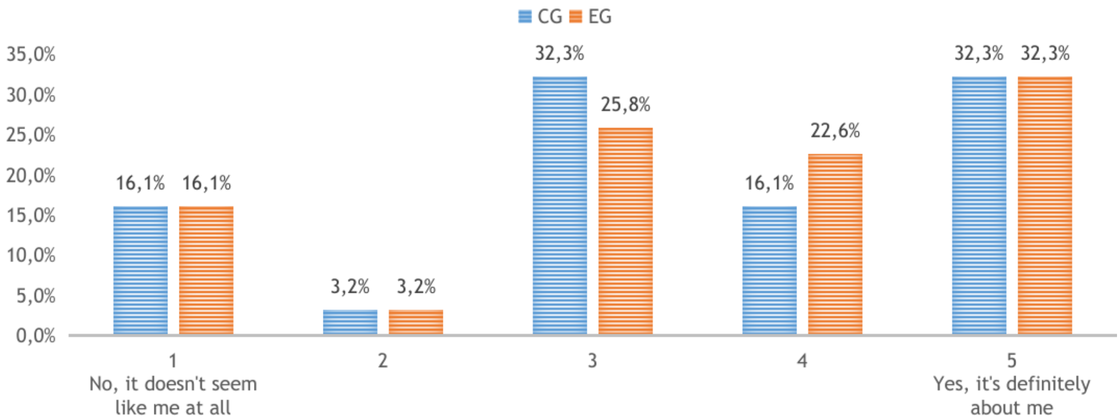


**Figure 9:** The distribution of the survey answers. Question: "I am more eager to participate in discussions during lectures if I can gain some extra points for that".

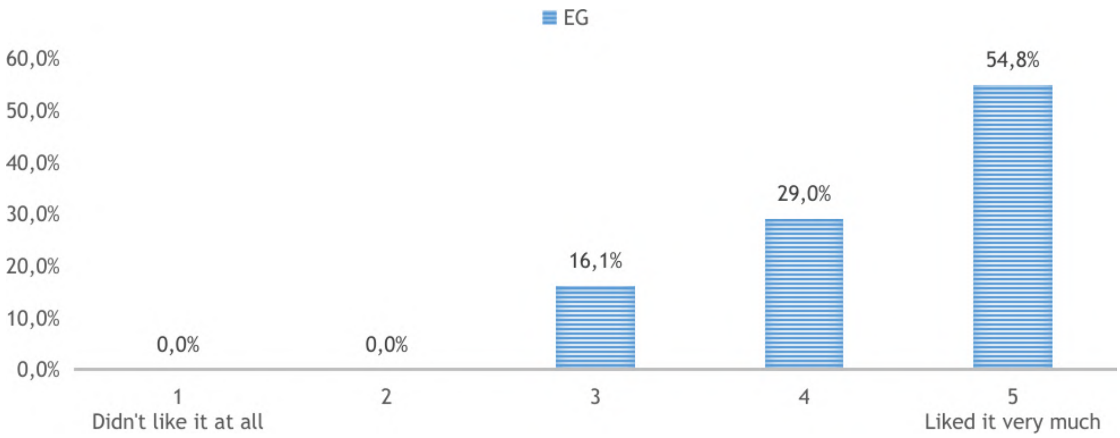


**Figure 10:** The distribution of the survey answers. Question: "How much did you like the Mentimeter experience during the lectures in Operating Systems?".

When asked to choose Mentimeter features they enjoyed the most (the multi-choice question, figure 11), students reported they liked the new experience (83,9%), the lectures becoming more diverse, containing less teacher's monologue (71%), the opportunity to interact more with fellow students and teachers (58,1%), the opportunity to check yourself and your understanding of the material (48,4%), the fun pictograms, animation (48,4%), the opportunity to compete with the others answering the questions where the correctness and speed were assessed (25,8%), the support of the access from different devices (22,6%). Only one respondent reported that liked nothing specific about Mentimeter quizzes (forming 3,2%). Also, no one has chosen the open-ended option ("Other: ").

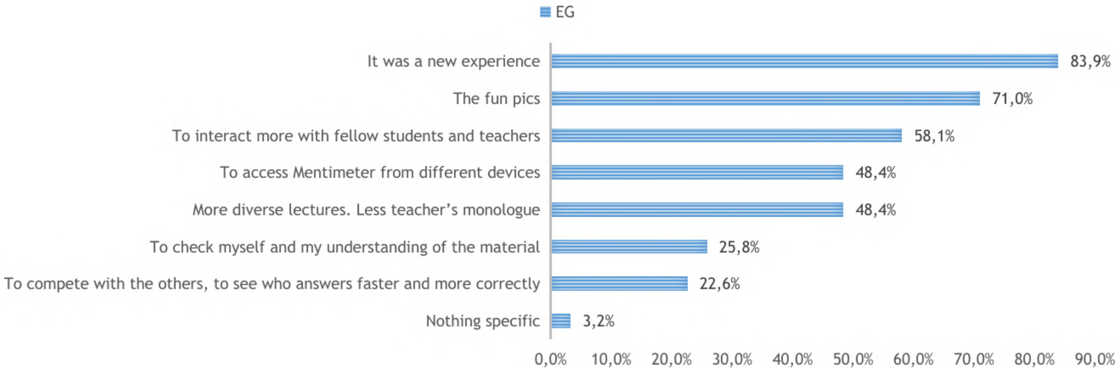


**Figure 11:** The distribution of the survey answers. Question: "What Mentimeter features did you enjoy the most?" (multi-choice).

## 4.4. Differences between the control and experimental group

A comparison of self-reported levels of students' engagement was done. During the anonymous survey, the students were asked to choose how engaged they had been at lectures in the Operating Systems. The possible answers included five levels, followed by explanations.

- "My level of engagement is high. It is important for me to understand the lecture and not miss any discussion no matter if I am participating or just listening"
- "My level of engagement is above average. I'm trying to understand all the material. However, if I miss something, I would read about it elsewhere"
- "My level of engagement is average. I'm trying to understand the part of the material which seems important to me. If later I would need something I've missed then I would dig into it"
- "My level of engagement is below average. I'm trying to understand the course in general. It looks like I wouldn't understand some parts of the material, but it is impossible to know everything"
- "My level of engagement is quite low. I'm trying to understand some parts of the material, mainly those which seem interesting to me or those which are easy to understand"

The anonymity of the survey and neutral formulations without noticeable judgement give reasons to assume that the respondents tried to answer fairly.

The results of the survey are given in table 4.

The histogram in figure 12 shows that the students of EG reported higher levels of engagement noticeably more often than the students of CG.

Researching the differences in CG and EG students' engagement during online lectures, the analysis of the number of students' answers during quizzes and discussions has been done.

The total number of students who participated in quizzes and discussions during lectures in Operating Systems among CG and EG are given in table 5.

Table 5 needs a few important notes.

The modules, *marked with the asterisk symbol* (*) took 2 lectures to discuss (4 hours instead of 2). The lectures held within the experiment were as follows.

**Table 4**
The comparison of the levels of students' engagement (self-reported, anonymous).

| Level of engagement | CG | | EG | |
|---|---|---|---|---|
| | Number of students | Percentage of students | Number of students | Percentage of students |
| High engagement | 2 | 6,5% | 7 | 22,6% |
| Engagement above-high | 9 | 29,0% | 13 | 41,9% |
| Medium engagement | 18 | 58,1% | 7 | 22,6% |
| Engagement below-medium | 1 | 3,2% | 1 | 3,2% |
| Low engagement | 1 | 3,2% | 3 | 9,7% |
| Number of answers | 31 | | 31 | |

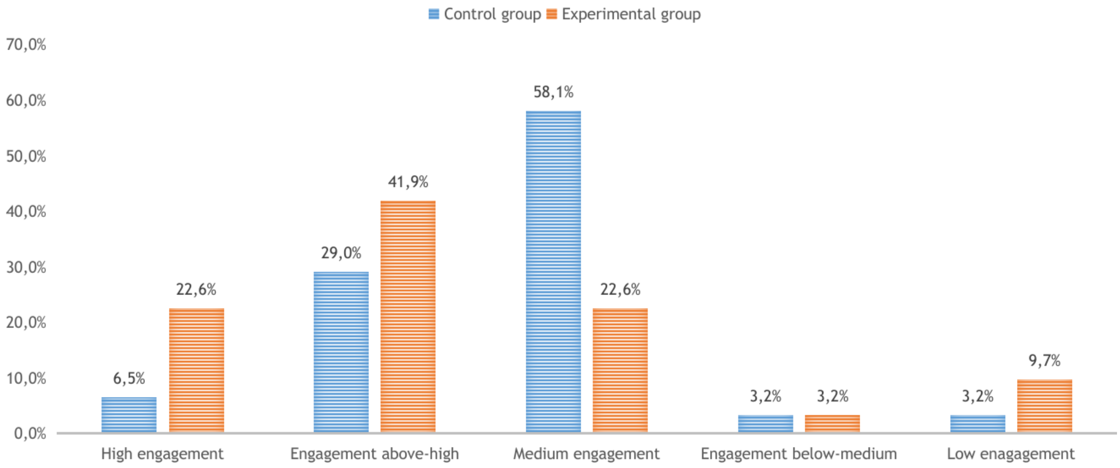


**Figure 12:** Levels of students' engagement in CG and EG (self-reported).

**Table 5**
The comparison of students' answers count during 8 modules of the Operating Systems course in the experimental and control group.

| Module | EG | | | CG |
|---|---|---|---|---|
| | EG (Menti) | EG (Chat+microph.) | **EG (Total)** | **CG (Chat+microph.)** |
| Module 1 | 26 | 23 | 49 | 26 |
| Module 2 | 11 | 22 | 33 | 29 |
| Module 3 | 22 | 3 | 25 | 13 |
| Module 4 | 12 | 0 | 12 | 9 |
| Module 5* | 23 | 0 | 23 | 14 |
| Module 6* | 3 | 4 | 7 | 2 |
| Module 7 | 0 | 24 | 24 | 22 |
| Module 8* | 5 | 2 | 7 | 6 |
| **Number of students** | **62** | | **126** | |

- Module 1. Operating systems overview.
- Module 2. The main principles of the operating systems (part 1).
- Module 3. The main principles of the operating systems (part 2).
- Module 4. Concurrency.
- Module 5. Scheduling and dispatching.
- Module 6. Memory management.
- Module 7. File systems.
- Module 8. Security.

The above-mentioned modules do not cover all the course materials. This list contains the modules, presented to the students exactly within the period of the experiment, meaning, in particular, observation and counting the number of answers.

Student *chat messages count* doesn't include organizational questions and answers.

Most lectures in the experimental group involved *two Mentimeter questions* (the limit for the free plan). The lecture on module 6 contained one Mentimeter question. Only the lecture on module 7 contained no Mentimeter questions.

Most lectures in the experimental group *also included questions answered in chat* (otherwise there are zero chat answers). Besides, some students tend to send one answer in several chat messages. Such answers are counted as one.

Table 6 contains the answers count from Table 5 divided by the number of students in the respective group (CG or EG).

**Table 6**
The comparison of students' answers count per student during 8 modules of the Operating Systems course in the experimental and control group.

| Module | EG | | | CG |
|---|---|---|---|---|
| | EG (Menti) | EG (Chat+microph.) | **EG (Total)** | **CG (Chat+microph.)** |
| Module 1 | 0,42 | 0,37 | 0,79 | 0,21 |
| Module 2 | 0,18 | 0,35 | 0,53 | 0,23 |
| Module 3 | 0,35 | 0,05 | 0,40 | 0,10 |
| Module 4 | 0,19 | 0,00 | 0,19 | 0,07 |
| Module 5* | 0,37 | 0,00 | 0,37 | 0,11 |
| Module 6* | 0,05 | 0,06 | 0,11 | 0,02 |
| Module 7 | 0,00 | 0,39 | 0,39 | 0,17 |
| Module 8* | 0,08 | 0,03 | 0,11 | 0,05 |
| **Number of students** | | **62** | | **126** |

In both tables (table 5 and table 6), the answers count per student in EG exceeds the answers count per student in CG.

The histogram in figure 13 presents the data from table 6 visually.

However, it is important to note that the number of students participating in discussions among students who used Mentimeter is decreasing by the end of the semester. We assume it may be partially caused by becoming Mentimeter more routine for students.

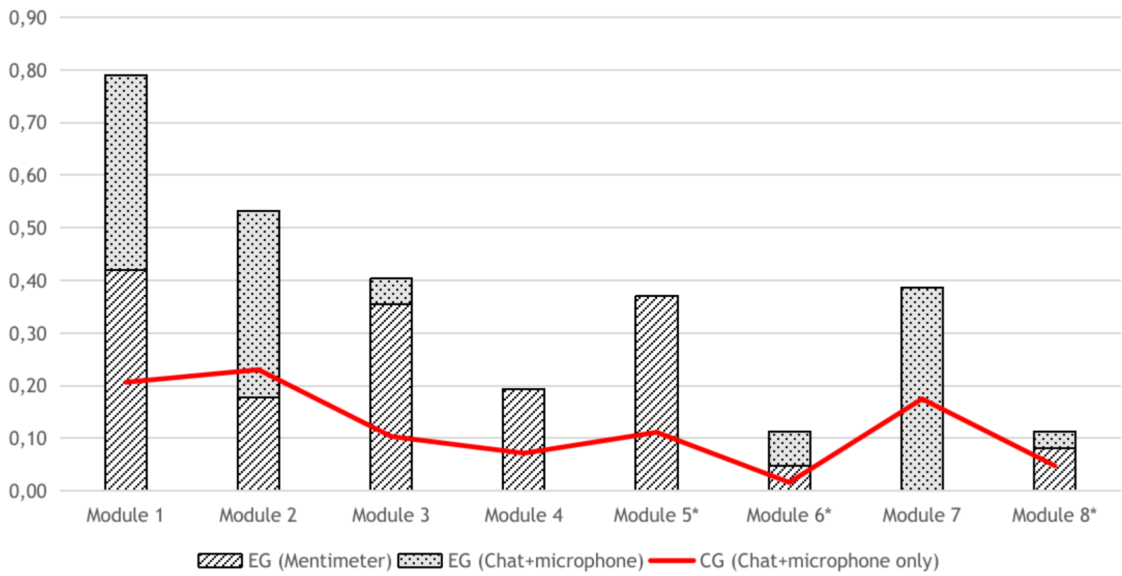


**Figure 13:** The histogram showing the comparison of answers count per student in CG and EG.

In order to investigate the existence of statistical differences between CG and EG, we analysed the distributions of answers count per student in both groups.

