Embedded Selforganizing Systems

Developing Information Competences of the Students in Technical Direction with Helping the Technology of "Network Boomerang" Principles

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***Abstract*— The article discusses ways of increasing students' engagement, motivation and participation in higher education using "Network Boomerang" technology, as an example of pre-service IT teacher training. With the onset of the global pandemic, the role of digital technologies has significantly increased, highlighting the importance of digital transformation, particularly for developing countries, including Uzbekistan. Indeed, digital transformation has the potential to further modernize society and integrate the national economy into global processes. In this context, within the framework of ongoing reforms and the Development Strategy of the New Uzbekistan for the next five years, special attention is being given to the digitization of key areas of activity and the establishment of a genuine information society in the country.**

Keywords-- education reforms, innovative teaching, active learning, e-learning, computer-assisted learning, innovative professional competence.

I. INTRODUTION

The development of pedagogy and information technologies on a broad scale is aimed at integrating teaching processes through technology, achieving effective education through information and communication technologies, and implementing research to adapt the management paradigm to meet quality requirements. Specifically, in the general education system, the implementation of strategies to shape relevant competencies in students, enhance their intellectual abilities, and utilize modern technologies and innovative information tools based on information and educational resources is gaining significant importance [1].

The open innovation (OI), which can be defined as "a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organisation's business model" [2], poses a range of challenges for the management of human resources involved in innovation, R&D and boundary-spanning activities [3] [4]. Relatively little is currently known about how the challenges of OI are handled at the individual level, even though "the effectiveness of firms' OI strategies strongly depends on the individuals tasked to bring those strategies to fruition" [5]. Rhe digitization environment refers to the state of digitization or the process of converting analog information into digital formats within a particular context or setting. It encompasses various aspects related to the adoption, implementation, and utilization of digital technologies and tools to transform and store information digitally. The digitization environment has evolved rapidly in recent years, driven by advancements in technology and the increasing demand for efficient information management and accessibility.

Over the last few decades, the concepts digital competence and digital literacy have been used more frequently and are increasingly discussed, particularly in policy documents and policy-related discussions related to "what kinds of skills and knowing people should have in a knowledge society, what to teach young people and how to do so" [6]. Often, they are used synonymously although they have distinct origins and meanings. Sometimes they are used to underpin each other, such as the EU framework of key competencies for all citizens where digital competence as one of eight key competencies is defined as follows:

"Digital competence involves the confident and critical use of Information Society Technology (IST) for work, leisure and communication. It is underpinned by basic skills in ICT: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet" [7].

Furthermore, works like [5] and [6] 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.

Digital competence refers to the confident, critical and responsible use of digital technologies for learning, at work, and for participation in society. It is defined as a combination of knowledge, skills and attitudes [8]. The European Digital Competence Framework for Citizens (DigComp) consists of 21 competences divided into five competence areas: information and data literacy; communication and collaboration; digital content creation (including programming); safety (including digital well-being and competences related to cybersecurity); and problem-solving. UNESCO has digital competency development initiatives on accessing, understanding, sharing and creating information

wisely using digital technologies, including for learning and employment purposes.

Here are some key elements that contribute to the digitization environment:

Digital Infrastructure: The digitization environment relies on robust digital infrastructure, including hardware, software, networks, and storage systems. This infrastructure enables the efficient processing, storage, and transmission of digital information.

Data Storage and Management: Digitization necessitates effective data storage and management systems. This involves the use of databases, cloud storage, content management systems, and other tools to organize, store, and retrieve digital information efficiently.

Digitization Processes and Workflows: The digitization environment incorporates processes and workflows for digitizing physical assets and documents. This includes scanning, optical character recognition (OCR), metadata creation, quality control, and other steps involved in converting analog materials into digital representations.

Data Standards and Formats: Standardization of data formats and metadata is essential for interoperability and effective utilization of digitized information. Common standards and formats ensure compatibility, consistency, and long-term accessibility of digital content.

Digitization Policies and Guidelines: The digitization environment is influenced by policies, guidelines, and best practices that govern the digitization process. These may include copyright and intellectual property considerations, preservation guidelines, data privacy regulations, and standards for digitization quality.

