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The effectiveness of a practice-oriented approach with smart technology for training future computer science teachers

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ABSTRACT: In the context of the rapid development of information technology and global digitalisation, training highly qualified specialists able to effectively use advanced technologies has become one of the main goals of modern education. This study aims to evaluate the effectiveness of a practice-oriented approach to teaching smart technology among future computer science teachers. Students in their second and third year of study were involved, with a total of 112 participants divided into two groups: an experimental group (n = 57) and a control group (n = 55). The experimental group was taught using a practice-oriented method, which involved performing specific tasks and projects with Arduino, while the control group followed a traditional methodology. For quantitative and qualitative analyses, data were collected through pre- and post-test surveys, as well as pre- and post-assessment of the students. The statistical analysis showed that there were no significant changes in the level of knowledge and skills among the participants in the control group. However, in the experimental group, a significant improvement was observed. This finding confirms the effectiveness of a practical approach to learning smart technologies and highlights the importance of integrating this approach into the educational process to train highly skilled professionals well prepared for the demands of modern digital society.

Keywords: Practice-oriented approach, smart technologies, computer science, teaching training, efficiency assessment, teaching methods

INTRODUCTION

The rapid advancement of information and communication (ICT) and the extensive digitalisation of various aspects of society have necessitated a re-evaluation of teaching methods and a reform of educational systems. Taking into account the rapid technological progress and the digital transformation of various aspects of socio-economic life, it has become imperative to train highly skilled professionals with expertise in the use of modern and sophisticated technologies [1].

Educational systems are facing new challenges due to the development of innovative technologies in the new century, hence the need for graduate specialists who are proficient in these technologies and have been trained in their use. Not only is it important to develop these technologies, but it is also crucial for future specialists to possess both theoretical knowledge and practical skills required to operate in a constantly evolving technological landscape.

Traditional teaching methods, which focus mainly on theoretical knowledge, frequently fail to meet the demands of the contemporary job market, which requires practical skills and the capacity to innovate. Consequently, it is essential for the educational systems to incorporate in-depth knowledge from both a theoretical and practical perspective. One way to acquire such professional competence is through a practice-based approach.

Recently, the importance of smart technologies (ST) has been increasingly discussed, and they are deployed in various fields, including education. Smart technology does not have a clear definition, but it can be called *smart* depending on the characteristics and capabilities of the technology [2]. For example, these technologies include devices that make cities smarter, such as self-igniting light bulbs. Considering smart technology as simple smart devices or objects, one can understand the principles of their work and make them with one’s own hands.

In the context of the curriculum, intelligent technologies are defined as advanced tools, systems and methods that combine artificial intelligence (AI), the Internet of things (IoT), machine learning (ML) and other innovative technologies to enhance functional aspects and improve user experience. These technologies allow the creation of *smart* objects and systems that can make autonomous decisions and change environments. Some examples of these technologies studied in the curriculum include self-connecting lights, smart watches, smart home, smart heating systems, smart alarm system, smart radar, etc. Students have designed and built smart devices and applications using the Arduino platform to control them.

The aim of this study was to assess the effectiveness of a practice-oriented approach (POA) to teaching smart technologies and its impact on students' motivation to enhance their professionalism as future computer science educators. Additionally, the focus was on providing students with in-depth knowledge through practical work, leading to improved learning outcomes. The study employed both quantitative and qualitative data analysis methods to comprehensively evaluate learning outcomes.

The relevance of this research lies in the fact that, in the educational context of computer science, teaching smart technologies is becoming increasingly popular, and one of its key roles is application for effective learning and solving specific problems in practice. There is also a variety of popular and little-known techniques in the learning process. In particular, it is relevant to study the effectiveness of different approaches to learning and teaching smart technologies as this is essential for computer science educators, who aim to ensure that students can correctly apply the acquired knowledge in their future professional careers.

In this study, the following aspects were examined:

- Analysis of the academic results of students who studied through the traditional method and those who completed the ST course using a practice-oriented approach;
- Examination of how practical training in ST contributes to developing basic professional skills, including programming, working with Arduino and creating smart objects;
- Analysis of the impact of practical assignments on students' interest in the course, as well as their participation in the educational process;
- Examination of how the acquired knowledge and skills can be used by students as computer science teachers in their future careers;

The theoretical and practical significance of this research is that it can contribute to the development of education and pedagogy. Specifically, the findings can help to improve the training of future computer science professionals. The results of this study provide valuable insights into the effectiveness of practice-oriented teaching methods for smart technologies and their impact on student learning. These findings can be applied to improve educational programmes and develop innovative teaching approaches, leading to more effective learning outcomes for students. Additionally, they can inform the training of teachers, helping them to better prepare their students for future careers. Ultimately, these improvements have the potential to enhance the quality of education and ensure the graduation of highly skilled professionals.