Both distributions are visually close to the normal distribution (figure 14), although this assumption might be inaccurate due to the small size of the samples.

According to the results of the Shapiro-Wilk normality test, the p-values for the distributions are 0,6485 for CG and 0,3934 for EG, both are greater than the significance level 0,05. So, we can conclude that the data does not significantly deviate from a normal distribution.

The homogeneity of variance of given distributions can be investigated through the F-test (`var.test` function in R). The ratio of variances is 0,1096445 which is less than 1, and p-value for the F-test is 0,009256, which is less than 0,05. Therefore, the homogeneity assumption of the variance is not met.

However, the samples are mutually independent. The Kruskal-Wallis rank sum test can be applied. The null hypothesis and the alternative hypothesis were as follows.

H0: both CG and EG have been drawn from identical populations with the same median.
H1: CG and EG have different medians.

The test showed p-value = 0,01541, which is less than the significance level 0,05. Therefore, we reject the null hypothesis and accept the alternative hypothesis: CG and EG have different medians. We found a statistically-significant difference in the number of answers per student in CG and EG. Also, according to the visual analysis, the number of answers per student in EG is greater than the number of answers per student in CG.

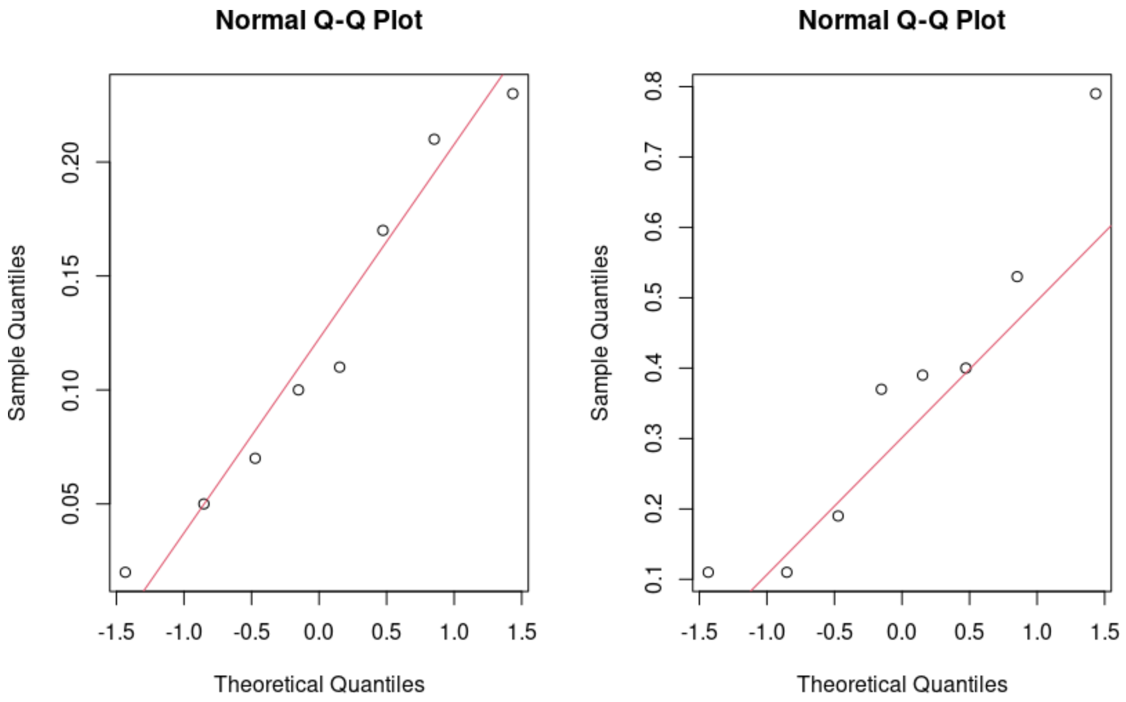


**Figure 14:** Normal Q-Q plots for the distributions of answers per student in CG (left) and EG (right).

### 4.5. The recommendations for using student response systems within online lectures

The analysis of the experience of using Mentimeter during the experiment and its further implementation within the next semesters allowed us to formulate recommendations on efficient usage of SRS at online lections. The recommendations are as follows.

- Test online quizzes before the lecture. Moreover, it is highly recommended when new question types are used.
- Clarify quiz questions. Some quizzes engage fewer students than expected not because the question is hard, but because the question has an unclear formulation.
- Select the relevant question types in each case.
- Combine anonymous and non-anonymous quizzes. The anonymous quizzes are recommended to engage students who are less confident or answer less quickly. Non-anonymous quizzes attract students who are more active when given the ability to compete.
- Add some extra points for students being active during online lectures. The anonymous survey shows that such an approach could additionally motivate some part of the students.
- Combine SRS with the more traditional way of interacting with students within the online lecture. Students may write the answers in the meeting chat or turn on the microphone and answer orally. This may prevent interactive surveys from becoming routine for students, so the students would still consider interactive quizzes novel and entertaining.
- Combine various types of questions to keep students interested.

We see online lectures as a challenge that leads to new opportunities. Taking into account the experience of lectures during online and mixed learning also gives educators a promising option to facilitate students' experience in regular lectures. Interactive surveys also help the lecturer to see more full feedback and could be used for self-analysis.

### 4.6. Discussion

The article investigated SRSs and their application to facilitating students' engagement and overall students' experience during online lectures. We also formulated recommendations for more effective usage of SRS.

After a comparison of SRS available for free, the Mentimeter SRS had been chosen for this research. Although all the analysed SRS provide similar functionality, Mentimeter supports questions of multiple types and has no limitations on participant number.

Our experience of using Mentimeter within online lectures in Operating Systems for IT students showed the SRS effectiveness for facilitating students' engagement, as the number of answers per student during the lectures with Mentimeter was greater than the corresponding value without Mentimeter. The difference in the number of answers per student proved to be statistically significant.

Furthermore, we formulated recommendations for efficient usage of SRS within online lections. The recommendations summarized our experimental findings, as well as the experience of giving lectures with the use of SRS, and may be applied in online and mixed learning.

However, there are some limitations of the study, including the following.

- Part of Mentimeter quizzes are anonymous, and the same student may answer more than once. Therefore, it is difficult to take into account highly active students in this case.
- The research does not take into account students with disabilities who may experience difficulties answering quickly through SRS and prefer other tools (like a microphone).

Moreover, we believe that the findings presented in this article are generalizable and could be applied to lectures for IT students at large.

Future studies should focus on the analysis of using different SRS within other course activities (namely, practice and lab classes), as well as choosing the SRS for lectures on other courses for IT students (Cryptology, Cybersecurity, Networking, Higher Mathematics and others).

## 5. Conclusions

SRS are widely used during online and offline student activities. The related work overview shows variuos ways of applying SRS in education. The comparison of the free features of Mentimeter, AhaSlides, Kahoot!, Wooclap, Socrative, Poll Everywhere, and Slido SRS showed they have similar functionality with differences in some features like the maximum number of quizzes, a maximum number of participants or types of questions supported. The Mentimeter SRS had been chosen for this research because it allows an unlimited number of participants and supports questions of multiple types.

The experimental part of the study focuses on IT students of Zhytomyr Polytechnic State University (Software Engineering, Computer Science, Computer Engineering, and Cybersecurity specializations). The work provides experimental results on using the Mentimeter student response system at online lectures in the Operating Systems course. During one semester the lectures for Computer Engineering and Cybersecurity second-year students (experimental group) included Mentimeter quizzes, while the second-year students of Software Engineering and Computer Science (control group) during the lectures were questioned only using online meeting chat and microphones. The number of students' answers in both cases was analysed, showing a statistically-significant difference between the groups. The authors also analyse the data collected from the anonymous survey, which includes the self-reported level of students' engagement, students' problems, preferences and suggestions, and students' answers about their Mentimeter experience during lectures. The results of the study showed an increased number of students' answers during the lectures in the experimental group. Most of the students from the experimental group, who take part in the survey, reported an increased level of engagement and note that they liked their Mentimeter experience. The analysis of the survey also showed that students in the control and experimental group experienced similar difficulties when attending online lectures.

The recommendations on using SRS during online lectures for the lecturer's interaction with the audience include testing online quizzes before the lecture, clarifying quiz questions, selecting the relevant question types, combining anonymous and non-anonymous quizzes, adding extra points for active students, combining SRS with the traditional way of interacting, and combining various types of questions.

Future studies should focus on the analysis of using different SRS during other course activities and choosing the SRS for lectures on other courses of IT students.

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# Using a mobile application to teach students to measure with a micrometer during remote laboratory work

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**Abstract**

In modern conditions, the transition to distance learning has set new tasks for teachers, in particular, related to laboratory work. In these works, students not only study the structure and features of special equipment, but also acquire practical skills in working with the tool. The purpose of the article is to present our own experience of developing and using in the educational process a mobile application for teaching micrometer measurements during the relevant remote laboratory work in the disciplines "Interchangeability, Standardization and Technical Measurements" and "Physics". The literature analysis showed that ICT is widely used in the educational process in higher education, but computer programs and mobile applications are usually developed for secondary school disciplines, so there was a need to develop an information program for teaching students in distance learning, in particular during laboratory work. In order to teach students to work with a micrometer during distance learning, we have developed a mobile application. The process of developing the application included modeling the micrometer in the CAD system, creating training scenes in the Unity game engine and writing scripts to fully immerse students in the learning process. The mobile application developed by us consists of three parts: theoretical, educational and practical. In the theoretical part, students learn the structure and principles of working with a micrometer. The training part is developed in the form of a video lesson of working with the equipment. The practical part contains an electronic model of the micrometer and allows you to make measurements. Thus, during distance learning using the developed application, the percentage of qualitative success of students in laboratory work on the topic "Measuring parts with a micrometer" increased by 7.3% compared to the same period of distance learning without the use of this application.

**Keywords**

micrometer, distance learning, distance laboratory work, mobile application, Unity



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## 1. Introduction

During the quarantine, distance learning has gained considerable popularity in all educational institutions [1, 2, 3]. Such training involves teachers conducting lectures as video conferences using Google Meet or Zoom platforms, and theoretical material and individual practical tasks are posted on the Moodle platform [4]. The experience of teachers in distance education in the study of mathematical disciplines in primary school showed the use of WebEx, e-class, e-Me, Word wall, Quiziiz, Learning apps, GCompris, Jigsaw planet, Wheel of Luck as tools for learning and practice [5].

Special attention is focused on laboratory classes, where students not only study the structure and features of special equipment, but also acquire practical skills in working with the tool. During distance learning, these works are also translated into the format of video demonstrations and have an exclusively review character. Passive observation by students negatively affects the assimilation of educational material and the acquisition of programmed learning outcomes in the specialty. At the end of distance learning, both teachers and students experienced a variety of positive and negative emotions, insufficient content of training, lack of technological equipment and knowledge [6, 7].

In this regard, there is a need to adapt the educational process to the new conditions of distance learning, which involves the assimilation of students not only theoretical material, but also the acquisition of appropriate skills during experiments in the laboratory. Especially urgent is the need to perform laboratory classes by students of engineering specialties, which is important for their future professional activities [8].

In order to solve this problem, we consider it necessary to organize the educational process using mobile applications when performing remote laboratory work. After all, the rapid development of educational computer technologies, including augmented (AR), virtual (VR) and mixed (MR) reality, has stimulated the creation of new approaches to the presentation of educational material and new teaching tools in all areas of education.

The purpose of the article is to present our own experience of developing and using in the educational process a mobile application for teaching micrometer measurements during the relevant distance laboratory work in the disciplines “Interchangeability, Standardization and Technical Measurements” and “Physics” by students majoring in 208 “Agroengineering” and 133 “Industrial Engineering”. The article reveals all the stages of development and description of the application “Measuring parts with a micrometer”, the experience of its use and the results of research on its practical implementation in the educational process during distance learning of students of technical specialties.

To achieve this goal it is necessary to perform the following tasks:

- to conduct a theoretical review of the literature on the issue of performing laboratory work remotely, including through educational information programs;
- to develop a micrometer model in CAD system;
- to develop a mobile application in the Unity game engine;
- to describe the basics of the information and educational program “Measuring parts with a micrometer”;
- to analyze the results of students’ success after studying this topic using a mobile application.

The object of research is the educational information program “Measuring parts with a micrometer” for conducting relevant laboratory work in the disciplines “Interchangeability, standardization and technical measurements” and “Physics” during distance learning of students of technical specialties. The subject of research is the process of development and implementation of this educational program in the educational process of higher educational institutions.

## 2. Literature review

The introduction of information and communication technologies in education has been a subject of debate and controversy among researchers for a long period of time. At the Department of Early Childhood Education of the University of Crete, Papadakis et al. [9] conducted a study to find out whether there are compelling benefits of using tablet devices in early childhood education to implement proposals for educational reform to introduce realistic mathematics education in kindergartens. According to the results of the study, scientists propose the integration of mobile devices with developmentally appropriate applications in kindergarten classes. Researchers note [10] that due to the flexibility and creativity of tablet-type devices, they can act as an active source of data receivers from a set of quite different experimental situations during STEM learning in preschool and early school education.

