Embedded Selforganizing Systems

Innovative Teaching Methodology for Developing Digital Competence in Future Engineering Pedagogues

Rasulova Nasibakhon Yusufjanovna
Tashkent University of Information Technologies named after Muhammad al-Khwarizmi
Tashkent, Uzbekistan
ORCID 0000-0002-0420-8306

***Abstract*-- This article focuses on the development of a methodology aimed at fostering the digital competence of future engineering pedagogues through the utilization of digital tools. With the digital transformation of the education system, it becomes imperative to adapt the methods of working with educational stakeholders. The creation of a digital educational environment involves equipping organizations with modern equipment and advancing digital services and content. Future engineering pedagogues require digital competencies to effectively integrate digital technologies into the educational process. This article presents a concept for the methodology, which involves the design of practical tasks at three levels: basic, intermediate, and advanced. The results of an experiment conducted with students demonstrate that the proposed methodology yields higher grades compared to traditional methods. The findings underscore the importance of empowering engineering pedagogues with digital competences to prepare students for the digital era.**

Keywords*-- *engineering pedagogues, digital tools, educational environment, methodology, practical tasks, digital literacy, digital integration, educational transformation.

I. INTRODUCTION

In the context of the digital transformation of the education system, changes in the methods of working with educational stakeholders come to the forefront. The development of a digital educational environment in educational institutions involves not only equipping organizations with modern equipment but also the advancement of digital services and content for educational activities [1, 2].

Digital technologies are playing an increasingly significant role in modern education, demanding corresponding competencies from future engineering pedagogues. In today's world, where digitalization is penetrating various spheres of life, the preparation of highly skilled engineering pedagogues with digital competence becomes a necessity. These professionals must be able to utilize modern information and communication technologies (ICT) in the educational process to ensure high-quality and innovative education for students [3].

Digital competence has become an integral part of modern pedagogical practice. In the contemporary educational context, engineering pedagogues play a crucial role in preparing the younger generation for the digital world, where technology permeates all aspects of life and work. To successfully equip future engineering pedagogues for the digital landscape, it is necessary to develop effective teaching methodologies that enable them to acquire not only technical skills but also foster digital competence.

In recent years, significant progress has been made in researching the development of digital competence among future engineering pedagogues. Foreign studies, such as [4] and [5], present various approaches and models used to enhance digital competence in different countries. These studies identify key components and practices that help students-future educators acquire the necessary skills.

Furthermore, works like [6] and [7] offer an international perspective and a systematic literature review examining the impact of technology integration on the development of digital competence among future engineering pedagogues. They highlight success factors and provide recommendations for effective digital competence formation.

Today, the country is creating all the necessary conditions for the development of digital technologies. This is undoubtedly the result of successful collaboration between the government, the private sector, civil society, and the information technology community. It is not surprising that in such conditions, as emphasized in the Address, our country can join the ranks of advanced nations where digitization is not only a symbol of economic success but also of societal development as a whole in just one year, 2020.

Digital culture of an individual is an integrative quality that includes a special level of digital literacy and competence [9, 10]. The primary responsibility for shaping individuals with an adequate level of digital competence lies with the education system, particularly schools. In order to develop the digital competence of students, it is essential for educators to employ effective instructional strategies and utilize modern teaching tools that facilitate practical experience in utilizing digital technologies[11, 12].

Digital competence implies the ability of an individual to critically, confidently, safely, and effectively organize their work using information and communication technologies, while achieving positive outcomes [13]. A person should be able to operate in a digitalized environment and understand the significance of self-education and self-improvement in this field. Digital competence entails the capacity and willingness

of an individual to apply information and communication technologies to solve various tasks. Thus, digital competence is a fundamental characteristic of personal effectiveness in the context of the development of information and communication technologies [14].

The aim of this article is to describe the concept of an innovative method as a means of developing the digital competence of learners.

II. The Digital Competence

Digital competence is a multi-component structure that encompasses four components [15]:

Information and media competence denote the possession of knowledge and skills, motivation, and responsibility of an individual to search for relevant information, process it, and systematize it.

Communicative competence involves organizing one's communication using information and communication technologies.

Technical competence entails understanding the functioning of personal computers and other technical devices, and being able to utilize gadgets to organize one's work.

Consumer competence entails utilizing the capabilities of modern gadgets to solve various tasks.

In academic literature, there is a variety of definitions of digital competence, each emphasizing specific aspects of this concept. It would be difficult to provide a complete list of all these definitions. An analysis of scientific publications on this topic also indicates the lack of a unified approach to defining and understanding terms such as "digital competence," "digital literacy," and "digital skills." Sometimes in research, these terms are used interchangeably [16].