Digital Preservation: Preservation is a critical aspect of the digitization environment, ensuring the long-term accessibility and usability of digital content. It involves strategies for backup, disaster recovery, data migration, and ongoing management to prevent data loss or degradation.

Access and Dissemination: The digitization environment aims to enhance access to information by providing user-friendly interfaces, search capabilities, and platforms for sharing and disseminating digitized content. This enables wider audiences to benefit from the digitized resources.

Security and Privacy: Digitized information must be protected from unauthorized access, alteration, or misuse. The digitization environment incorporates security measures such as encryption, access controls, and secure authentication protocols to safeguard digital assets and maintain data privacy.

Technological Advancements: The digitization environment is continually evolving due to technological advancements. Innovations in areas such as artificial intelligence, machine learning, data analytics, and cloud computing are reshaping the digitization landscape and introducing new possibilities for information management and analysis.

Overall, the digitization environment encompasses a broad range of factors that contribute to the digitization, management, and utilization of digital information. It involves the convergence of technology, processes, policies, and standards to facilitate the transition from analog to digital formats and enable efficient access, preservation, and dissemination of digitized resources [9].

Uzbekistan has been giving priority attention to the development of information and communication technologies (ICT) and digitalization since the early 2000s. For example, the country initiated the "Comprehensive Program for the Development of the National Information and Communication System of the Republic of Uzbekistan for the Period 2013-2020," the National Action Strategy on the five priority areas of development of the Republic of Uzbekistan for 2017-2021, the "Digital Uzbekistan 2030 Strategy," and the "Development Strategy of the New Uzbekistan for 2022-2026," aimed at implementing digital transformation in the national economy, industry, and society as a whole [10].

One of the main directions of the current era of information dissemination is education. It identifies innovation as the key direction for further development of education in this environment. Additionally, it provides opportunities to address numerous complex issues related to scientific and technological advancements in society and their relevance to our lives [11].

The tasks defined for improving the effectiveness of teaching in higher education institutions include enhancing the professional competence of specialists, directing leaders and pedagogical staff towards innovative activities, improving the quality of education through the creation of an innovative learning environment and the integration of electronic information and learning environments, incorporating advanced foreign experiences, and preparing competitive personnel for the labor market. This, in turn, emphasizes the need to implement innovative forms and methods of teaching, as well as to widely implement modern information and communication technologies in teaching, based on the completion of the content of innovative activities in higher education institutions [12].

In the education system, the implementation or emergence of any innovation is related to the need to solve problems in certain areas of the educational process or to carry out complete modernization.

After that, the independent existence of innovations begins, and the innovation process proceeds to the next stage. It occurs only if there is acceptance of innovation. The stages of utilizing innovations are divided into the following three stages:

The stage of disseminating innovations, which involves spreading innovations that are part of a wide-ranging selection. Diffusion of innovations in new areas;

The stage of managing innovations in a particular field when innovations have passed their novelty stage and have lost their uniqueness. This stage is characterized by the emergence of effective competition or the adaptation of this novelty to its further success;

The stage of reducing the scale of utilizing innovations associated with the improvement of new products [13].

In general, any innovation process in education begins with identifying the need for changes in certain areas of the educational process. This is the result of analytical work by specialized scientific institutions, educational institutions, educational institution leaders, and teachers.

II. The Digital Competence

During our research process, the author has developed comprehensive and specialized curriculum programs from

various disciplines, which have been enhanced through innovative activities. These programs include:

- Educational technologies
- Digital learning technologies
- Scientific education

These programs have incorporated topics directly related to fostering innovation in their content. In addition, course assignments and completion tasks have been aligned with the innovative activities, and the proposed suggestions have been generated as a result.

The first stage is called the innovation-orientation stage. During the first and second semesters of the academic year, students engage in the process of orientation towards the high-quality education system. They familiarize themselves with the content and characteristics of innovative activities in improving the humanities and socio-economic, mathematical and natural-scientific subjects, as well as the "Introduction to Education" course.