According to Dotsenko [11], a special mobile application can be considered as an educational game simulator. The main purpose of such a simulator is aimed at the formation of professional competencies in the information and educational environment. The work on the simulator develops professional engineering competencies, includes familiarization with parts and devices, principles of learning to operate complex equipment, installation skills, assembly and repair systems.

Voloshynov et al. [12] showed an educational information system of blended learning. It includes the alternation of traditional and online learning, virtual learning using VR technology and training on simulators. The authors described the results of an experiment on the introduction of VR technologies for the formation of professional competence “operation of rescue equipment”. They noted the better dynamics of acquiring practical skills in using the simulator compared to online learning.

The technology of using 3D models in electrical engineering in laboratory work was presented by Batsurovska et al. [13] and Modlo et al. [14]. In the process of research, the Batsurovska et al. [13] developed 3D models and guidelines for the use and development of computer 3D modeling during laboratory work in the field of electrical engineering.

Kiv et al. [15, 16] note that the use of AR technology allows conducting physical experiments in laboratory work in the absence of the necessary equipment. AR provides the ability to move, rotate, scale 3D models, view them from any angle, combine and separate virtual objects, model processes and phenomena, etc. At the same time, the authors emphasize that most of the available mobile applications and computer programs are limited exclusively to the school physics course.

Semerikov et al. [17] developed a training course “Virtual and Augmented Reality Software Development”. Thus, the researchers solved the problem of developing augmented and virtual reality applications [18, 19, 20]. In [21, 22], we also reviewed the development of mobile AR applications for performing laboratory work on projection drawing and physics.

The possibilities of using ICT in teaching students and pupils were discussed by Kharchenko et al. [23], Stepanyuk et al. [24], Scaravetti and Doroszewski [25], Midak et al. [26], Kovalchuk et al. [27], Ferrario et al. [28], Shepiliev et al. [29], Chiappe [30], Mourtzis et al. [31], Gezgin [32], Striuk et al. [33], Ivanova et al. [34], Katzis et al. [35], Campos-Pajuelo et al. [36], Mamolo [37] and others. The use of educational mobile ICT in the educational process has increased significantly during the quarantine due to COVID-19. Tkachuk et al. [38, 39, 40] conducted a comprehensive study, which included theoretical substantiation, development and experimental testing of the methodology for using mobile technologies in teaching students in quarantine. As a result, a cloud-based immersive learning environment was developed as an open multi-dimensional technological and pedagogical system. This system includes mobile ICT, VR/AR technologies and provides interaction, cooperation, development of university teachers, students and administration in solving educational, technological and scientific problems.

According to Marienko et al. [41], a promising trend in education is the introduction of teaching methods that combine adaptive technologies with VR/AR. Integration of adaptive cloud-based systems, augmented reality technologies and modern pedagogical methods will be an effective solution to the problem of adaptability of the education system.

Burov and Pinchuk [42, 43, 44] believe that the role of research and development in the use of ICT in education remains extremely important. Augmented, mixed, virtual and augmented reality are becoming part of everyday human life in all spheres of activity. But the synthetic virtual environment is not natural for humans and its impact on their mental and physiological processes remains insufficiently studied [45]. The authors believe that the control of operating parameters in AR/VR/MR/XR is important to mitigate cyber-exposure, especially in the learning process, which can take hours of human activity. Therefore, a methodology was developed to assess the impact of AR/VR/MR/XR in the form of short tests with the registration of informative physiological parameters.

Thus, the analysis of literature sources has shown that ICT, in particular mobile applications, are widely used in the educational process: in teaching mathematics in preschool and secondary schools; engineering graphics, physics, chemistry, history and other disciplines of higher education. But, despite this, the issue of using ICTs in remote laboratory work in technical disciplines in the training of future engineers is not widely disclosed. Therefore, this issue is relevant and requires further research.

## 3. Description of the program

During the training of future engineers, an important place is occupied by the acquisition of practical skills in the use of measuring instruments, including micrometers. Students acquire these skills during the laboratory work on the topic “Measuring parts with a micrometer” of the disciplines “Interchangeability, standardization and technical measurements” and “Physics”. This can be realized only through the use of a micrometer in real conditions in direct contact with the tool.

During distance learning, students do not conduct real experiments. Therefore, such work cannot be called a full-fledged laboratory. Despite the fact that students have the opportunity to observe real experiments in video, record and process data, they are not directly involved in the experiment. While watching the videos, students, in fact, observe a demonstration experiment. Obviously, in this version, they are often presented only successfully completed attempts. In real demonstrations of experiments, the teacher can repeat the attempt and explain the reason for failure. In a remote experiment, such an opportunity is available only in online experiments. As a result, there was a need to develop a mobile educational information system that allows the student to independently conduct a step-by-step study of the device structure and the basics of working with a micrometer in real conditions. As a result, it became necessary to develop a mobile educational information program that allows the student to independently conduct a step-by-step study of the structure and basics of working with a micrometer in real conditions.

A micrometer (figure 1) is a tool used to measure the external dimensions of parts, the thickness of sheets and tapes and pipe wall thickness in engineering work and research [46, 47]. It consists of a bracket 1 with a heel 2. In the right part of the bracket, a stem 5 with smooth and threaded guide belts is fixed, which serve as a support for the micrometer screw 3, which has a thread pitch of 0.5 mm. At the curved end of the screw there is a belt on which the drum 6 is seated. Tight connection of the drum with the belt is obtained by screwing the cap 7 on the end of the drum. The rotation of the drum and the micrometer screw 3 is carried out by a ratchet 8, which creates a measuring force within 7 N. To fix the micrometer screw reading, a lock 4 is used.

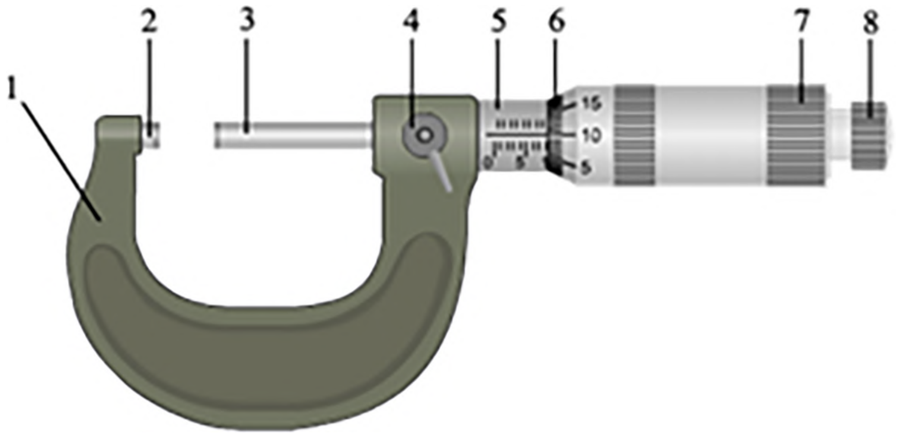


**Figure 1:** Micrometer of MK series.

The development of the mobile educational information program was conditionally divided into stages:

1. Justification of the functionality and interface of the program;
2. Development of an electronic micrometer model;
3. Writing of scripts;
4. Development and compilation of the program in Unity;
5. Approval of the mobile application.

The mobile application was developed as a methodical and practical educational information program. It should have information on theoretical training of work with the micrometer, video instruction and practical simulator of the micrometer. The main screen of the program (figure 2) shows the appearance of the micrometer with the main elements signed. On the right side of the screen there are buttons "Practical training", "Knowledge test" and "Information about authors" to switch to additional scenes of the application. The button "Theoretical preparation" activates the departure of the information panel from the top of the screen.


**Figure 2:** Main program screen.

The object of study of this program is the micrometer itself. Therefore, the development of the program continues with the design of an electronic model of the micrometer. To make an electronic model, you can use various three-dimensional modeling programs. Figure 3 shows the electronic model of the micrometer developed in CAD system Compass 3D. This assembly consists of the following parts: 1 – bracket; 2 – heel; 3 – micrometer screw; 4 – stopper; 5 – stem; 6 – drum; 7 – cap; 8 – ratchet. Each micrometer part is designed as a separate element. The parts are assembled and the model is saved in obj.

The educational information program was developed in the Unity 2021.3.9f1 game engine [48]. To compile mobile applications for the Android system, we additionally installed the latest versions of Android SDK [49] and JDK from Oracle [50].

To layout the main screen of the application (figure 4), create a new scene called "MenuMain-New". In the tab "Hierarchy" load the component "Canvas". This component serves as the basis for placing all the elements of the application. On the "Canvas" add the UI object "Panel" called "PanelMain". As the background image of object "Panel" we set the picture of micrometer model. Using command "Button" we add the menu buttons "Theoretical training", "Practical training", "Knowledge test", "Information about authors" and information buttons of micrometer elements. All buttons are placed as shown in figure 4.

Theoretical information about each micrometer detail is placed in the "ScrollView" com-

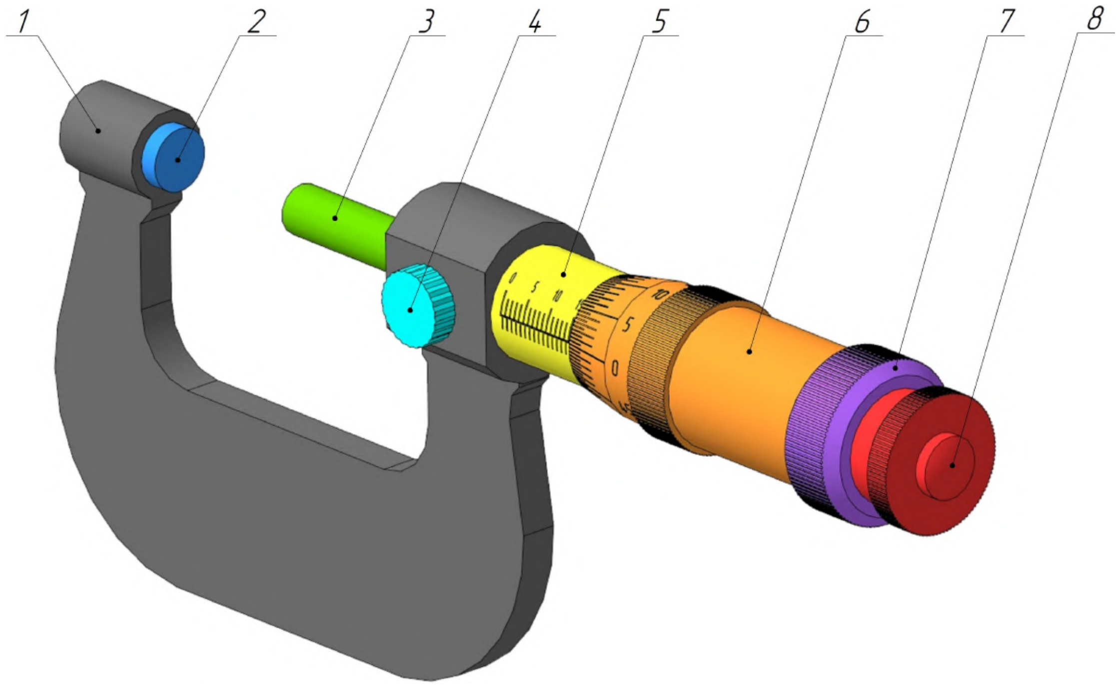


**Figure 3:** Electronic micrometer model.

ponents. The “ScrollView” objects are located at the top of the scene and are invisible to the observer’s eye. The implementation of the effect of “ScrollView” moving from the top to the middle of the screen after pressing the corresponding button is created using the “Animator” component. For this purpose, two animations of departure and arrival of theoretical information were recorded. The “Animator” component was added to each “ScrollView” and the corresponding animation controller was selected. Similarly, the effect of lifting the “ScrollView” objects after pressing the “Back” button was implemented.

Figure 5 shows the final result of the “ScrollViewPiatka” component with information about the “Heel” part. The animation of this object is performed after clicking on the “ButtonPiatka” object called “Heel”. In this case the animation controller is activated and the information panel moves from the top of the screen to the center. When you click on the “Back” button, the animation controller is also triggered to return the panel outside the screen upwards. Similarly, information panels for all parts of the micrometer and the “Theoretical preparation” button are implemented.

To go to the stage of practical training, press the button of the same name on the main screen of the program. Practical training is a training video [51] that explains all the details of working with the micrometer. Figure 6 shows the implementation of this scene on the mobile phone screen. The main part of the screen is occupied by the video. The bottom of the screen shows control buttons to start, pause, stop the video and a slider to rewind it. At the bottom right is the “Back” button to return to the main menu.