The main structure of this articles is as follows:

1. Introduction: This section an overview of the field of study, as well as the relevance and importance of the research.
2. Literature review: A review of the literature conducted on practice-oriented learning is presented.
3. Materials and methods: The experimental database, sample set and data collection methods are described.
4. Results: The results of the experiment are presented in this section.
5. Discussion: An analysis of the results is conducted in this section, drawing conclusions from the data.
6. Conclusions: The final section summarises the main findings and provides recommendations for future research.
7. References.

LITERATURE REVIEW

According to Denning, computer science consists of mechanics, design principles and practice [3]. One of the features of computer science is its applied side, which is the application of knowledge in practice. This statement can be supported by a practice-oriented approach.

The application of practice-oriented approaches to the educational process provides many opportunities for both students and teachers. A practice-oriented method, in turn, allows students to not only acquire theoretical knowledge but also apply it in practical situations, which contributes to a better understanding of the materials being studied and the development of professional skills [4]. The formation of an integrated competency structure that corresponds to the flexibility of future specialists' workplaces is a key element of the educational process leading to personal and professional success [5].

According to Berikbol at al, the use of practice-oriented methods is evaluated in the course of research as one of the components of organising independent work and motivating teaching in social, humanitarian and creative arts [6]. In addition, it was shown by Moldabekova and Bitibayeva that the practice-based approach primarily contributes to the development of students' flexibility, skills and creative thinking [7]. The practical application of acquired knowledge forms a broad scientific outlook for future teachers providing training for scientific and pedagogical activities, and an understanding of professional prospects, which is a major motivation. A model based on experience and supporting technology can prepare future graduates for work and social life, making it more interesting and relevant [8][9].

Geert de Haan shows that there are differences between students who use a practice-oriented approach in their research and those who do not use this approach in independent work [10]. It also confirms that this approach helps to strengthen students' knowledge. In practical classes, students exchange ideas, creations and interests with the teacher, other students and members of the group. By applying practice-based learning, students have the opportunity to discuss ways to solve real-world problems through direct communication with the teacher. Critical thinking about effective problem-solving methods can help students evaluate their work and improve their skills. When solving practical problems, students individual and group activities support creative learning [11], which is the basis of modern education systems. Creating projects, especially in combination with teamwork, increases creativity by finding solutions using the most effective algorithms, rather than simply solving tasks in one way.

This literature review shows that the integration of smart technologies and a practice-oriented approach to learning has meaningful potential to improve the quality of education. However, in order to successfully implement these methods, it is necessary to consider the challenges associated with their implementation and to continue research aimed at optimising educational practice.

The next chapter discusses research methodology aimed at evaluating the effectiveness of a practice-oriented approach to teaching smart technologies to students of computer science.

MATERIALS AND METHODS

For the study, students from the second and third year of the educational programme 6B01511 - Computer Science at *L.N. Gumilyov* Eurasian National University (ENU, Astana, Kazakhstan) and 6B06104 - Computer Science at Toraighyrov University (TU, Pavlodar, Kazakhstan), so those who study computer science at higher educational institutions were selected. The selected students were divided into two groups: an experimental group (n = 57, 51%) and a control group (n = 55, 49%). As an experimental approach, a practice-oriented course was conducted for the experimental group, while the control group followed a traditional educational process at the TU.

Prior to the experiment, the educational programmes of the universities had similar content based on the study of basic computer science concepts, theoretical foundations and basic programming skills. Before starting the experiment, questionnaires were collected from both groups. The experiment lasted seven weeks and was conducted off-line. For seven weeks, the course included solving various practical tasks, which were divided into three levels of difficulty: low, medium and high. This approach allowed students to gradually deepen their knowledge, starting with basic tasks and moving on to more complex ones. Tasks for each level were developed with indications of the stages, equipment connection, and use of diagrams and flowcharts that reflect the logic of software. Finally, students were engaged in project work based on their acquired knowledge.