In one scientific publication [17], the importance of digital competence for students in addressing global challenges is emphasized. Concepts such as "digital competence," "digital literacy," and "digital skills" are mentioned in the literature and used as synonyms. However, there is a close connection between digital competence and digital literacy, and sometimes they complement each other, even if they have some differences in meaning [1].

In foreign scientific publications, there is an opinion that digital competence should be replaced by digital literacy in an educational context. This is because digital competence pays more attention to ethical and social aspects as well as security in using digital technologies. It also encompasses a wider range of knowledge, skills, and interests [17, 18]. Digital competence can be regarded as a vital skill for successfully adapting to the era of digital technologies, involving the ability to learn, work, relax, play, and use digital resources with confidence and creativity [1].

Digital competence should be considered as a set of skills that facilitate the use of digital technologies, teamwork, the development of critical thinking, the stimulation of creative approaches, and improvement in communication. In an educational context, digital competence means the ability to apply knowledge and skills for planning, implementing, evaluating, and continually improving teaching and learning processes supported by digital technologies, in addition to a solid theoretical foundation.

The International Telecommunication Union (ITU) distinguishes three skill groups: basic, intermediate, and advanced. The basic group encompasses skills necessary to function at a minimal level in society, i.e., the skills that all members of society should possess, known as basic digital literacy. Intermediate skills enable professional use of digital tools to achieve results, including rudimentary programming skills or the ability to prepare technical assignments. Advanced skills are geared towards professionals who create the digital environment, those who shape the new digital reality Fig.1

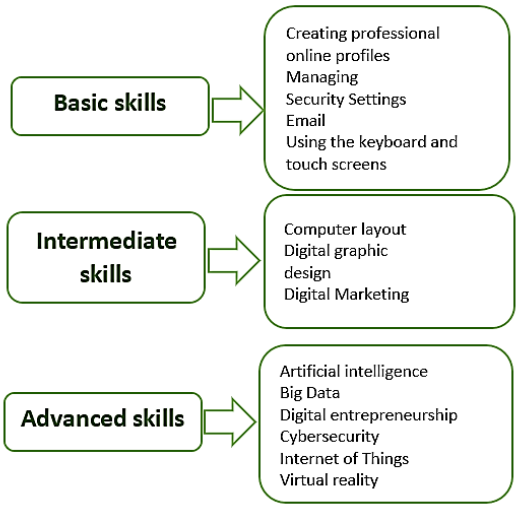

Fig. 1. Continuum of Digital Skills [16].

Analyzing the presented model, an original approach can be identified, which is related to the segmentation of target groups based on the level of competency. However, the skills are presented as specific actions and even key directions. To utilize this model, it is necessary to modify the skill names in formulations that are commonly accepted in higher education and professional standards.

The vision of the European Digital Competence Framework for Citizens (DigComp) closely aligns with the "Digital Uzbekistan 2030" program. DigComp identifies five areas of digital competence:

1. Information Literacy: Enables the acquisition of skills and abilities to identify information needs, conduct searches for reliable and up-to-date digital data, and utilize digital tools for storing, managing, and organizing digital information and data.
2. Communication and Collaboration: Develops the ability to interact in a digital environment, communicate and collaborate using digital technologies, and utilize specific digital services.
3. Digital Content Creation: Involves the ability to create and edit digital content, integrate new information into existing knowledge frameworks while adhering to copyright and licensing regulations, and formulate clear questions and tasks for computer systems.
4. Security: Emphasizes the protection of devices, content, and the confidentiality of personal data as a crucial skill for operating in a digital environment, including safeguarding the physical state of technologies.

5. Problem-Solving: Focuses on the capacity to identify needs and problems, as well as the ability to address them in a digital environment. This includes utilizing digital skills and tools to update software products.

DigComp proposes a conceptual reference model of competencies, highlighting the importance of information literacy as a primary skill. Additionally, communication and collaboration, digital content creation, security, and problem-solving are recognized as significant competencies [16].

Analyzing the DigComp model and comparing it to the key competencies in the field of digital literacy required for future engineering pedagogues in the field of vocational education, we can identify overlapping aspects, which are presented in Table I.

TABLE I. COMPARISON OF KEY COMPETENCIES IN QUALIFICATION REQUIREMENTS AND COMPETENCIES PRESENTED IN THE DIGCOMP MODEL

Qualification requirements	**DigComp Model Competencies**
Communication and collaboration in the digital environment	Communication and collaboration: ▪ interaction through digital technologies ▪ exchange using digital technologies ▪ cooperation through digital technologies ▪ network etiquette ▪ digital identity management
Self-development and self-education in conditions of uncertainty	Problem solving: ▪ identifying gaps in digital competencies
Creative thinking	Problem solving: ▪ solving technical problems ▪ identification of needs and technological responses ▪ creative use of digital technologies
Information and data management	Information literacy. Viewing, searching and filtering data, ▪ information and digital content. Digital Content Creation: ▪ digital content development ▪ integration and processing of digital content ▪ copyrights and licenses ▪ programming
Critical thinking in a digital environment	Information literacy. Evaluation of data, information and digital content. Safety: ▪ protective devices ▪ protection of personal data and privacy ▪ protection of health and well-being ▪ environmental protection

Compiled by the author based on the research materials.