Setting the control buttons in this scene is similar to the buttons of the previous scene. The

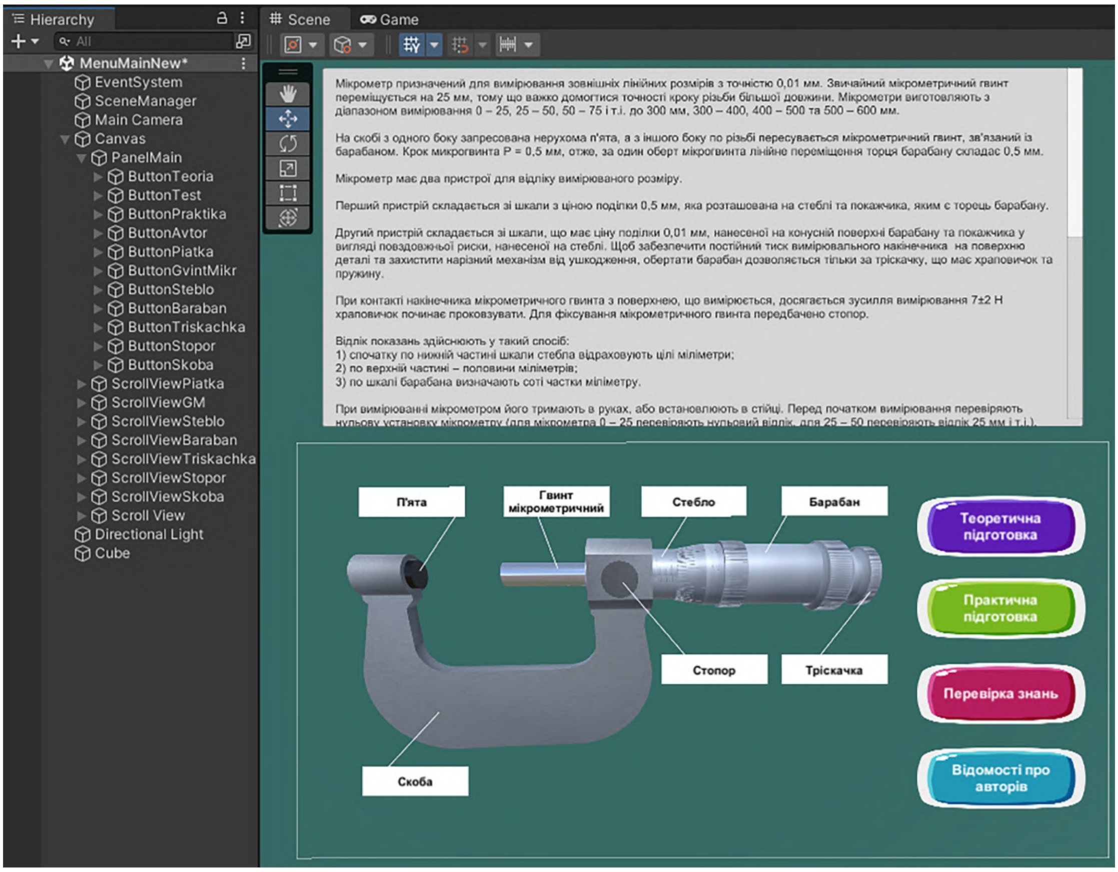


**Figure 4:** Developing the main screen program in Unity.

functional action of the control buttons is implemented using the corresponding script. The main object of this scene is the training video. The video is displayed using the video player built into Unity 2021.3.9f1.

Figure 7 shows the "Knowledge test" scene. Most of the screen is occupied by an electronic micrometer model and a cube model for measurement. The drum is designed as a moving assembly of parts – the drum itself, the cap and the ratchet. It rotates around its own axis and simultaneously moves left or right, i.e. screws or unscrews. During the movement of the drum, the micrometric screw also moves. Thus, the work of the micrometer is simulated. After stopping the drum, you can determine the micrometer readings on the stem scale.

The corresponding script is responsible for the operation of the drum rotation buttons. The operation scenario of the "Screw the drum" button is as follows:

```
public class UserInterfaceButtons : MonoBehaviour {
  public float rotationSpeed = 70.0f;
  public float translationSpeed = 5.0f;
  bool repeatRotateUP = false;
```

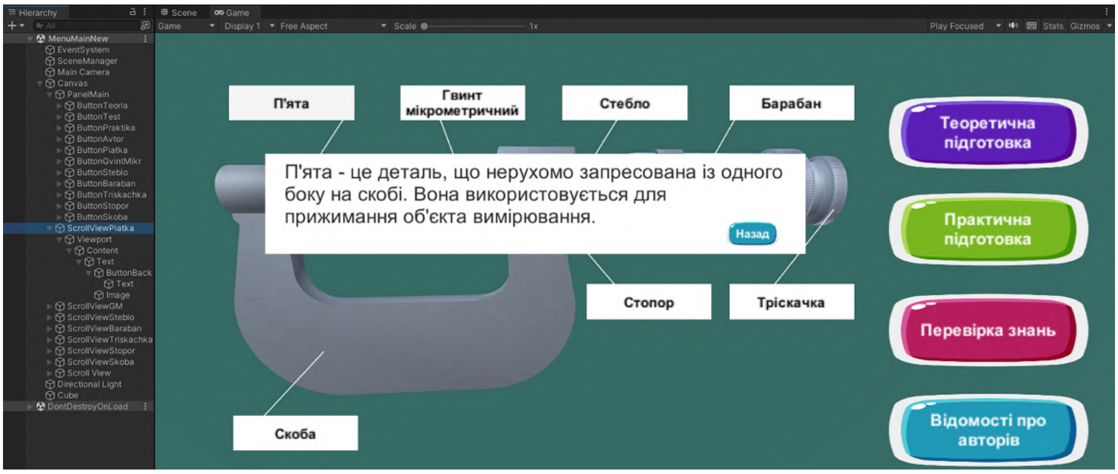


**Figure 5:** Implementation of the component "ScrollViewPiatka".

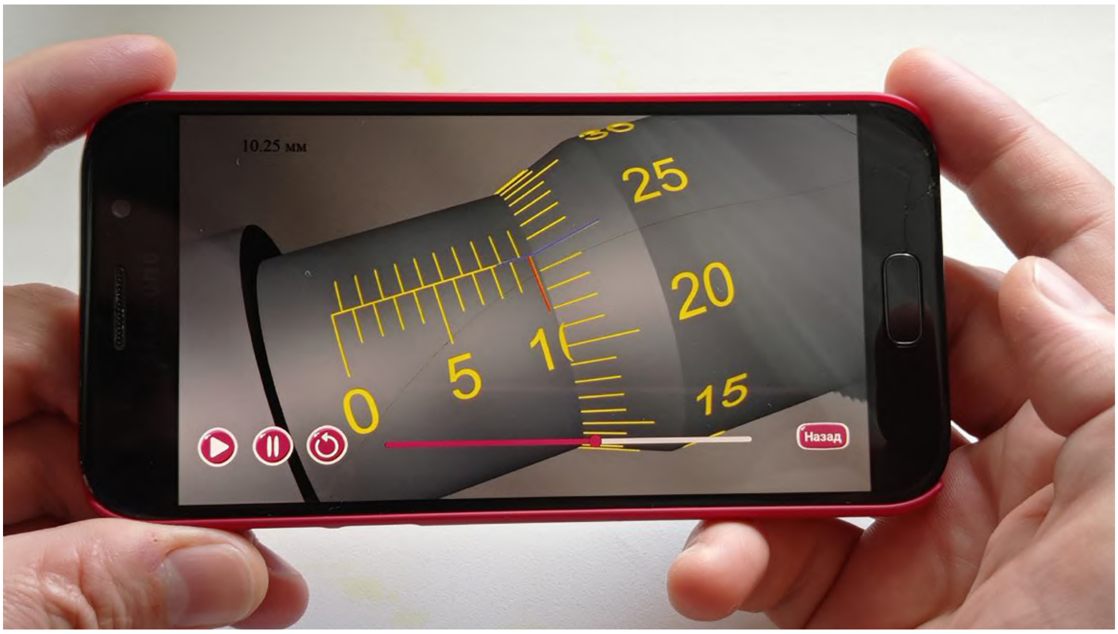


**Figure 6:** The scene of practical training.

```
void Update () {
  if (repeatRotateUP) RotationUPButton();
}

public void RotationUPButton () {
  GameObject.FindWithTag ("baraban").transform.Rotate
                              (-rotationSpeed * Time.deltaTime, 0, 0);
```


**Figure 7:** Scene “Knowledge testing”.

```
    GameObject.FindWithTag ("baraban").transform.Translate
                           (translationSpeed * Time.deltaTime, 0, 0);
    GameObject.FindWithTag ("VintMetrich").transform.Translate
                           (translationSpeed * Time.deltaTime, 0, 0);
  }

  public void RotationUPButtonRepeat () {
    repeatRotateUP=true;
  }

  public void RotateUPButtonOff () {
    repeatRotateUP = false;
    Debug.Log ("Unscrew the drum");
  }
}
```

Writing the script of the “Screw the drum” button, we begin with the introduction of variables: “public float rotationSpeed = 70.0f”, which is responsible for the speed of the rotation process; “public float translationSpeed = 5.0f”, which is responsible for the speed of the translation process; “bool repeatRotateUP = false” – a boolean variable that determines whether the rotation button is pressed or not (by default, this parameter has the value “false”, that is, the button is not pressed).

The “void Update ()” method constantly checks whether the “repeatRotateUP” variable has changed its value to “true”, if so, the “RotationUPButton” public method is triggered. Through this method, the program accesses the GameObject properties of the model and has access to its other components.

The prefabricated drum model used in the program consists of three smaller models that need to be rotated and moved. To do this, we call the “Tag” of the prefabricated model “baraban”. In the code, we write a component for finding tags with the name “baraban” – “FindWithTag (“baraban”)” for their further transformation by the components “transform.Rotate” and “transform.Translate”. Simultaneously with the rotation and movement of the drum, the micrometric screw moves. We assign the tag “VintMetrich” to the screw and search for it for transformation by the component “transform.Translate”.

The public methods “public void RotationUPButtonRepeat ()” and “public void RotateUPButtonOff ()” determine the position of the pressed and released rotation button. To track the button release, the following line was written in the system messages: “Debug.Log (“Screwing finished”)”. A similar script is written for the button “Unscrew the drum”. When the micrometer screw touches the cube, the drum stops completely. This effect was implemented using a trigger.

Figure 8 shows the last scene of the mobile application “Information about the authors”. It shows the participants who were directly involved in the development of the application – from planning the interface to compiling the finished program. Since the application was tested in Poltava State Agrarian University, this tab has an important motivational and encouraging value for both students and teachers-developers.

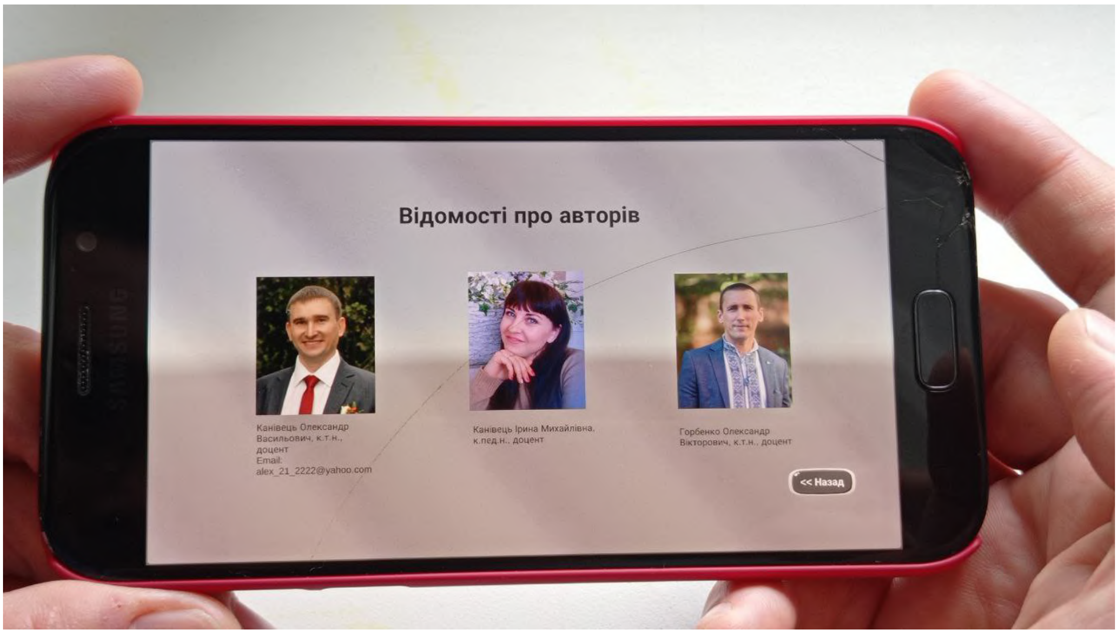


**Figure 8:** Scene “Information about authors”.

Transitions between scenes of the program are implemented using the “SceneManager” script:

```
public class LoadScene : MonoBehaviour {
```

```
  public void SceneLoader (int SceneIndex) {
    SceneManager.LoadScene (SceneIndex);
  }
}
```

This code has a child public class “LoadScene”. The public method “void SceneLoader ()” contains the variable “int SceneIndex”, which makes the script universal for switching between all scenes of the program by setting the variable to the corresponding scene number. When you click on the button, the “SceneManager” command is triggered, which implements the transition to the specified scene number.

## 4. Implementation of the application in the educational process

Performing laboratory work on the topic “Measuring parts with a micrometer” by students majoring in 208 “Agroengineering” and 133 “Industrial Engineering” is of great initial importance. During direct work with the equipment, students acquire practical skills and form the program learning outcomes presented in table 1.

**Table 1**
Program learning outcomes.

| № | 208 Agroengineering |
|---|---|
| 1 | Evaluate and argue the significance of the results of agricultural machinery tests |
| 2 | Reproduce machine parts in graphic form in accordance with the requirements of the design documentation system. Apply measuring tools to determine the parameters of machine parts |
| **№** | **133 Sectoral engineering** |
| 3 | Carry out engineering calculations to solve complex problems and practical problems in sectoral engineering |
| 4 | Select and apply the necessary equipment, tools and methods |
| 5 | Apply means of technical control to assess the parameters of objects and processes in sectoral engineering |

To analyze the research, the data on student performance after studying the topic “Measuring parts with a micrometer” during 2019-2022 on the basis of Poltava State Agrarian University and Poltava Polytechnic College of the National Technical Kharkiv Polytechnic Institute were used. In total, 394 students from different higher education institutions (HEIs) took part in the study.

The study was conducted in three stages:

- the first stage: the analysis of the state of development of the problem in scientific, methodological literature and practical activities of higher educational institutions; substantiation of the research problem; questioning of students;
- second stage: development of a mobile application on the topic “Measuring parts with a micrometer” of the disciplines “Interchangeability, standardization and technical measurements” and “Physics”;

- the third stage: implementation, processing, verification, systematization and generalization of the research results were carried out.

