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Formation of Methodological Competence of Informatics and Information Technology Teachers in a Digital Learning Environment Through Universal Design and Virtual Collaboration Approaches

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Abstract: This article analyzes the issues of developing the methodological competence of Informatics and Information Technology teachers in a digital learning environment. In particular, it highlights the significance of the Universal Design for Learning (UDL) concept developed by CAST, as well as virtual collaboration-based teaching models. The results show that UDL principles contribute to the individualization of learning and improvement of educational effectiveness, while virtual collaboration supports teachers' professional development. The integration of these approaches enables the effective development of teachers' methodological competence.

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1. Introduction

In the modern era, digital technologies are rapidly penetrating all spheres of society, and this process is closely associated with global digitalization trends. The development of information and communication technologies is transforming not only economic and social sectors, but also requires fundamental changes in the content and structure of the education system. In particular, for teachers of Informatics and Information Technology, this process is of special importance, as it requires them to effectively operate in a digital learning environment, to deeply master modern pedagogical approaches, and to purposefully implement them in practice [1].

Main Part

A modern educator is expected not only to possess deep theoretical knowledge, but also to be able to effectively organize the teaching process, take into account the individual needs of diverse learners, make purposeful and rational use of digital technologies, and apply innovative pedagogical methods. In addition, teachers are expected to create a modern learning environment that enhances students' engagement and fosters independent thinking and creativity[2].

This situation, in turn, makes the development of teachers' methodological competence an urgent scientific and practical issue. In the context of digital education,

methodological competence goes beyond the mere transmission of knowledge; it encompasses a wide range of activities, including the design of the learning process, the integration of digital tools, and the effective assessment of learning outcomes.

In a broader sense, methodological competence includes a teacher's ability to effectively deliver educational content, engage learners, manage and assess the teaching process, and integrate modern pedagogical technologies. In a digital learning environment, this competence becomes more complex and is enriched with new dimensions.

From this perspective, the Universal Design for Learning (UDL) concept developed by CAST, along with virtual collaboration-based teaching models, serves as an important theoretical and practical foundation for developing the methodological competence of Informatics teachers [3]. While the UDL approach focuses on the individualization of learning, taking into account learners' cognitive and personal characteristics, and creating an inclusive learning environment, virtual collaboration models ensure effective interaction between teachers and students, making the learning process more interactive and dynamic.

In this regard, these approaches play a significant role in enhancing the effectiveness of education and modernizing the pedagogical process in a digital learning environment [4].

The purpose of this study is to scientifically substantiate the role and importance of universal design and virtual collaboration approaches in developing the methodological competence of Informatics teachers in a digital learning environment, as well as to identify the possibilities for their effective implementation in educational practice.

In modern pedagogy, the concept of "methodological competence" is considered an important category associated with the effective organization of a teacher's professional activity. In particular, within the educational frameworks developed by OECD, competence is interpreted as an integrated system of knowledge, skills, and attitudes [5]. This approach allows for a comprehensive evaluation of a teacher's performance and contributes to the systematic development of their professional capacity.

In the scientific literature, methodological competence is defined as a teacher's ability to select educational content, determine its structure, appropriately apply teaching methods and tools, and effectively organize students' learning activities. As Tony Bates (2019) emphasizes, in the context of digital education, a teacher is not merely a transmitter of knowledge, but rather a designer, organizer, and manager of the learning process [6].

Moreover, methodological competence also encompasses the teacher's reflective activity, that is, the ability to analyze, evaluate, and continuously improve their pedagogical practice [7].

In a digital learning environment, methodological competence acquires a broader meaning and requires the integration of didactic, technological, communicative, and reflective components. The didactic component is related to the selection of educational content and teaching methods, while the technological component involves the effective use of digital tools. The communicative component ensures effective interaction with students, whereas the reflective component enables teachers to analyze and improve their own professional practice [8].

These components are closely interconnected and collectively form an integrated system that ensures a teacher's effective performance in a digital environment.