The teaching of ST at the TU was mainly carried out using a traditional approach. As part of the educational process students mastered the theoretical aspects of ST, such as artificial intelligence, the IoT and ML through lectures and seminars. The practical component of the programme included performing tasks on on-line platforms (Tinkercad), which helped to develop the basics of programming and modelling smart objects in a virtual environment. In addition, a limited number of works were done with hardware components, including Arduino.

The ENU used a practice-oriented approach. As part of the experiment, students performed practical tasks to create smart objects using Arduino. These tasks were aimed not only at acquiring technical skills but also at solving specific tasks that contribute to the development of analytical and creative thinking. This is because, in solving the same problem, students can choose not only one method but also various solutions at their discretion, which allows them to create accurate prototypes of smart objects according to their preferences. The practical tasks had various difficulties, which ensured a step-by-step development of the main aspects of working with ST.

At the basic level, students studied the connection of sensors and their integration with Arduino, which allowed them to master the basics of working with equipment. At the average level, the tasks were related to using IoT technologies, including connecting devices to the network, exchanging and collecting data. These tasks allowed students to understand the principles of the IoT and its application in smart systems. At the advanced level, students developed mobile applications for managing intelligent objects and integrated artificial intelligence elements to create functional solutions and solve practical problems.

Students in the experimental group were provided with the Advanced Arduino Starter Kit UNO R3 to complete tasks, as additional sensors were provided depending on the type of work. Choosing Arduino was firstly due to its accessibility, and secondly because projects created with it provide an opportunity to delve into technical knowledge.

Arduino oriented tasks are also ideal for creating simple smart devices, objects and control systems [12]. They allow students to work more deeply with microcontrollers and electronics, giving them a solid basis for creating projects in the field of smart technology. The structure of the pilot training project can be seen in Figure 1 and Figure 2.

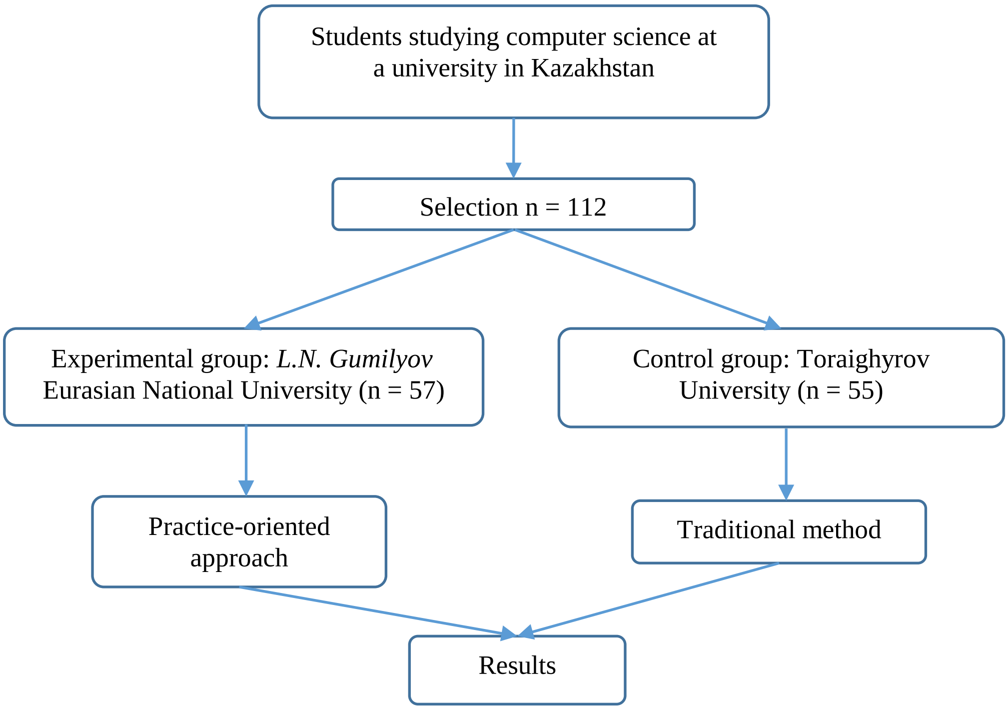

Figure 1: Design of the pilot training project.