In order to determine the readiness of students to work with mobile applications during their studies, a survey was conducted before the study. In the process of conducting the study, a survey of students was carried out.

The questionnaire contained the following questions:

1. What is the format of classes in academic disciplines during distance learning?
   a) The teacher sends the materials of his lectures for self-study and gives assignments;
   b) The teacher asks to watch video lectures on the Moodle platform and complete assignments;
   c) The teacher conducts lectures, practical and laboratory classes online on the Moodle platform using video communication programs.
2. How do you use your smartphone in the learning process?
   a) As a calculator;
   b) Information search;
   c) View social networks.
3. On which platform is your smartphone built?
   a) Android
   b) iIOS
   c) Windows
4. Do you have experience in using any mobile application, including AR, VR, MR?
   a) Yes
   b) No
5. Are mobile applications used in the educational process of your higher education institution?
   a) Yes
   b) No
6. Would you use a mobile application when studying the topic "Measuring parts with a micrometer"?
   a) Yes
   b) No

As the results of the survey to the first question showed: 94% of the respondents said that the teacher conducts classes via video communication; 1% of students reported that the teacher sends educational materials through messengers, 5% – the teacher asks to view educational materials on the Moodle platform and complete the appropriate tasks. Students' answers to the second question were distributed as follows: 64% of the surveyed students use smartphones as calculators, 17% – to search for educational content, 19% – for correspondence in social networks, including in the classroom. The statistics of answers to the third question showed that 98% of respondents use smartphones with Android system and only 2% – smartphones on iOS platform. Smartphones with Windows mobile system were not used by any of the surveyed students and teachers. Answering the following questions, all students (100%) noted that they have experience in using any AR application, but do not use such applications in the educational process. Answering the last question, all respondents expressed a desire to use a mobile application to acquire practical skills in working with a micrometer.

Thus, the survey of students helped to increase motivation to develop an application for smartphones on Android and iOS platforms. The interview with teachers also showed interest in developing such an application. In their opinion, the application should help to improve the process of distance learning and increase students' interest in learning.

To conduct the study, a sample of students was formed. It included students of specialties 208 "Agroengineering" and 133 "Sectoral Engineering". Upon completion of the study of the topic "Measuring parts with a micrometer" by students, an analysis of their progress during 2019-2022 was carried out.

Students were divided by levels of academic achievement on the topic "Measuring parts with a micrometer" in accordance with a 4-point grading system. Thus, according to the evaluation, the grade "(A)" or "excellent" corresponded to a high level of academic achievement, respectively, the grade "(B, C)" or "good" - to a sufficient level, "D" – to an average level and "F, FX" or "unsatisfactory" – to a low level.

During the second stage, the application was developed. Organizational measures necessary for the practical implementation of the study were also planned. Consultations were held for students and teachers to familiarize them with the features of the application.

At the third stage, the process of implementing the mobile educational information program in the educational process was carried out. For practical work with the program, the compiled application file was placed in the Moodle system of the discipline along with the theoretical material. Thanks to this, students had the opportunity to download this file to their phones and install the mobile application. Thus, this program is a separate complete application for the study of the topic "Measurement of parts with a micrometer", and each student had the opportunity to remotely perform a laboratory lesson independently under the guidance of a teacher.

The results of students' progress were recorded step by step in the journal for further analysis. The summary results of students' performance on the topic "Measuring parts with a micrometer" of the disciplines "Interchangeability, standardization and technical measurements" and "Physics" are shown in figure 9.

In the 2019-2020 academic year, the study of the topic "Measuring parts with a micrometer" was carried out under the guidance of a teacher using laboratory equipment in a specialized laboratory in the presence of students. During the training, students gained practical skills and abilities to use a micrometer. As can be seen from the diagram (figure 9), during this period students had the following performance indicators: excellent – 12.9%; good – 46.2%; satisfactory – 38.7% and unsatisfactory – 2.2%. The qualitative performance is 59.1%.

With the transition to distance learning in 2020-2021, laboratory classes were conducted by teachers in the form of demonstrations of micrometer measurements during video conferences. During this period, students did not have the opportunity to learn the basic principles of working with a micrometer in practice. The level of success of students on this topic is as follows: excellent – 5.4%; good – 42.4%; satisfactory – 45.7% and unsatisfactory – 6.5%. The qualitative performance is 47.8%.

When studying the topic "Measuring parts with a micrometer" in 2021-2022 in the conditions

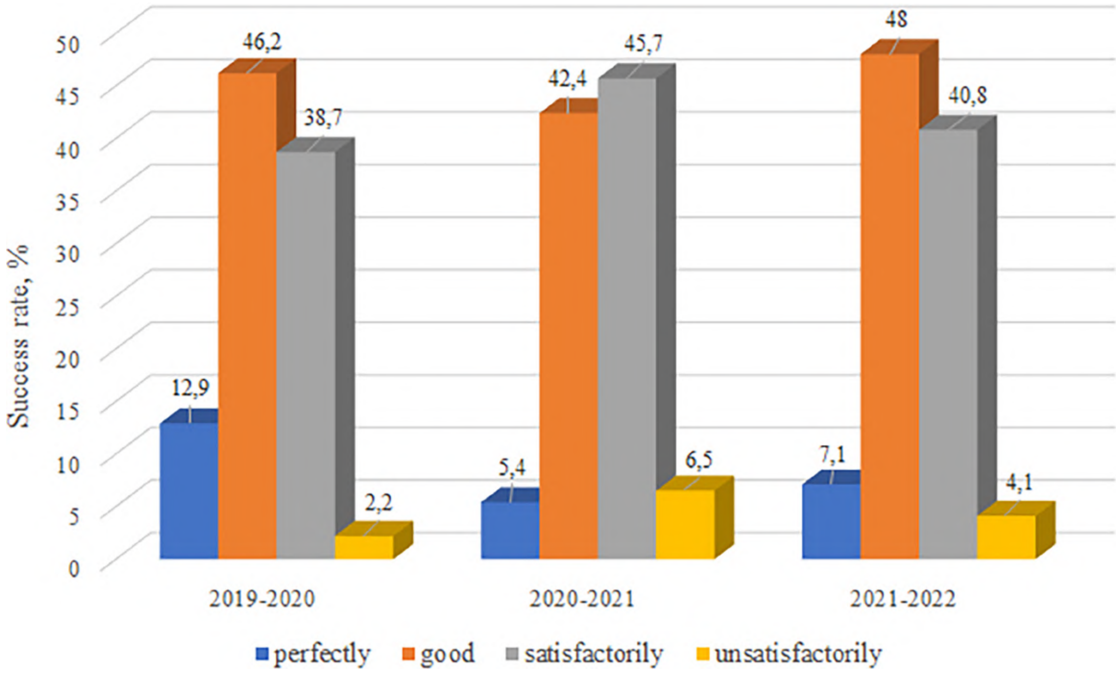


**Figure 9:** Graph of students' knowledge on the topic "Measuring parts with a micrometer".

of distance learning, a mobile application developed by us was introduced into the educational process. Thanks to this application, students independently measured a virtual model with a micrometer, took screenshots of the phone screen with the measurement results and sent them to the teacher for verification. The results of academic performance in this period are as follows: excellent – 7.1%; good – 48.0%; satisfactory – 40.8% and unsatisfactory – 4.1%. The qualitative performance is 55.1%.

Thus, based on the results obtained, it can be concluded that during the study period 2021-2022, the percentage of qualitative performance of students on the topic "Measuring parts with a micrometer" of the disciplines "Interchangeability, standardization and technical measurements" and "Physics" increased by 7.3% compared to the study period 2020-2021.

## 5. Conclusions and perspectives of further research

The transition to distance learning in today's conditions has changed approaches to the basic principles of the educational process, which involves the search for new methods and means of teaching, including the use of ICT. During distance learning, there is an urgent issue of laboratory work, where students must independently conduct experiments on the appropriate equipment and take the necessary indicators. To solve this issue, we have developed and implemented a mobile application on the topic "Measuring parts with a micrometer" of the disciplines "Interchangeability, standardization and technical measurements" and "Physics".

The main object of the laboratory lesson is a micrometer. Therefore, its electronic model consisting of 8 parts was developed in CAD system. The mobile application was developed in the Unity game engine. It contains scenes with theoretical information about the micrometer, a video with its practical use and a scene with an electronic model of the micrometer. The ability to measure a virtual cube is implemented using scripts. To perform remote laboratory work on the above topic, students downloaded the installation file from the Moodle system to the phone and installed the application.

The performance of the program was checked during the laboratory work on this topic. As a result, during distance learning with the use of the application developed by us, the percentage of qualitative success of students in laboratory work on the topic "Measuring parts with a micrometer" increased by 7.3% compared to the same period of distance learning without the use of this application. Thus, the educational process in distance learning, which involves the use of mobile devices, stimulates independent work of students in preparation for the class, increases their cognitive activity, creates conditions for the development of creative abilities.

In the process of using the application in the educational process, a number of tasks have arisen that need to be further addressed: to analyze the operation of the program on mobile phones of different resolutions and screen sizes and make the necessary adjustments; for better visual perception of the material by students, it is necessary to add a video with a real micrometer to the theoretical part of the program; expand the practical part to test students' knowledge, in particular, add parts of different thicknesses for measurement and consider the inverse problem in which the teacher sets the value of the corresponding parameters.

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# Development of the information system for navigation in modern university campus

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**Abstract**

According to the aims, the paper highlights algorithmic, interface and technological solutions for the development of the information system for navigation in university campus. In the process of searching for algorithmic and interface solutions, the peculiarities of the scientific and applied problem of indoor navigation were analyzed, as well as the capabilities of selected analogues of navigation systems implementing similar functions of this subject domain were evaluated. It was concluded that the analyzed analogues, despite their significant functionality, have the set of limitations. The specification of functional and non-functional requirements for the university navigation system was carried out, its architecture was defined as a set of interconnected modules, for the implementation of which appropriate interface and algorithmic solutions were elaborated and covered. The main stages of design and development of the university navigation system in the context of the elaborated solutions are highlighted. The functionality of the implemented system is characterized. It was established that during the design it was possible to overcome the main limitations inherent in similar systems implementing indoor navigation. The results of the system implementation in the educational practice of a national university are highlighted. Feedback from users received during the approbation testified the feasibility of developing and using the information system for navigation in university campus. The prospects for further work are formulated.

**Keywords**

indoor navigation, information system for navigation, university campus, web technologies, problem of the shortest path search



## 1. Introduction

An effective solution to the scientific and applied problem of navigation and orientation in closed spaces is gaining more and more relevance today. Most of the known technological solutions to this problem are aimed at providing informational support for users of different statuses in navigating in buildings with a complex, multi-level and branched structure and topology (office and cultural premises, commercial centers, cultural objects, parking lots, etc.).

Nowadays, easy, quick and reliable navigation in the university campus and its premises requires special attention, because the buildings and spots of a modern university usually have

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a complex structure with a large number of stores, studies, offices and locations of various purposes. Modern universities are important educational, scientific and cultural hubs that are daily attended by a large number of people on different purposes. Applicants, students, participants of competitions and tournaments, new tutoring staff and visitors who are unfamiliar with the location of its buildings and their topology have a need for convenient navigation in the premises of the university, which makes urgent the design and development of the appropriate information system for navigation.

According to Idrees et al. [1], Savchuk and Pasichnyk [2], information and navigation system is an electronic system that provides navigation solving the problem of determining the location of the user, laying a route from one point to another, and also supplementing the above functionality with certain useful information to facilitate users' orientation.

A fairly wide range of information and communication technologies are used to build systems that use information about the user's location inside the premises. In the context of orientation in the university premises, the involvement of web technologies for solving navigation tasks has definite advantages, as web applications do not require pre-installed software (other than browsers, which are usually available in every modern device), do not need to be installed on the device, and enable to use browser cache and PWA technology to provide work offline.

The analysis of scientific and applied sources testifies that there are various technological approaches to solving the problems of orientation [3, 1, 2]. In the context of our research, the focus should be on the analysis of applications providing indoor navigation. Such applications cannot use the capabilities of GPS navigation (like the systems such as Google Maps, 2Gis, OpenStreetMaps, etc.), due to the fact that navigation takes place on a small scale and usually indoor. Therefore, the involvement of GPS navigation technologies will lead to significant errors. Thus, most navigation systems for premises use indoor navigation.

According to the definition, indoor navigation means detecting objects (devices or people) and orientation inside the building using radio waves, acoustic signals, wireless networks (Wi-Fi), infrared sensors, magnetic field, Bluetooth technology or other means [3, 4].

However, the challenge of such navigation is that each building where it is necessary to orient, must have special devices configured to work with the navigation system. According to recent studies, it makes the development of such a system expensive and long-term. It is also pointed out that it causes certain difficulties to its testing, maintenance and expansion opportunities [3, 4, 5, 6].

In addition, researchers note that indoor navigation technologies based on the processing of visual images, as well as QR codes, are underused and unjustifiably forgotten, although they require less investments and have significant prospects for their using for the development of mobile and web applications [1, 6].

Thus, the analysis of the functionality of existing systems for indoor navigation testify their shortcomings and limitations (highlighted below) which cause the necessity of searching new efficient approaches to the design of information system for indoor navigation.

The aim of the paper is to elaborate and cover algorithmic, interface and technological solutions for the development of the information system for navigation in university campus.

## 2. Theoretical framework

Theoretical background of the work is made by the analysis of the (1) the applications which realize similar functions of the subject domain and (2) approaches to solving the mathematical problem of the shortest path search.

To analyze the possibilities of the applications which realize similar functions of the subject domain, there were selected several services that provide orientation in the premises using indoor navigation and implement the following general functions: visualization of the building/floor layout, virtual movement on the floor (viewing parts of the room), providing the user with visual information to simplify perception of the layout and intuitive navigation.