The second stage continues in the 3rd, 4th, 5th, and 6th semesters and is referred to as the innovation-utilization stage. In this stage, based on the subjects of "Digital Educational technologies" and "Teaching technologies," students explore and discover innovative sources of information, and develop knowledge, skills, and competencies in using modern electronic teaching technologies.

The third stage, which is the innovation-research stage, takes place during the 7th semester. This stage differs significantly from the previous ones and holds a crucial place in preparing for innovative activities. It involves the integration of specialized subjects and the "Scientific Education" course, marking the beginning of innovative research activities. Students are encouraged to actively participate in research and design work, enhance their creative abilities, and become competitive professionals in the field of innovation.

The fourth stage, the innovation-project stage, is implemented in the 8th semester. This stage emphasizes independent work activities. During this stage, students carry out a final practical project related to their professional field, demonstrating their practical skills and the application of innovative approaches.

In the field of innovative pedagogy, we refer to the theoretical knowledge of pedagogical innovations, understanding, acquiring, and applying knowledge related to pedagogical activities, organizing and managing professional-pedagogical processes, developing new goals to enhance the effectiveness of the educational process, and the ability to successfully implement them in practice. Innovative-technological competence refers to the ability to improve existing technologies, utilize modern innovative tools and technologies, and integrate pedagogical innovations into technological aspects. Innovative-professional competence refers to the utilization of innovations in one's profession, purposeful and creative development of professional activities, the ability to employ modern educational technologies, and the capacity to create innovations in the field. Each level of competence that we have listed in Table I. is evaluated at three levels: basic, intermediate and advanced.

TABLE I. CRITERIA AND LEVEL INDICATORS FOR EVALUATING THE READINESS OF VOCATIONAL EDUCATION STUDENTS FOR INNOVATIVE ACTIVITIES

Criterion	Low	Medium	High
Innovative pedagogical knowledge	- has an idea about the concept of innovation and novation; - has an idea about the concept of innovative activity, innovative process and stages.	- can understand the concepts of innovation and novation; - is able to understand innovative activity and innovative process and its stages;	- can distinguish the concepts of innovation and novation; - innovative activity, innovative process and its stages, and carry out innovative educational research and projects.
Innovative - technological skills	- has a vision of innovative educational technologies.	- knows and can explain innovative educational technologies ; - has the ability to use some innovative educational technologies.	- has the competence to use innovative educational technologies and can fully use them; - able to carry out educational research and projects based on innovative educational technologies.
Innovative professional competence	- can give examples of innovative educational technologies in his profession;	- uses innovative educational technologies in his profession.	-innovative educational technologies in his profession, develop research and projects.

During the research process, we, on our part, developed a web application of the "Smart Boomerang" technology for use in teaching the subject of "Scientific Education." The final project of the CET ensures the formation of guaranteed knowledge, skills, and competencies that will enable the independent implementation of innovative activities in the future.

In the delivery of knowledge in the subject of "Scientific Education," it is required to have a clear understanding of the teaching process based on innovative activities, ensuring coherence with the topics, providing material support, and pre-planning the lesson structure. The choice of teaching methods, techniques, and tools in the subject of "Scientific Education" provides an effective utilization opportunity within 80 minutes.

Every teacher can benefit from the "Smart Boomerang" technology during their teaching activities. To utilize the "Smart Boomerang" technology, it is necessary to enter and arrange the teacher's tasks before the activity and, if the use of a computer is not possible, tasks can also be performed through mobile phones during the activity.

After registering in Fig.2, students log into their personal account through the login window. In his profile, the student sees his group and assignments. The process of dividing into groups and providing tasks is controlled by the Administrator, his control window is shown in the Fig.3