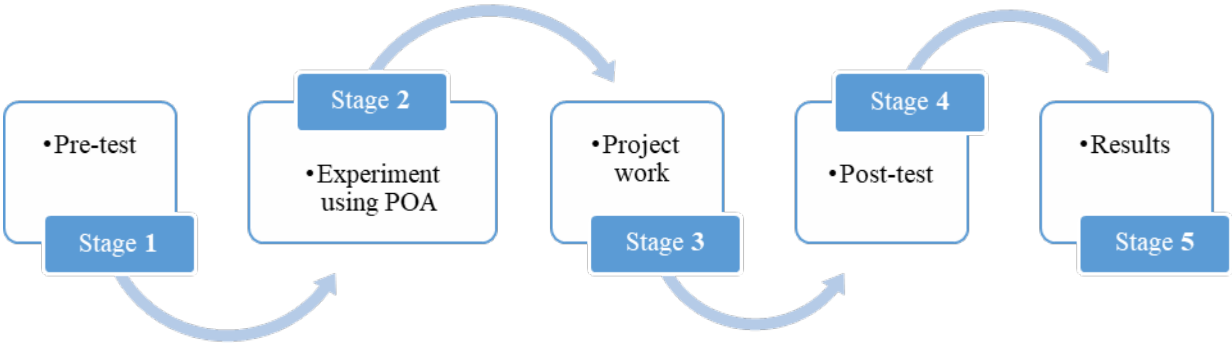

Figure 2: Experimental educational process.

Quantitative and qualitative data were collected in order to determine the impact of the practice-based approach to teaching smart technologies on students' knowledge level. To obtain quantitative data, the average grades of students in both groups before and after the experiment were calculated. For qualitative results, survey data before and after were compared. A 5-point Likert scale (1 - very low, 5 - very high) [13] was used for the survey questions, which were asked both before and after the experiment. This was based on the assumption that a 5-point scale was effective for evaluating students' responses. The questionnaire included ten questions about students' knowledge, skills and motivation. Due to some semantic similarities between questions some were excluded, leaving only seven questions included in this study.

MS Excel and IBM SPSS Statistics were used to analyse the data from the experiment. A *t*-test was applied to the quantitative data to compare the averages between the two groups before and after the experiment. For the qualitative data, a Pearson x^2 test and Fisher's exact test were used to compare two independent samples. The aim of these analyses was to test the following hypotheses:

$H1_0$ - There is no difference between the before and after survey responses from students at Toraighyrov University (control group).
$H1_1$ - A difference is observed between the before and after responses from the same students at Toraighyrov University (control group).
$H2_0$ - No difference exists between the responses from students at *L.N. Gumilyov* Eurasian National University (experimental group) before and after the experiment.
$H2_1$ - A significant difference is found between the responses of students at *L.N. Gumilyov* Eurasian National University (experimental group) before and after the intervention.
$H3_0$ - No difference is observed between students of *L.N. Gumilyov* Eurasian National University (experimental group) and students of Toraighyrov University (control group)
$H3_1$ - There is a significant difference between students of *L.N. Gumilyov* Eurasian National University (experimental group) and students of Toraighyrov University (control group).

RESEARCH RESULTS

The content of the survey and the rating scale used before and after the experiment are presented in Table 1.

Table 1: Questions asked in the questionnaire.

Question	Very low - low - medium - high - very high
	1-5
Q1 - Evaluate your knowledge and skills in working with Arduino.	
Q2 - How would you rate your programming skills?	
Q3 - How useful are practical tasks in understanding theoretical concepts?	
Q4 - How would you rate your proficiency in using sensors?	
Q5 - How confident are you about your knowledge and ability to work on projects related to smart technology?	
Q6 - How motivated are you to learn and develop your skills in the area of smart technologies?	
Q7 - How confident are you about applying your knowledge in real-world situations?	

The survey results presented a mixed picture regarding the impact of the experimental exposure on average values. Nevertheless, the growth rate can be seen in the survey findings. This is particularly evident in the experimental group. The data on the growth dynamics and standard deviation for each group are presented in Table 2 and Figure 3.

Table 2: The average value and standard deviation of student learning outcomes.