In the progress of the analysis, we focused on the evaluation of the analogues of indoor navigation systems, according to the following criteria: (1) route building functionality; (2) adaptability of the interface; (3) convenience and ergonomics of the interface; (4) quality of visualization of graphic content; (5) design aesthetics; (6) price; (7) technological possibilities for use in devices of various types; (8) possibilities of functionality extension and refining.

According to the said criteria and based on the resources [7, 8, 9, 10, 11], there were discussed the following applications:

- AAU Map (software for navigation in buildings and area of Aalborg University (Denmark));
- Mapsindoors (extension of the MapsPeople platform built on Google Maps technology which ensures the transition from external to internal navigation and its rapid implementation);
- AnyPlace (a free open indoor navigation service that provides location determination using smartphones);
- Situm Mapping Tool (indoor navigation application that accompanies visitors in a specific building to find their way in real time mode);
- BSB Navigator (a smartphone application that navigates through the library on Ludwigstrasse in Munich and uses beacon technology based on smartphone Bluetooth).

The analysis carried out according to the specified criteria proved that despite the significant functionality of these indoor navigation services, they have the following set of drawbacks and limitations. Most of the analyzed analogues are able to provide navigation inside a specific building, but they are not suitable for use in other premises. At the same time, they do not have a sufficiently developed functionality of extension and refinement. They do not provide users with language localization. They are either web services or mobile applications.

These limitations cause the search for appropriate algorithmic, interface, and technological approaches to design of the information system for university navigation. It is also relevant to take them into account when determining the functional and non-functional requirements for the said system.

Apart from this, it is essential to discuss approaches to solving the mathematical problem of the shortest path search, which is going to be solved by the module of navigation system as one of its functions.

The mathematical formulation of the problem can be presented as follows. Let the graph is given:

$$G = (V, E)$$

Here $V$ is a set of vertices, $E$ is a set of edges with given values $c_{ij}$ on each edge $(i, j)$. In terms of our subject area, the vertices of the graph are the various locations of the room and the QR code labels; the edges of the graph are the physical connections between the vertices that allow to get to them. It is necessary to find the shortest path between the selected vertices. This means that it is necessary to find such a path $P$ between the vertices $v_1$ and $v_2$ $P(v_1, v_2, ..., v_n)$, that

$$\sum_{i=1}^{n} C_{ij} \to \min,$$

This problem in the scientific sources is also called "The Shortest Path Problem" (SPP) [12, 13, 14].

There are several different but related problems in which it is necessary to find out the shortest paths in a graph:

1) find out the shortest path from *s* to *t* (one selected pair of vertices);
2) find out the shortest path from *s* to all vertices;
3) search for all pairs of vertices of the shortest paths.

In addition, it is also distinguished the tasks of finding the shortest paths depending on the type of graphs that are received as input data.

To solve the specific practical problem of finding the shortest path for indoor navigation, an appropriate analysis was conducted to select an adequate search algorithm among such well-known algorithms as Dijkstra, Bellman-Ford, Floyd-Warshall, Johnson's and others [12]. The main selection criteria for this problem are the properties of the graph, as well as the execution time of the algorithm. As a result, the two most popular algorithms were chosen: the Dijkstra algorithm and the Floyd-Warshall algorithm.

When selecting between them, the following characteristics were taken into account. The biggest difference between the algorithms is that Floyd's algorithm finds the shortest path between all vertices, while Dijkstra's algorithm finds the shortest path between a single vertex and all other vertices. At the same time, the costs for Dijkstra's algorithm are much higher than for Floyd's algorithm. If Dijkstra's algorithm is run *n* times, on $n$ different vertices, the theoretical time complexity is $O(n * n^2) = O(n^3)$. In other words, when using Dijkstra's algorithm to find paths from each vertex to any other vertex, we get the same efficiency and result as using Floyd's algorithm. Of course, a specific problem can be solved by repeatedly applying Dijkstra's algorithm with successive selection of each vertex of the graph as an initial vertex. However, Floyd's algorithm is more efficient than multiple iterations of Dijkstra's algorithm. At the same time, Floyd's algorithm is much simpler to implement. In this regard, the choice was made in favor of the Floyd-Warshall algorithm.

Let us characterize its characteristics and features. Although this algorithm has the name of Floyd-Warshall, and its appearance in the information space dates back to the early 1960s, it essentially includes the works of previously published work by Roy [15] and is closely related to the Kleene's algorithm, published in 1956 [16, p. 37-40], for converting a deterministic finite automaton into a regular expression. The modern formulation of the algorithm as three nested for-loops was first described by Ingerman [17] in 1962. The Floyd-Warshall algorithm [13] is an example of dynamic programming, and was published in its currently recognized form by Floyd [18] in 1962. This allows to apply it to solve many problems (optimal routing; search for the shortest paths in graphs; transitive closure of graphs; calculation of similarity between graphs and others).

As mentioned above, the Floyd-Warshall algorithm is based on the use of the dynamic programming method, which is an alternative to solving the problem by the brute force method or greedy algorithms. In a general interpretation, this method consists of the following stages:

1. Splitting the task into smaller subtasks.
2. Finding the optimal solution of subproblems by recursive method.
3. Use of the obtained solution for problems to construct a solution to the original problem.

The step-by-step implementation of the Floyd-Warshall algorithm based on the dynamic programming method is shown in figure 1 [12].

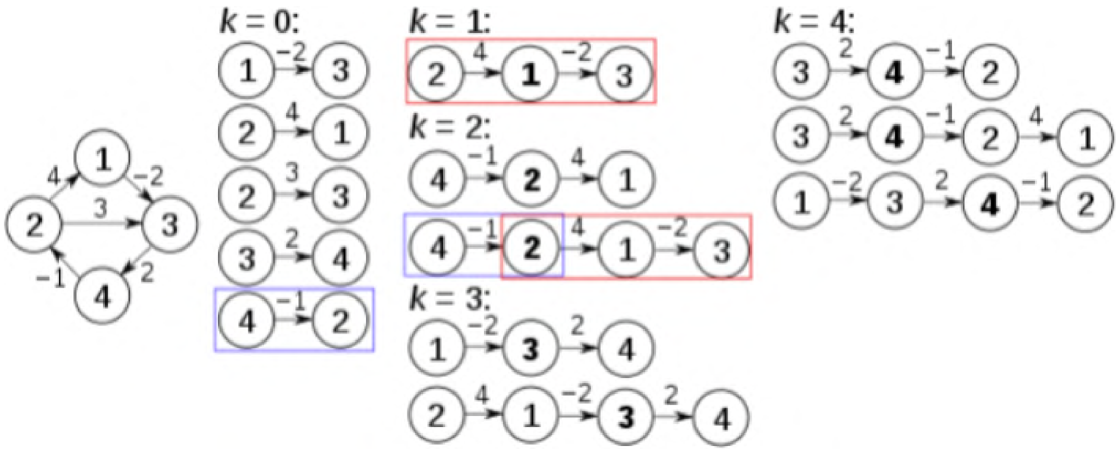



**Figure 1:** The step-by-step implementation of the Floyd-Warshall algorithm based on the dynamic programming method.

Characterizing this algorithmic solution, it is essential to point out that to find out the shortest paths between all vertices of the graph, it is not used brute force (which in fact is an enumeration of all possibilities that will lead to a significant time of the algorithm's operation and takes up more memory), but bottom-up dynamic programming. Therefore, all subproblems that will later be needed to solve the original problem are solved in advance, and then their solutions are used.

The presented theoretical framework is used below for elaboration of proper solutions at different stages of the navigation system design.

## 3. Results and discussion

In the progress of solving algorithmic, interface and technological tasks, the specification of the requirements for the whole information system was carried out by building use case diagram, minding that the system user is a university campus visitor who has the system installed on their smartphone as a web application or a web link to it. There were defined the following intended options for using the system by the user:

- reading of user instructions;
- viewing settings (including changing language localization);
- determining user's location;
- selection of the initial spot (the point that corresponds to the coordinates of location of the physical QR code relative to the building scheme);
- selection of the final spot (any location in the university premises marked on the interactive map of the campus for which the user wants to find out a route);
- receiving the built route between the initial and final spots;
- obtaining an animated visualization of the built route;
- use of a QR code scanner;
- viewing of the current floor plan;
- changing the scale of the interactive map;
- changing the current floor in the map.

The analysis of the use cases enabled to provide detailed specification of the functional requirements for the system being developed. In particular, the set system for navigation has to supply for a user:

- language localization settings;
- selection of existing locations on the interactive map;
- determining the location of the user;
- finding the optimal route from the start spot to the final spot;
- visualization of the obtained route;
- review of the current floor plan;
- free change of floors on the interactive map of university premises;
- changing the scale of the interactive map;
- providing prompts on types of locations;
- adaptability of the interface to different sizes of devices and their graphic settings.

Based on the defined functional requirements, the technological approaches to the design and development of the navigation system were substantiated. In addition, it was taken into account the need to minimize the limitations inherent in the existing analogues of navigation systems emphasized above (lack of the possibility of extension the functionality of the system, absence of adaptation to navigation in different premises and language localization; strict dependence on the platform of operation).

Thus, it was substantiated the involvement of a combination of technologies:

1) Angular as a platform for the development of complex single-page applications, which uses the TypeScript dialect of the JavaScript language to describe interface components using the principles of object-oriented programming [19];

2) SVG.js library which applies the HTML and JavaScript facilities for dynamic generation, processing and animation of vector documents, which is helpful in creating an interactive map [20];
3) reactive programming based on RxJs library [21].

Then, the specification of non-functional requirements for navigation system was provided, which were followed in the progress of development of algorithmic and interface solutions.

Based on the determined functional and non-functional requirements, the general architecture of the system was built as a set of interconnected modules: graphic module, module of detecting user's location, shortest path search module, module of the searched rout visualization.

In the context of interface solutions implemented in the navigation system, a key place in the architecture is taken by its graphic module that plays the role of an intermediary between the user and the entire logic of the application including data processing and execution of complicated algorithms of detecting the user's location and visualization of built optimal route from the start spot to the final spot. Its role is to provide the user with a convenient and intuitively clear interface for interaction with the functionality of the system, as well as visualization of the interactive map and navigation information (names of specific locations, additional marks, etc.). However, analyzing the place of the graphic module in the architecture of the navigation system, it should be emphasized that it provides not only the appearance of the application together with the means of interaction with the user, but also the logic of interaction of the data related to the visual part of the system (map scale factor, position relative to the screen, selected user setting, etc.).

In general, the graphic module can be characterized as a set of interface elements and program code that allows the user to interact with the system, influence its state, and also obtain certain information. In addition, the graphic module implements the visualization of the premises map and the user's route for his navigation. A core component of the graphic module is the interactive map of the current floor for which the said module provides the ability to change the position of the screen regarding the map as well as its scale using the touchpad of the user's device.

When designing the graphic module, its connections with other modules of the system and features of data exchange between them were considered. Therefore, the main task was the realization of data management responsible for the interface and state of the interactive map (scale factor, position of the map regarding the screen, current floor, etc.), which would ensure the correct functioning of the entire system and its further extension. Accordingly, the following approach was implemented for development of the graphic module of the university navigation system:

- implementation of interface control components in the form of a template, styles and controller, html, css and ts files for each component;
- implementation of an adaptive user interface as a grouping of all control elements with additional display logic;
- organization of the business logic of the interface in the form of services that store data and means of their processing, using reactive programming based on RxJs library;
- the organization of utilitarian classes and methods that enable to remove repetitive parts of processing that are not directly related to the logic of the whole graphic module.

In accordance with the offered approach and the above-defined functional requirements for the system, the development of graphic module was implemented as an element of the general architecture of the university navigation system which is responsible for the interface, and generation and processing of interactive map data.

Mockups and prototypes of the system interface were created, along with the design of premises schemes for each floor. Mockups were designed for maximum ergonomic use. On this purpose, the screen was divided into three interactive zones which can adapt to ease of use and accessibility according to the screen size of the user's device, scale, etc. These zones are upper area, right and left ones.

The upper zone is the search zone, where there are interface elements for establishment of the start and final spots for the searching rout. One of the most important functions of navigation system is to determine the user's location and destination spot to enable finding the optimal route or indoor orientation. It is crucial that the system does not track the user's location in real time which is not user's physical location, but close initial spot with a physical QR code. Therefore, there is a need for the user to independently choose the start and final spots for searching and visualizing the route (or only the destination spot without rout). On this purpose, the system interface provides the upper area of the screen, which contains two forms for searching. Each form consists of the poper control elements including (1) an input box where the user can input the name of a start location where the physical QR code is; (2) a drop-down list of hints based on the text entered by the user; (3) search buttons with a magnifying glass icon, which sets the entered point as the start or final spot for the current one, if such exists, and starts the route search algorithm if both points are defined (figure 2).


**Figure 2:** Two forms of the upper (search) zone of the screen.

Control elements of graphic module for changing the position on the map, its scale, etc. are placed in the left area of the screen in order not to interfere with the user's view of the map, to ensure an ergonomic arrangement without accidentally pressing on unnecessary elements with the user's finger when holding a mobile device. This zone of the screen contains map scale controls, map centering button, arrows for changing the floors and the number of the current floor (figure 3).

Graphic module also enables additional functions that are not mandatory and refer to the general control elements of the navigation system. Such control elements are placed into the right zone of the screen and include reference getting button (marked with letter "I"), settings button with a gear icon that opens a window with selection of the interface language localization, a button with a scanner icon that allows to open a QR code scanner and determine the point to which a successfully scanned code corresponds.

The color palette of the system interface was chosen based on the general physical conditions of its using (in well-lit university premises), so the image on the screen should be quite bright and contrasty. The main color of the interface light blue, white, and hues of gray with smooth


**Figure 3:** Interface elements of the left zone of the screen for interactive map control.

and light gradients. Soft shapes of the interface elements and various icons are used to simplify user perception.