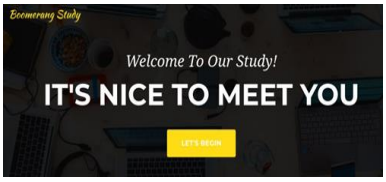

Fig. 1. The main page of the web application

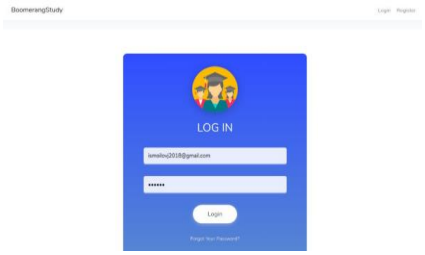

Fig. 2. Login window

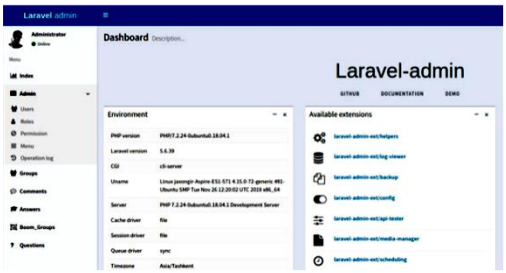

Fig. 3. The admin panel section will contain comments, structured questions, answers, boomerang groups.

In this window, Fig.4, the teacher publishes questions for students. Questions can be in the form of images or text. The difficulty level of the questions is determined by the numbers. At the bottom there are 4 different variants of questions marking the correct answer. The following Fig.5 shows the process of completing the assignment by the student.

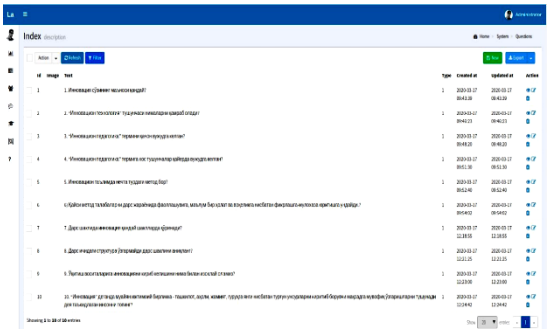

Fig. 4. List of structured questions

This is a project primarily designed for higher education institutions for the benefit of students. It aims to incorporate assigned tasks into a software program and provide students with a networked environment where they can independently execute the given tasks and achieve successful outcomes.

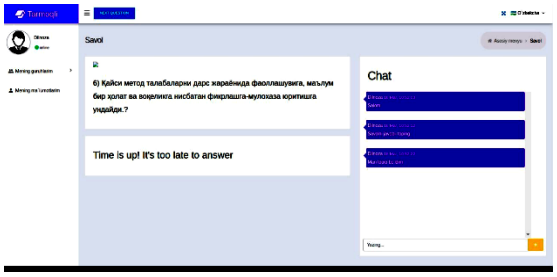

Fig. 5. A window indicating the time delay for receiving responses

The functionalities of this application include:

Implementation of assigned tasks through a networked environment using the "Networked Boomerang" technology.

Dividing students into groups via the network after presenting the tasks in the form of diagrams or tables from all subjects.

Encouraging independent thinking during task execution.

Complete utilization of the program.

This application is developed using the PHP Laravel framework and JavaScript programming languages, with a total size of 30 MB.

The "Networked Boomerang" technology promotes in-depth and comprehensive learning, fosters creative thinking, and encourages independent exploration. It facilitates the understanding of various topics with different content and characteristics (problematic, debatable, diverse content). The application provides visual and written materials, enables the execution of various tasks during the learning process, whether as a student or a teacher, and allows the accumulation of necessary scores.

The "Networked Boomerang" technology promotes critical thinking and logical structuring. It enhances the development of ideas, opinions, and arguments through written and oral means. It facilitates student engagement during the lesson and beyond, working with various literature and texts, retaining learned material, expressing oneself verbally, freely presenting ideas, and evaluating all students during a lesson.

To implement the "Networked Boomerang" technology in the electronic version of the educational program, a specific folder must be created on the computer, containing the main page file (course name, index, HTML). The remaining files are divided into folders as follows:

IMG: Graphics, images, animations, and others.

CHARTER: Lectures, laboratory work, and their content.

TEST: Tests, monitoring tasks, exercises.

FILE: Guidelines and additional materials related to the "Networked Boomerang" method.

Once the specific folder is created, students can proceed to the registration. This "Networked Boomerang" technology promotes in-depth and comprehensive learning, fosters creative thinking, and encourages independent exploration. It effectively covers topics with various content and characteristics (problematic, debatable, diverse content) and offers a variety of interactive tasks during the learning process. The application allows each student to independently complete different tasks during the lesson. The application also facilitates group allocation for students and allows them to work remotely.