Question	Control group (n = 55)				Experimental group (n = 57)			
	Mean pre-test	Mean post-test	SD pre-test	SD post-test	Mean pre-test	Mean post-test	SD pre-test	SD post-test
Q1	1.87	2.58	0.84	1.07	2.12	3.54	1.14	0.80
Q2	2.91	3.09	1.09	1.09	2.91	3.89	1.11	1.09
Q3	3.04	3.09	1.12	1.09	3.11	3.56	1.13	1.05
Q4	2.93	3.04	1.15	1.11	3.09	3.53	1.11	1.02
Q5	3.76	3.53	1.04	1.17	3.86	4.32	1.06	1.02
Q6	2.76	2.95	1.02	1.00	2.88	3.89	0.95	1.09
Q7	3.76	3.09	1.04	1.09	3.86	4.23	1.06	0.93

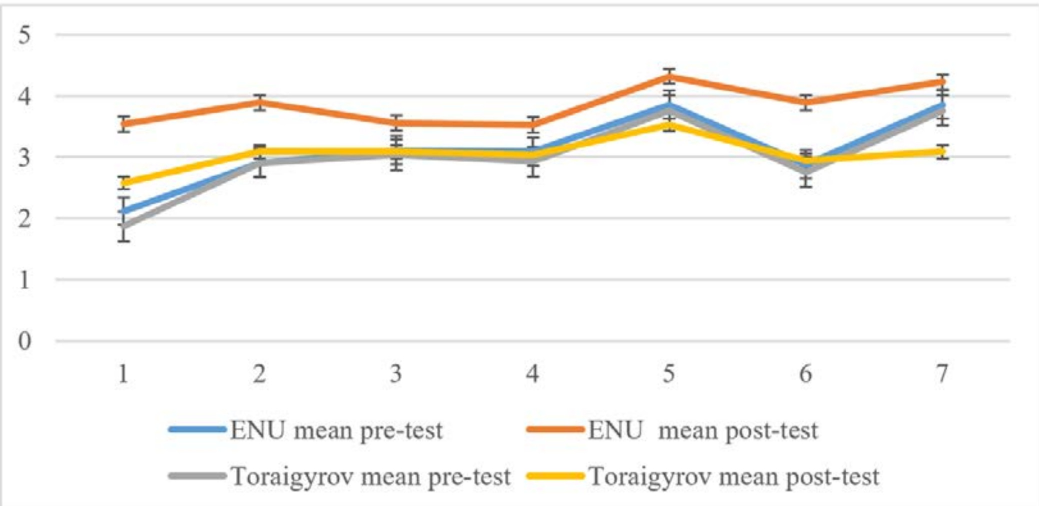

Figure 3: Dynamics of the pre-test and post-test.

The results of the statistical analysis show differences in the level of knowledge and skills between the control group and the experimental group during the pedagogical experiment that aimed to evaluate the effectiveness of a practice-oriented approach to teaching smart technologies. These differences are also reflected in the grades awarded to students at the end of the course, as well as in the results obtained before the experiment began. Table 3 and Figure 4 below provide statistical information on the results and differences between the experimental and the control group.

Table 3: Statistical data regarding the results and differences between the two groups.

Group	Pre-test	Post-test	*p* - meaning	*t* - test
Control group (n = 55)	76.31 ± 10.38	79.87 ± 10.29	0.078	-1.799
Experimental group (n = 57)	81.53 ± 7.32	88.30 ± 5.39	< 0.001	-5.833

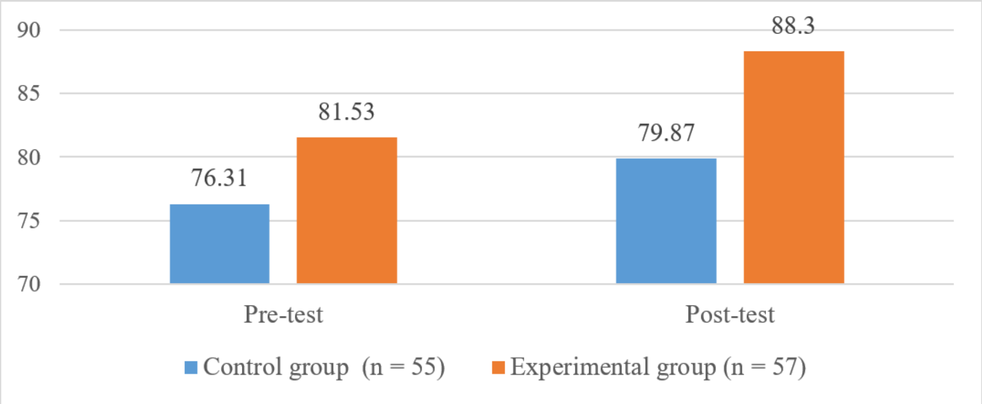

Figure 4: Results of the control and the experimental group.