From this perspective, the Universal Design for Learning (UDL) concept developed by CAST serves as an important theoretical foundation for the development of methodological competence [9]. This approach is grounded in the achievements of neuropsychology and cognitive science and aims to adapt the learning process to meet the needs of all learners. As David H. Rose and Anne Meyer emphasize, UDL is designed not

to make education uniform, but flexible, taking into account each learner's individual needs, learning styles, and abilities[10]. This, in turn, plays a crucial role in ensuring equal learning opportunities and creating an inclusive educational environment [11].

According to the UDL framework, the learning process should incorporate multiple means of representation, engagement, and expression. Such variability allows for the diversification of educational content, enhances student engagement, and improves overall learning effectiveness. In particular, in Informatics education, this approach is especially significant for individualizing and adapting the learning process through the use of digital tools, multimedia resources, and interactive platforms.

Terry Anderson (2008) defines online learning as a system of interactive communication among learners, teachers, and educational resources[12]. This approach is grounded in the theories of constructivism, social constructivism, and connectivism, and emphasizes active, independent, and collaborative knowledge construction.

In virtual collaboration-based teaching, models such as collaborative learning, project-based learning (PBL), the flipped classroom, and peer learning are widely applied. These models contribute to the development of students' independent thinking, foster teamwork skills, enhance their ability to solve problems, and support practice-oriented learning. Furthermore, they provide valuable opportunities for teachers to exchange experiences, collaborate with one another, and engage in continuous professional development [13].

As Terry Anderson emphasizes, the effectiveness of teaching in a virtual learning environment largely depends on the quality of interaction and collaboration within the learning process[14]. In this regard, collaboration organized through digital platforms is a key factor in improving the quality of education, ensuring students' active participation, and facilitating effective knowledge acquisition.

The integration of universal design and virtual collaboration approaches holds particular significance in a modern digital learning environment. Such an approach enables the individualization of the learning process, promotes active student engagement, and ensures effective collaboration in digital settings. According to UNESCO, the implementation of innovative pedagogical approaches is one of the key factors in enhancing the quality of education[15]. In this context, these approaches not only enrich the content of education but also create new opportunities for organizing the learning process more effectively.

From this perspective, the in-depth study of the theoretical and practical aspects of universal design and virtual collaboration approaches, as well as their purposeful implementation in Informatics education, is of particular scientific importance. This, in turn, necessitates the clear definition of the methodological foundations of the study and the application of a comprehensive research approach.

2. Materials and Methods

In this study, a comprehensive approach was employed to examine the process of developing the methodological competence of Informatics teachers in a digital learning environment. To address both theoretical and practical objectives, a range of scientific research methods was utilized. In particular, the method of analyzing scientific and methodological literature was used to explore the theoretical foundations of methodological competence, Universal Design for Learning (UDL), and virtual collaboration-based teaching models. In this process, scholarly sources developed by international organizations and researchers were examined, including materials from CAST, UNESCO, and OECD. These sources played a significant role in strengthening the theoretical foundation of the study.

In addition, the study employed methods of analysis and synthesis to generalize existing scientific perspectives and to identify the interrelationships among them. Through

the use of comparative analysis, the differences and advantages of traditional educational approaches and modern digital and innovative pedagogical models were examined. This made it possible to provide a scientific justification for the advantages of innovative approaches in contemporary education.

From a practical perspective, observation and elements of pedagogical experimentation were also utilized within the study. In particular, lessons conducted through digital platforms were analyzed to examine the application features of Universal Design for Learning (UDL) principles and virtual collaboration-based models[8]. During this process, factors influencing students' engagement, level of participation, and learning effectiveness were identified and their interrelationships were analyzed in depth. Based on the generalization of the obtained results, further analytical work was carried out to evaluate the effectiveness of applying these approaches in Informatics education and to identify the possibilities for their implementation in practice. During this analytical process, the collected data were systematized, the interrelationships among them were identified, and the key factors influencing the pedagogical process were determined.