The interface solutions implemented by the graphic module of the university navigation system also include the interactive map generation by digitizing floor layout of university premises using the vector image editor Adobe Illustrator. The results of the digitization of the floors layout generated by the graphic module of the system are used for interactive maps building. Thanks to the application of vector graphics, a map was obtained for each floor in the form of a document with its own syntax and rules, which describes the corresponding graphic elements of the image using attributes and formulas. This provides dynamic interaction with such a document using program code, which will allow further adaptation of the input data of the graphic module to extend the capabilities of the system for its application to navigation in different premises. In addition, the use of digitized maps prepared by means of vector graphics gives an advantage over raster analogues in terms of loading speed and image quality.

The interface solutions used in the development of the graphic module ensure the adaptability and flexibility of the whole navigation system, thanks to which it can be used both on computers (laptops) and on mobile devices with the user interface displayed correctly on the device screen. Adaptive design was obtained by taking into account the geometric dimensions of the device, as well as the density of virtual pixels with respect to physical ones, according to [22]. Possible browser and device display scale settings were also regarded.

As a result, the system interface is adapted correctly for different devices (figure 4): on relatively large screen sizes, the application has a fairly convenient interface with intuitive division of the screen zones, preserving the same properties on the screens of a mobile device. On mobile devices with small screen sizes, low pixel density or in portrait mode, the indentation from the edges of the screen and between the control elements, as well as the orientation of the map scale controls are changed to provide enough space for the upper zone elements, map center buttons, and floor switcher buttons to be displayed.

One of the important interface facilities of the system for navigation in a modern university is its implemented language localization, which allows you to select the language (Ukrainian or English) for all of the interface elements and user reference.

Thus, the interface solutions implemented by the graphic module of the navigation system (1) enable interaction with all subsystems (modules); (2) allow to visualize an interactive map of the premises with the user's route built by the proper module of the system; (3) provide the user with a flexible and adaptive interface.

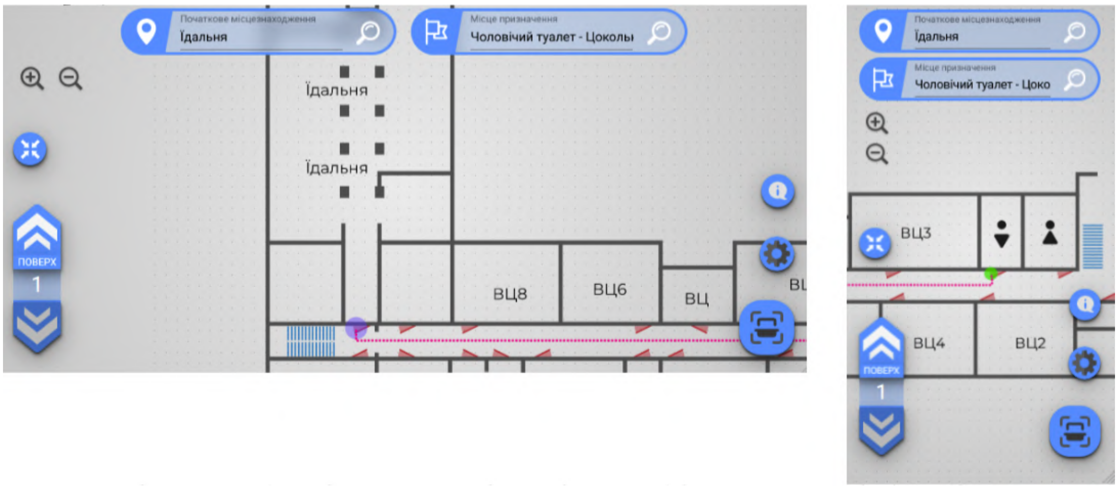



**Figure 4:** The system interface presented on a laptop with a screen resolution of 1366x768 and on an iPhone 5 SE in portrait mode.

The algorithmic solutions for the system design were shaping in the lines of data storing and algorithms realization for user's optimal rout finding. At the stage of design of the database structure, conceptual infological design, logical and physical database design was carried out. They are characterized below, as data structure has a paramount significance and allows to determine basic classes and objects for the system program realization, as well as to opt for proper search algorithms.

It is important to point out that the whole logic of the university navigation system does not require regular and dynamic creation, updating or deletion of data. However, it needs for the storage certain static data that describe the necessary information for the operation of the navigation system (to determine the path, indicate spots, etc.). The use of full-fledged DBMS and a server that requires a regular Internet connection is impractical due to the fact that the system must fully work offline in PWA mode.

In this regard, it was decided to use a local file with serialized data in JSON format. The text data exchange format JSON is built on two universal data structures [19]: a collection of name-value pairs and ordered list of values which in most languages is implemented as an array, list or sequence, vector, and so on. This format was also chosen because it is a fairly compact and valid description of the essence of the JavaScript language, which makes it easy to read such a file that is convenient for human perception. This solution allows to store all the necessary data for the operation of search algorithms locally on the server hosting the system. When the browser accesses the application address, this data will be automatically downloaded in parallel with the web application itself, and when using a PWA, such data will be fully stored on the user's device. In addition, the flexible and hierarchical nature of the database document enables to be developed in accordance to the extension of the navigation system.

Input and output information for the navigation system is represented by documents provided for processing and received as a result, respectively. Input information is data on user location (start spot) and/or final (destination) spot; output information is visualized location of the start spot and/or built route to the final (destination) spot.

When designing the logical data model, it was taken into account that the data are not updated by users, are neither to be regular requested nor to be parallelly requested, and they are stored on the application server itself, so the weight of the data directly affects the speed of initial application loading. Therefore, the data should be stored in a compact format that will be easily processed by the navigation system. It was also taken into account that when dividing the main entity of points by categories, in the case of corridors and stairs (physically existing in the university premises), there will be connections between entities of the same category (each point of the corridor has connections with other points of the corridor, each point of the stairs has connections with other stairs points).

For a more specific consideration of the data structure in the form of entities and relationships between them, in accordance with the method of their preservation, a physical data model was designed, shown in figure 5. At the next stage, the general structure of the system class hierarchy and their semantics was modeled using the UML class diagram, minding the following basic principles of the university navigation system architecture: (1) all business logic of the system, including that related to user interface components, is located in services; (2) utilitarian classes and methods are created to avoid duplication of code that does not generally relate to the business logic of services; (3) all data of a non-primitive type must have interfaces describing them.

In the context of the elaboration of algorithmic solutions in the design of the navigation system, the implementation of the shortest path search module as a component of the integrated architecture of the entire system, whose input data is the location (start spot) and the destination (final spot), is of significant importance.

For the software development of the shortest path search module by the Floyd-Warshall algorithm, an appropriate data structure was created that reproduces the graph on which the search is performed and which can be easily expanded when new vertices and edges are added. On this purpose, the Graph class, its methods and necessary properties were built, which allows adding new vertices, removing and editing them. The common structure of the Graph class is presented in figure 6.

After creating a graph and executing the Floyd-Warshall algorithm (function floydWarshall.ts), a third-party program, code, or service can request the shortest route between the specified vertices of the graph by passing two arguments, “from” and “to”, which are the names of the start and end points search accordingly.

The necessary vertices and their indices are obtained from the Graph class. Next, the presence of a route in the matrix, obtained thanks to the implementation of the Floyd-Warshall algorithm, is checked. If the route exists, it is checked whether the next vertex is the end vertex of the route (then the recursion should stop). If the matrix still has vertices, the recursion continues. During recursion, the proper array is filled with the optimal route. If the route in the matrix does not exist, an empty array is returned, that is, the route between the specified vertices was not found.

In figures below there are selected examples of the results of searching for the shortest route. The result of the search and display of the optimal path from the initial location to the searched location, which are on the same floor, is shown in figure 7. The dashed line shows the found optimal path from one vertex (university dining room) to another vertex (computer laboratory).

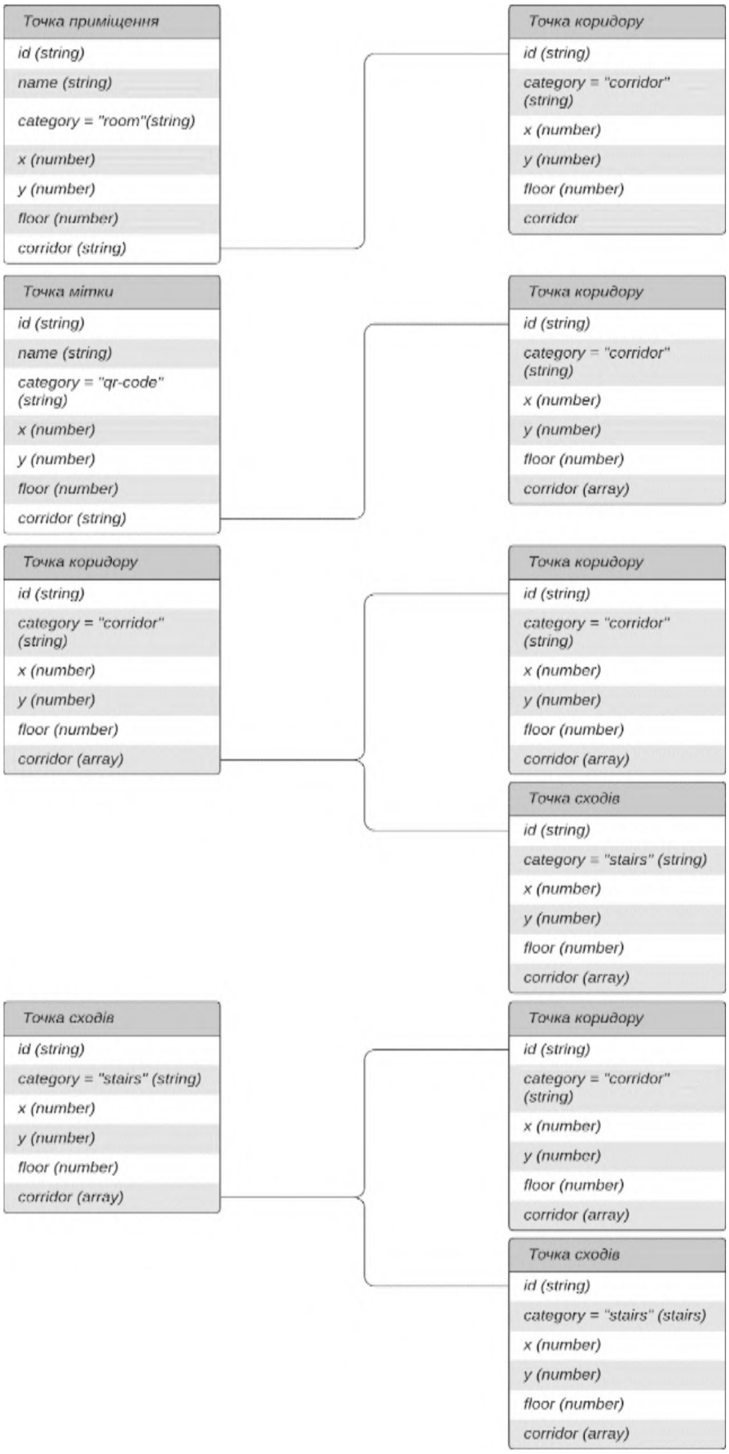



**Figure 5:** Entity-relationship diagram for physical model entities.

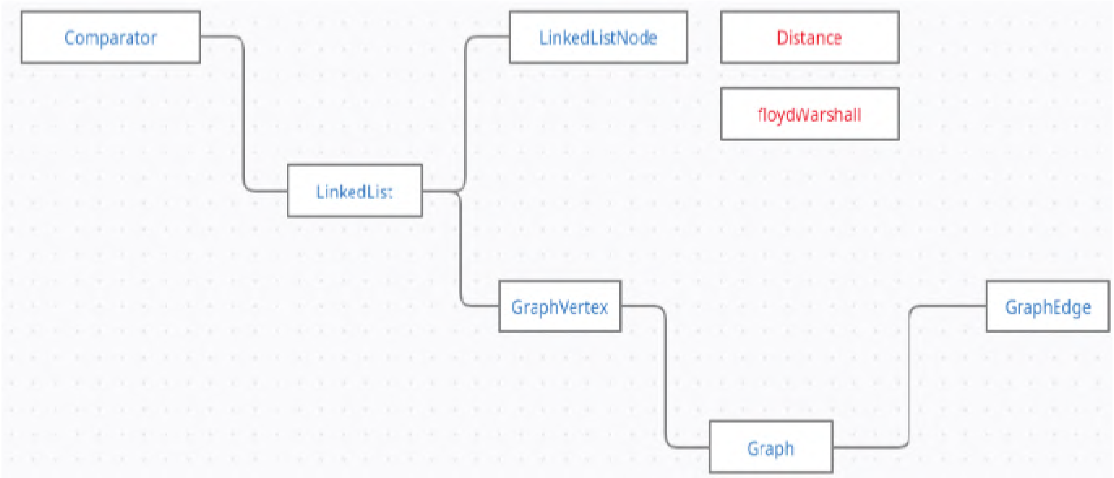



**Figure 6:** The common structure of the Graph class.

It is realized the possibility to search and visualize routes between two university locations on different floors. In figure 8a and figure 8b the dashed line visualizes the optimal route from the start location (the men's toilet, which is located on the basement floor) to the stairs to the second floor (figure 8a) and from the stairs to the final location (lecture room 222 located on the second floor of the main building of the university) (figure 8b).

Implementation of both the interface and algorithmic solutions highlighted above is facilitated by the module of detecting user's location, which works as an intermediary between the core modules of the navigation system in accordance with its architecture.