In the control group, where traditional teaching methods were employed, the results demonstrated that the change in knowledge and skill levels was not statistically significant (t = -1.799, p = 0.078). Although the average values in this group increased slightly, this growth was not statistically meaningful. On the other hand, in the experimental group where a practice-oriented approach was implemented, there was a noticeable improvement in students' knowledge and skills levels (t = -5.833, p < 0.001). These results demonstrate that the practice-based approach has been effective in enhancing educational outcomes.

DISCUSSION

As a first step, the authors compared the answers to the students' questionnaires. Table 2, shown above, presents the results of a survey for students using Google Forms. Before and after the pilot course, a questionnaire based on the same survey was completed to determine the impact of a practical approach on changes in students' self-assessment of their knowledge, skills and motivation. Feedback was very successful, with all students who participated fully responding to both the pre- and post-surveys. The results were obtained from surveys with students at *L.N. Gumilyov* Eurasian National University (experimental group) and students of Toraighyrov University (control group).

Through Q1, Q2 and Q4, the students' technical skills were assessed, and through Q5 and Q7 their confidence in applying these skills in real-world conditions was assessed. Questions such as Q3 were specifically designed to assess the perceived impact of teaching methods on students understanding of theoretical concepts through practical assignments. This allowed the authors to compare the effectiveness of the practice-oriented approach implemented at the ENU with the traditional methods used at the TU.

Prior to the experiment, many students showed interest in the course, expecting that it would help them gain practical skills which would be useful in the future. However, some students expressed distrust in their programming and technical skills. After completing the experiment, most students in the experimental group noted that the course exceeded their expectations and emphasised the practical value and attractiveness of the course. They stated that it helped increase their motivation and confidence, especially among students in the experimental group and this was reflected in their responses to questions (Q6 and Q7) in the open-ended survey. When students are confident in their knowledge, their self-confidence also improves.

It was noted that the use of a practice-oriented approach to studying smart technologies also contributed to improvement in students programming skills (Q1, Q2, Q4). This was due to the fact that students learned how to program the basic principles of using the C/C++ programming language for microcontrollers, Arduino libraries, write and configure codes to perform tasks using a microcontroller, connect wireless networks (Bluetooth, WiFi) to connect devices, work with power supplies and connect external components. Some students, after completing tasks and creating smart objects, independently selected the necessary equipment to solve real problems and wrote the code themselves.

As a result, students in the experimental group showed a high appreciation for the practice-based approach, emphasising the importance of practical tasks in understanding theoretical concepts and applying knowledge in practice (Q3). Creating simple and medium-sized prototypes of Arduino-based devices, by solving practical problems, installing teaching devices to perform specific tasks (temperature measurement, motor control, lighting, turning on/off motors, automation, etc), designing interactive systems, working with various models (RFID, GPS, GSM, camera, display, and so on), and also having learned how to combine several modules to create complex systems, were their achievement. All this knowledge helped the students to successfully complete the project work at the end of the experiment.

Project work makes a significant positive contribution to students' academic performance and forms basic skills, such as critical thinking and ability to perform problem-solving actions to solve real-life problems, depending on the purpose of the project [14][15]. The tasks of the project work require students to conduct in-depth analysis and comprehensive work. There may also be situations that require extracurricular discussion due to a lack of classroom hours to complete project work.

Another features of project work is that students become more attracted to working outside of school hours. Because in some cases, students can clearly express their thoughts outside the classroom and not in the classroom [16]. In the case of such communication, students can actively promote, discuss and make adjustments to their opinions. This forces students to implement the practical knowledge gained in the classroom at a different time. During project work, they acquire communication skills between team members, important skills for future teachers, such as timely completion of work, leadership. This can be confirmed by the results of Q5.

The quantitative data from the study revealed different outcomes among students who participated in the practice-based approach and those who received traditional teaching. The statistical analysis supported the $H1_1$ hypothesis, indicating that the use of traditional teaching methods for smart technology was not significantly related to increased student knowledge (t = -1.799, p = 0.078). In contrast, the group that used the practice-oriented approach demonstrated a progress in knowledge and skills (t = -5.833, $p < 0.001$). These findings supported the $H2_1$ hypothesis, suggesting that practice-based learning led to a substantial enhancement in student performance. The data also showed that traditional methods had a slight impact on the average student score (increasing from 76.31 ± 10.38 to 79.87 ± 10.29).