To integrate the functioning of the application with relevant information, the programming languages PHP and Laravel are used.

Thus, students are assessed through a rating system based on the level of completion of the assigned task. The teacher familiarizes the students with the evaluation criteria and the rating procedure, for example, the answers to the questions - if there is a complete answer - 3 points, if there is an addition - 2 points, if they just answer from the seat - 1 point, if there is no answer - 0 points are set. In the grading system, it is possible to assign 5 grades for a complete answer, 4 grades for an addition, 3 grades for an answer close to the answer, 2 grades for no answer, and 1 grade for no participation at all.

The assessment of students' knowledge and skills is an essential component of vocational education institutions, aiming to evaluate their competence, acquisition of knowledge and practical abilities, as well as their readiness for professional activities. Assessment is a process that occurs at a certain stage of the educational process, which involves measuring, identifying results, and analyzing them based on predefined criteria and indicators. The educational significance of assessing knowledge and skills lies in providing both the teacher and the learner with specific information about the improvement of the learning material. It enables the adaptation of educational materials to enhance overall and specialized subjects based on the assessment of students' competencies.

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)

A special program was developed for conducting experimental and test works within the framework of the research. The program includes the objectives, specified tasks, stages of experimental and test works, and designated areas for conducting experiments. The program also covers the acceptance of pedagogical conditions, material-technical support, and information provision when selecting experimental areas.

Our main rationale was to identify publications that explicitly defined or discussed the concepts digital competence and digital literacy the motive for which was that if the authors have included these concepts there, then these concepts are central to the publications as well [10].

The experimental and test works were carried out in three stages: introductory (2018-2019 academic year), shaping (2019-2020 academic year), and final (2021-2022 academic year) stages. The experimental fields were organized at the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi. A total of 114 students from TUIT participated in the conducted experimental and test works.

As the results of the experiment in Fig.6 show, 15% more efficiency was achieved compared to the control group. Innovative pedagogical and information technologies, the level of their application, the state of the educational process preparation system and the need for its improvement were analyzed. Pedagogical observations, interviews, test questions and analysis of the level of knowledge in general and specialized subjects were used to assess the educational activity of students [9].

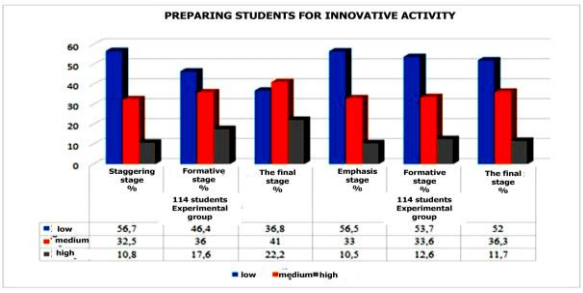

Fig. 6. Preparing students for innovative activity

Assessing a student’s readiness for innovation is a complex process that requires the use of various assessment methods. For our part, we have developed a collection of tasks aimed at promoting and evaluating innovation activities, which includes practical and theoretical tests, innovative pedagogical materials, innovative technological tools and the development of innovative professional competencies. These tasks include practical tasks aimed at problem solving and development.

In our research, under the conditions of information sharing, assessments of students' knowledge and skills are provided through tests, questions, and assignments that are specifically aligned with the educational objectives, meaning they correspond to the volume and complexity of the

learning content. These assessments are conducted in activities designed to prepare students for innovative activities and to enhance innovative-pedagogical materials, innovative-technological tools, and the development of innovative professional competencies.

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 [14].

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.

During the experimental research, the purpose, tasks, and methodology of the experiment were developed and implemented based on the selected methods. In order to promote innovative activities during the research, a methodology and information provision were created for practical and seminar activities, aiming to organize, manage, and supervise education and enhance its effectiveness. Pedagogical experiments were conducted to improve students' theoretical knowledge, practical skills, and competencies through the developed methodology, with the goal of increasing the quality and effectiveness of innovative activities, as evidenced by the results of pedagogical experiments.

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