According to the use case diagram, with the help of the system, a user can determine his location in two ways: choose it from a list of available ones or get it contextually in the university premises by scanning the QR code from the label placed near certain locations.

In order to choose a location from the list, the user has to get access to the navigation system (as a web-application) in one of the ways and find the field "Start spot" on its main screen. After clicking on this field, the user will be able to select a location by performing a search by name in this field or by finding the required item with the desired location in the drop-down list. Determining the location by selecting from a list is used in cases when the user wants to plan his movements in advance and is outside the campus; or the user knows exactly his location and does not need additional help in positioning. This method is implemented through user interaction with the graphical interface of the application.

In order to determine the location using the QR code from the label, it is also necessary to access the application in one of the ways and press the corresponding button on the main screen. After clicking on this button, the QR code scanner window will open. At this stage, the navigation system may send a request for permission to access the camera of the user's electronic device, if it has not been given before. After obtaining permission, the user will see the image from the camera of his device in the scanner window and will have to point it at the QR code from the label. The scanner will decode the code and process the data. Positioning takes place relative to the label with the QR code, so, the user's location is considered to be the

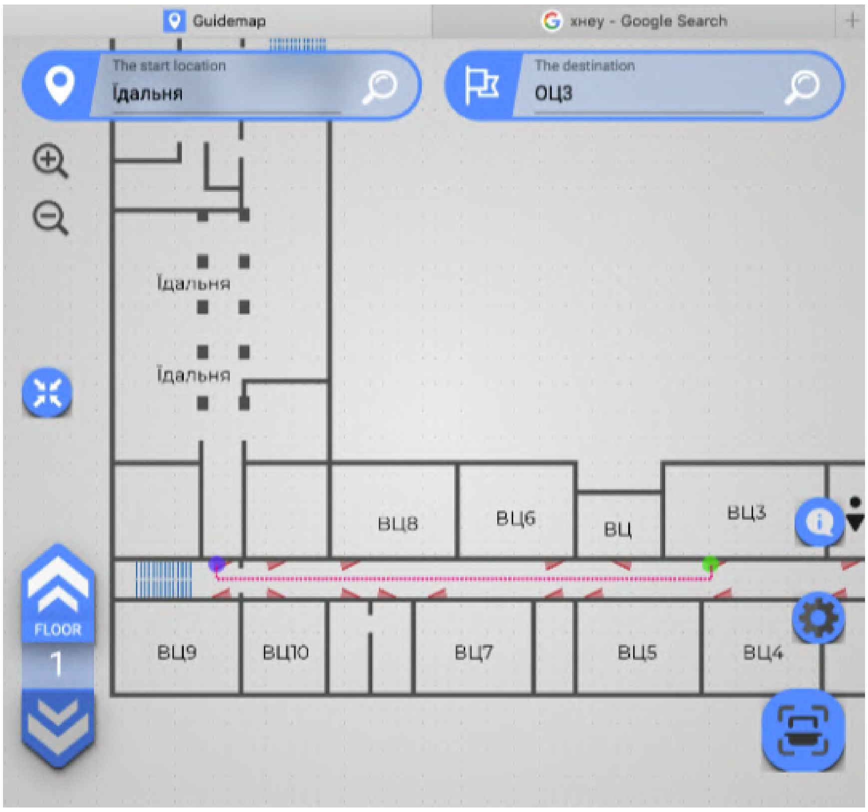


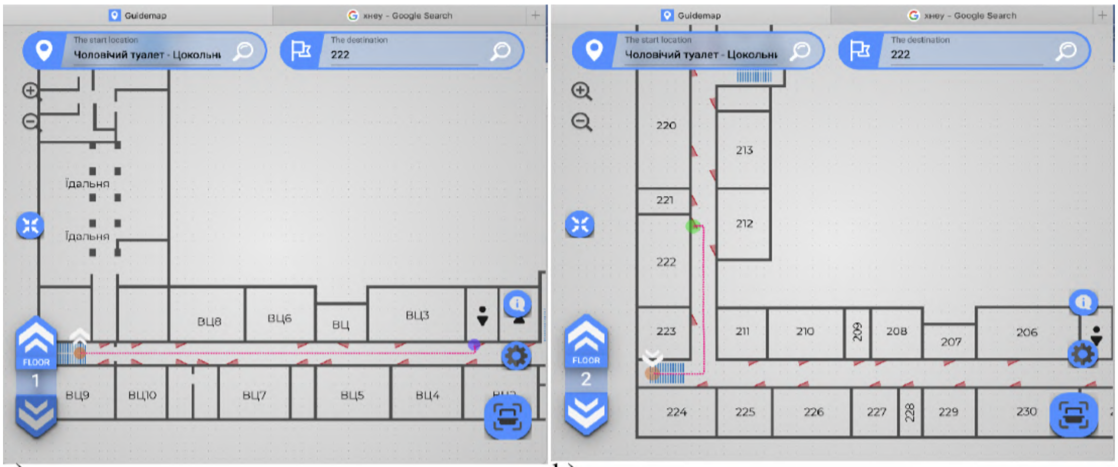

**Figure 7:** Visualized optimal path from the initial location to the searched spot located on the same floor.

physical location of the label itself.

Positioning by scanning the QR code is used in cases when the user is in university campus, but does not know his exact location and needs help in determining it. The expediency of using this method is explained by the fact that among the existing positioning methods (global positioning system, positioning relative to radio or Bluetooth tags), location determination by QR codes of labels has the highest accuracy in combination with the simplest implementation and the lowest cost of implementation [19].

Determining the location is implemented through the processing of data received from the QR code. Each label contains a link to the application with a specific code of the saved point. Thus, a third-party user who does not have the link can gain access to the application by scanning the code with any scanner that is often supplied with electronic devices with operating systems [1, 14]. If the QR code is scanned in the application itself, the stored point code will be obtained from its content and the search will be performed among the stored point objects.

The result of positioning the user with the help of this system module in any of these ways is a point object found in the storage and stored, containing the coordinates by which the location is visualized on the floor plan of the room and which will be used later as the start spot of the route by other modules of the system for navigation in university campus.




a) b)

**Figure 8:** Visualization of the routes between two university locations on different floors.

To ensure the operation of the module for determining the user's location as a part of the navigation system, it is necessary to store certain information on the user's electronic device, namely a detailed plan of the buildings and a description of the university premises. It should contain the coordinates of points of corridors, stairs, labels and locations, as well as concise data about them and their location with respect to each other. Each stored point object will contain a unique code, coordinates on the building's floor plan, floor number, and the point code of the nearest corridor or staircase with which the object is associated.

All saved objects will be divided into several specified categories. Space point objects and QR code labels will have a unique name that can be used by the user to search when selecting a location from the list. All data that will be used in the positioning process must be available at any time for continuous and error-free operation of the module. In order to download the application, the detailed building plan and description of the premises must be stored in some form on the web server and ready to be transmitted over an Internet connection. Once downloaded, all data will be stored in the internal memory of the user's device for use in the positioning process. Thus, for the operation of the module for determining the location of the user, it is necessary to apply the set of all data elements. The module for determining the user's location as a component of the architecture of the navigation system interacts with the graphic module of the system (which provides input data for the module's operation) and the shortest path search module (for which the location module provides input data). So, the module under consideration has a rather complex and specific object-oriented structure.

Characterizing the functionality of the developed information system for navigation in university campus, designed based on the presented technological, interface and algorithmic solutions, it should be emphasized a number of its implemented capabilities. The said system which has both mobile and web versions provides a user with the following basic functions:

- Free viewing of the scheme of the university premises on the interactive map.
- Free change of the current floor of the room.

- Free change of map scale.
- Finding the shortest route from the start spot corresponding to the physically located QR code to any accessible university location.
- Visual prompts about the location of all available locations.
- Change the floor by clicking on the stairs icon, if the path goes through them.
- Scanning of QR codes directly by means of the system.
- Centering the map.
- Localization of the user interface in three languages (Ukrainian, Russian, English).
- Viewing the instructions for the system using and additional information.

The developed navigation system provides a number of additional functions. In particular, the system implements the possibility for users to share a link to an application with an already built route from the nearest point with a QR code to the point of the desired location. This can be useful when organizing mass events, because it provides quick and reliable orientation of a large number of university visitors at the same time.

It is also possible to scan QR codes with third-party software to move to the navigation system. In addition to the location of the QR code itself, a QR code can also include any final spot or an entire route, which significantly expands the areas of use of QR codes for navigation systems users. The developed system can be also installed on a mobile device and used offline if necessary.

Due to the use of vector graphics for the generation and processing of interactive maps of premises, as well as due to the elaborated technological approaches, the developed navigation system has sufficient functionality for extension and refinement, and it is also suitable for adaptation to use in other premises as well.

Thus, thanks to the proposed algorithmic, interface and technological solutions, during the design it was possible to overcome the main limitations inherent in similar systems implementing indoor navigation.

Developed information system for navigation in modern university in its test version has been implemented into the educational practice of the Simon Kuznets Kharkiv National University of Economics. In particular, QR code labels were placed in the relevant locations of the university premises, which enables university visitors to access the system with their smartphones and use the functionality described above (figure 9).

In the progress of the system implementation, feedback from the system users (university visitors of different categories) was collected and analyzed. Users were asked to fill in a survey form evaluating the quality of implementation of both functional and non-functional requirements for the system on a five-point scale. In general, there was received positive feedback regarding the interface quality, the speed of loading the interactive map and the convenience of work with it, the clarity of the visualization of the user's initial location and the destination spot, as well as the correctness of the route proposed by the system. A positive user experience was pointed out by the user-tested ability to share a link to an application with a ready-built route as well as language localization facility. Among the wishes for improving the operation of the system, it was suggested to improve the quality of the animated visualization of the built route between locations on different floors. Feedback from users received in the process

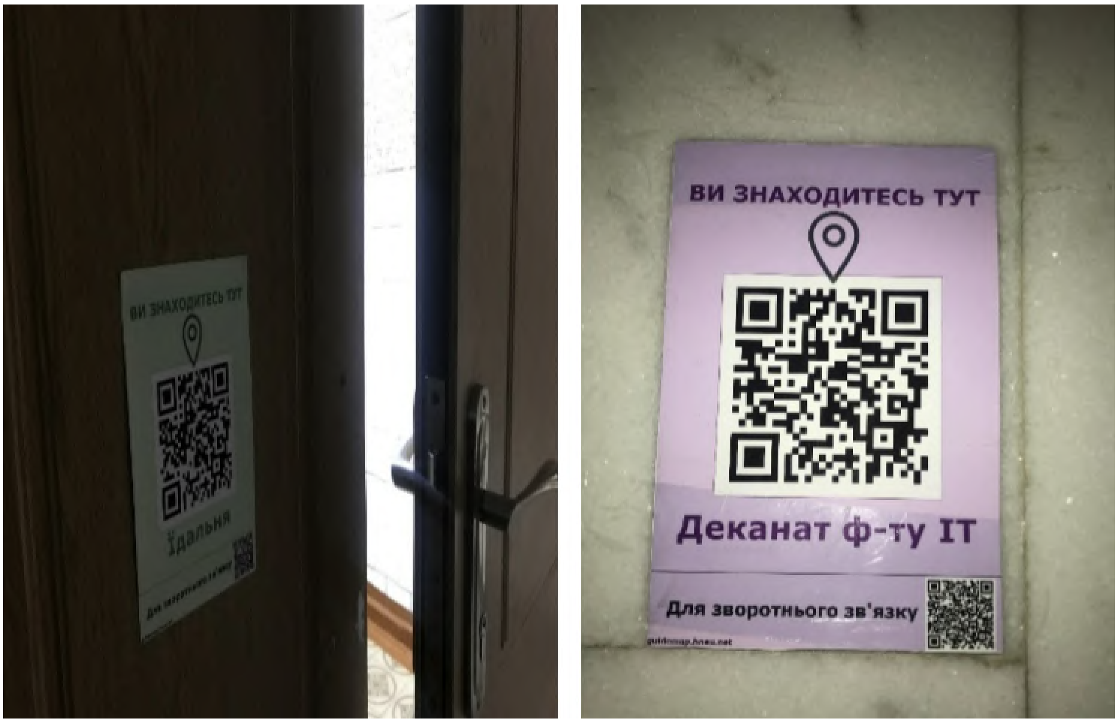



**Figure 9:** QR code labels placed in the relevant locations of the university premises which enable university visitors to access the navigation system, use it, and give a feedback.

of the system implementation testifies the feasibility of its developing for efficient navigation in the university campus. The users' wishes will be taken into account during the extension and improvement of the navigation university system, which is related to the prospects of our work.

## 4. Conclusions

According to the aims, the paper highlights algorithmic, interface and technological solutions for the development of the information system for navigation in university campus.

In the process of searching for algorithmic and interface solutions, the peculiarities of the scientific and applied problem of indoor navigation were analyzed, as well as the capabilities of selected analogues of navigation systems implementing similar functions of this subject domain were evaluated. It was concluded that the analyzed analogues, despite their significant functionality, have the following limitations. They are able to provide navigation inside a specific building, but they are not suitable for use in other premises. At the same time, they do not have a sufficiently developed functionality of extension and refinement. The said applications do not provide users with language localization.

The specification of functional and non-functional requirements for the university navigation system was carried out, its architecture was defined as a set of interconnected modules, for the implementation of which appropriate interface and algorithmic solutions were elaborated and covered. The main stages of design and development of the university navigation system in the context of the elaborated solutions are highlighted.

The functionality of the implemented system is characterized. It was established that during the design it was possible to overcome the main limitations inherent in similar systems implementing indoor navigation.

The results of the system implementation in the educational practice of the Simon Kuznets Kharkiv National University of Economics. Feedback from users received during the approbation testifies the feasibility of developing and using the information system for navigation in university campus.

The prospects for further work are outlined. It is planned to generalize the results of the users' survey, and elaborate the ways of the system improvement and their estimation.

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