On the other hand, the experimental group's results confirmed the $H3_1$ hypothesis, demonstrating the effectiveness of the practice-oriented approach by showing the dynamics of the increase in the average level of educational skills (from 81.53 ± 7.32 to 88.30 ± 5.39). This difference was observed between students at *L.N. Gumilyov* Eurasian National University (experimental group) and students at Toraighyrov University (control group). These results supported the hypothesis that the practice-oriented method has a positive impact on the assimilation of knowledge and its practical application. However, it is important to note that the use of a practice-oriented approach in education does not always guarantee a beneficial outcome. It requires specific conditions to achieve positive results. This means that the process of learning may depend on various factors, such as the organisation of training, the choice of software and hardware, and the order of practical tasks.

After analysing the results of the study, the authors have summarised the following: Learning using a practice-oriented method allows students to understand theoretical and practical aspects of intelligent technology, to learn how to design and implement smart systems based on specific examples and projects, as well as it prepares them for solving specific problems in computer science. In addition, students will gain useful experience and skills recognised by academic institutions that will improve their employment prospects in the future.

CONCLUSIONS

This project, which involved 112 future computer science teachers from two universities in Kazakhstan, confirmed the effectiveness of a practice-oriented approach to teaching smart technologies based on the results obtained. The application of this approach, including the execution of specific tasks and projects, led to a considerable improvement in the knowledge and skills of students in the experimental group compared to those in the control group who studied using traditional methods.

The study of smart technologies involves creating smart objects with one's own hands to solve real-world problems, such as understanding how advanced technologies operate in modern information systems. Such practical tasks allow students to analyse problems, choose appropriate tools and develop innovative solutions. This approach not only develops technical competence, but also prepares future computer science teachers to apply these methods in their classrooms, educating a new generation of technically savvy teachers. Conclusively, this study highlights the value of practice-oriented approaches to teaching smart technologies and emphasises the necessity of additional research and financial support to advance this area of education.

Implications for educational practice:

1. Educational institutions should consider the possibility of introducing practical methods of teaching ST to improve the quality of education and train highly qualified specialists.

2. When implementing smart technologies, educational institutions must create conditions that encourage active student participation and motivation to learn, with the necessary hardware and software - i.e. access to the required resources.

3. It is important to continue researching the effects of a practice-based approach to teaching and learning smart technologies. This will help expand knowledge about the capabilities of smart technologies and develop effective methods for their application in educational settings.

In conclusion, this study highlights the importance of a practice-based approach to teaching intelligent technologies, which provides students with the knowledge, skills and confidence to apply their expertise in the real world. This emphasises the need for continuous research and innovation in teaching methods to meet the challenges of the digital future.

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BIOGRAPHIES

Madina Yermaganbetova, is currently a candidate of pedagogical sciences, and an associate professor in the Department of Computer Science of the Faculty of Information Technology at *L.N. Gumilyov* Eurasian National University, Astana, in the Republic of Kazakhstan. She graduated a specialist of mathematics and informatics from Omsk State Pedagogical University, Omsk, Russia, and achieved a degree of candidate of pedagogical sciences in 1999 and 2011, respectively. Her research interests include informatisation of education, development of educational programmes, continuity of education, methods of teaching, to name a few.

Akerke Dildabek, is a doctorate student in the Department of Computer Science of the Faculty of Information Technology at *L.N. Gumilyov* Eurasian National University, Astana in the Republic of Kazakhstan. From 2019 to 2021, she studied in the Master's programme named *Smart City Technologies* at the same university and received a Master's degree in pedagogical sciences. During her studies, she focused on developing software solutions for smart technologies. Currently, she is strongly involved in research on the teaching of smart technologies in education.

Ainur Tokzhigitova is presently a senior lecturer in the Faculty of Computer Science at Toraigyrov University, Pavlodar, in the Republic of Kazakhstan. In 2023, she completed her doctoral studies, the subject of which was related to the methodology of using gamification technology in the educational process. Her current focus is on the problems of informatisation of education, as well as alternative methods of evaluating learning outcomes.