Based on these aspects, there was a need to develop a conceptual model of student digital competence, which is based on a systemic approach, according to which digital competence represents a certain integrity consisting of interconnected components contributing to the overall functioning. It is also part of a higher-level system - the digital educational environment. According to the classical understanding of a model as a conditional representation, the model of student digital competence remains dynamic, allowing for changes and additions to be made. The proposed model of student digital competence includes three main components: theoretical, practical, and evaluative (Fig.2).

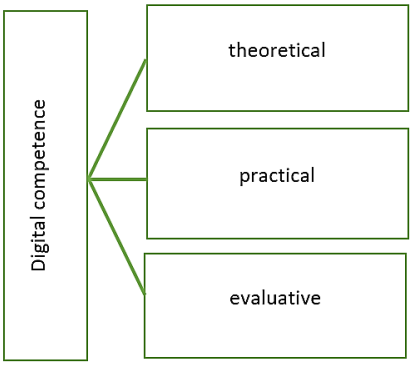

Fig.2. The component composition of the model of student's digital competence.

The theoretical component of digital competence provides students with the theoretical foundation and knowledge necessary for successful work and interaction in the digital environment.

The practical component of digital competence consists of a set of skills and abilities related to real actions and practical tasks in the digital environment.

The evaluative component of the model of student's digital competence includes aspects related to the assessment and measurement of student's level of digital competence. It assesses how proficient students are in essential digital skills and how effectively they can apply these skills in practice.

This model provides a systemic understanding of student's digital competence, encompassing both theoretical and practical aspects, along with evaluative mechanisms and self-assessment. It remains flexible and dynamic, allowing for adaptation to the rapidly changing digital landscape. The model facilitates an objective measurement of student's digital competence levels and encourages their development by helping create plans for skill enhancement. With a focus on practical application, it becomes relevant for real-world scenarios and seamlessly integrates into educational programs, contributing to the development of essential skills in the modern digital era.

III. METHOD OF STUDY

The concept of this methodology involves creating practical tasks at four levels: initial, basic, advanced, and high. When completing tasks, students are given the freedom to choose their initial level, and they can change levels or redo tasks until they achieve a satisfactory grade. An electronic platform for practical exercises and self-study was developed for this purpose. Video clips and assignments were created, with students having the option to choose the difficulty levels of the tasks. During the task completion process, both the teacher and the student can monitor progress and results. Additionally, the progress of the most active students can be observed in the form of a top 10 list, which serves as motivation for others.

Considering that our field of study is IT-related, the three levels were defined as grades: basic - satisfactory, intermediate - good, and advanced - excellent. Each task was designed to progress from simple to complex.

Third-year students of our university and its branches were invited to participate in the experiment. Of the 154

students, 124 students expressed a desire to participate. The selected students were randomly divided into two groups: experimental and control. During the semester, the course “Digital Technologies in Education” was held for groups. The experimental group (62 students) was given a course on the proposed methodology, and the control group (62 students) was given the traditional method.

Initially, all respondents underwent a survey to determine their level of digital literacy and ability to use digital tools. The survey revealed that all respondents owned smartphones, but they used them for various purposes, such as calls and internet browsing. In terms of educational purposes, 62% of respondents used smartphones. The term "digital competence" was familiar to almost every respondent to some extent. Only three individuals out of 124 (0.2% of the total respondents) stated that they did not understand the difference between digital and information competence. 97% of the respondents provided a definition of the term as the ability to use modern digital technologies (Fig.3)

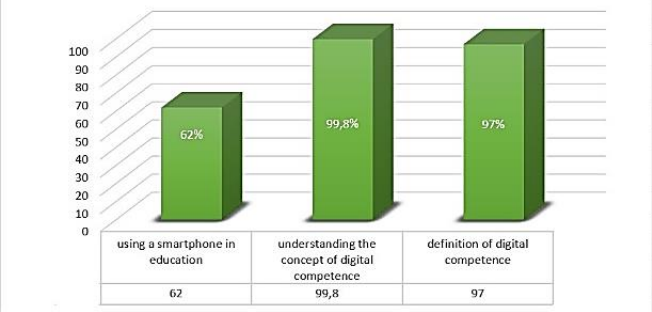

Fig.3. Survey results

After the survey, the students underwent training in the course "Digital Technologies in Education" throughout the semester. The final grades of the respondents were taken as the result of the experiment.

For the purposes of this study, a scale assessing the levels of students' digital competence was introduced. This scale included the following categories: the initial level, covering scores from 0% to 60% of the maximum grade; the basic level, assessed at over 60% but not exceeding 70%; the advanced level, encompassing scores above 70% but not reaching 89%; and the high level, evaluated at over 90%. Subsequently, formal assessments were normalized to 100% and correlated with the levels established in the scale. The course was considered successfully completed if a student scored above 60% on the final test, corresponding to at least the basic level of professional competencies.

The hypothesis of this research was that the methodology for developing students' digital competencies would be effective if the following conditions were met:

- The educational materials of the online course were based on modern concepts of web accessibility, universal design, and methods for organizing accessible educational web content.

- Learning was carried out independently on the online course with optional tutor support for students.

- Students successfully completed mandatory practical assignments and formative assessment tests.

As the diagram shows Fig. 4 students in the experimental group received higher grades compared to the control group. This can be attributed to the fact that students had the opportunity to exceed the requirements of tasks at more challenging levels to improve their results. This led to students being motivated to engage in self-learning to enhance their performance and boost their confidence, prompting them to tackle more complex tasks.

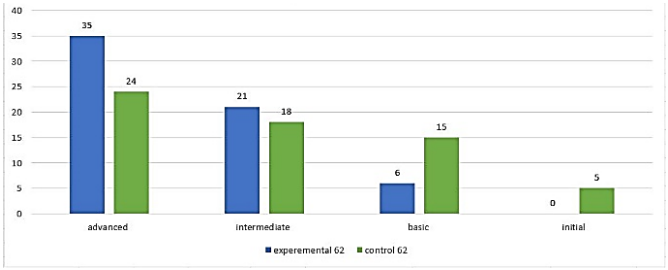

Fig. 4. Comparison of results

As a result of the experiment, it was found that students who underwent training in the discipline of “Digital Technologies in Education” achieved higher final grades compared to the control group. This indicates the positive impact of the educational program on the development of student’s digital competencies.

The advantages of the experimental group can be attributed to the fact that students were given the opportunity to tackle more challenging tasks and independently develop their skills in digital technologies. They were motivated to engage in self-learning, aiming to improve their performance and enhance their confidence in their abilities. As a result, students in the experimental group actively took on more complex assignments, leading to higher final grades.

This study confirms the importance of integrating digital technologies into the educational process for effective development of student’s digital competencies. Digital literacy not only improves academic performance but also prepares students for the modern digital world, where the ability to effectively utilize information and communication technologies is integral to success.

Further research in this area could focus on the development and adaptation of innovative teaching methodologies that actively incorporate modern digital tools and enable students to enhance their digital competencies. It is also crucial to ensure accessibility of such education for all students, so that no one is left behind in the digital age. Developing digital competencies is an essential component of successful student adaptation to the modern requirements and challenges posed by the digital transformation of society.

IV. CONCLUSION

Digital competence is an essential component of modern pedagogical practice. In the rapidly evolving digital era, where technology permeates all aspects of life and work, engineering pedagogues play a crucial role in preparing the younger generation for the digital world. Developing effective teaching methodologies that enable the acquisition of technical skills and foster digital competence becomes a necessity. The study has presented an innovative method for developing the digital competence of future engineering pedagogues. The methodology incorporates practical tasks at

three levels: basic, intermediate, and advanced. The experimental results demonstrated that students who were taught using the proposed methodology achieved higher grades compared to the control group, indicating its effectiveness. The success of the methodology can be attributed to its flexibility, allowing students to choose the level of task complexity and transition between levels, thereby stimulating self-directed learning and enhancing motivation. This approach facilitates the development of not only technical skills but also critical thinking, independence, and self-confidence among students.

The analysis of the learning outcomes did not reveal significant deficiencies in the developed methodological system for fostering digital competencies in the field of engineering pedagogy, creation, and integration of accessible educational content. The research hypothesis regarding the effectiveness of the new methodological system has been experimentally confirmed based on statistically significant results.

The developed methodological tools, including the online course, can be utilized for the professional training of future engineering educators, the cultivation of digital competencies in IT specialists, including web developers and web designers, as well as for enhancing the overall digital literacy of professionals engaged in the development of digital content.

Integrating digital competence into the educational process is a significant step in the development of the modern education system. Further research and the development of effective methodologies and approaches for fostering the digital competence of future engineering pedagogues will ensure high-quality and innovative education for students, equipping them with the necessary skills for success in the digital age.

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