The research was conducted in two phases. The first phase involved a theoretical analysis of existing literature and policy documents related to digital pedagogy, UDL, and virtual collaboration. During this phase, a conceptual framework was developed to guide the empirical component of the study. The second phase consisted of a practical pedagogical experiment carried out over a period of one academic semester. During this phase, a group of Informatics teachers participated in professional development sessions where UDL principles and virtual collaboration strategies were introduced and applied in their teaching practice.

Data collection instruments included structured observation checklists, reflective journals maintained by participating teachers, and pre- and post-intervention questionnaires designed to measure perceived changes in methodological competence. The questionnaires were developed based on established competency frameworks, including the European DigComp 2.2 framework and the OECD Teacher Competency Model. Responses were analyzed using both descriptive statistics and thematic analysis to ensure a comprehensive understanding of quantitative trends and qualitative shifts in teaching practice.

Ethical considerations were carefully observed throughout the research process. Participation was voluntary, informed consent was obtained from all participants, and the confidentiality of individual data was strictly maintained. The study adhered to the ethical guidelines established by the institutional review board and followed internationally accepted standards for educational research. These measures ensured the reliability and validity of the findings, as well as the ethical integrity of the entire research process.

3. Results

Traditional The analysis of lessons conducted in a digital learning environment during the study showed that the application of Universal Design for Learning (UDL) principles and virtual collaboration-based teaching models has a significant positive impact on the effectiveness of the learning process. In particular, presenting information in various formats (text, video, and interactive resources) not only increased students' level of comprehension but also helped maintain their attention for longer periods and enabled deeper understanding of the subject matter.

The use of virtual collaboration-based approaches, including online group work, project-based learning, and peer learning, significantly increased students' engagement. According to the analysis results, the level of student participation in such lessons was higher compared to traditional classes, and improvements were observed in their ability to think independently, analyze problem situations, and find solutions. In addition,

collaborative activities contributed to the development of students' communication and teamwork skills.

At the same time, the application of UDL principles made it possible to take into account students' individual characteristics, thereby promoting a more flexible and inclusive learning process. By presenting the same content in different formats for learners with diverse abilities, equal participation in the learning process was ensured. This, in turn, contributed to the creation of a supportive and effective learning environment for all students.

During the pedagogical experiment, positive changes were also observed in teachers' methodological competence. In particular, they acquired new skills in the effective use of digital tools, the scientific and methodological design of lessons, and the organization of interactive collaboration with students. This led not only to the development of their technological and didactic competences, but also to the improvement of their reflective practice.

Thus, the results of the study confirm that these approaches have a positive impact not only on the effectiveness of the learning process, but also on teachers' professional development. The analysis of the obtained results indicates that the combined application of universal design and virtual collaboration approaches not only increases students' engagement, but also contributes to the systematic development of Informatics teachers' methodological competence. This process enhances the effectiveness of teachers' pedagogical activities, supports the alignment of the learning process with modern educational requirements, and expands opportunities for the purposeful use of digital technologies. In this regard, the wide implementation of these approaches in educational practice is considered highly appropriate.

The results of this study demonstrate that universal design and virtual collaboration-based approaches play a significant role in the development of methodological competence among Informatics teachers in a digital learning environment. In particular, the application of Universal Design for Learning (UDL) principles was found to facilitate the individualization of the learning process, take into account students' cognitive and personal characteristics, and enhance overall educational effectiveness. This, in turn, contributes to ensuring equal learning opportunities for all students and to the creation of an inclusive learning environment.

At the same time, virtual collaboration-based teaching models proved to be effective in increasing student engagement, developing teamwork skills, and fostering independent thinking. These approaches also contributed to the development of teachers' methodological competence by expanding their ability to effectively use digital technologies, organize lessons on an innovative basis, and ensure interactive collaboration with students.

The findings of the study indicate that the integration of universal design and virtual collaboration approaches is a key factor in enhancing the effectiveness of Informatics education, organizing the learning process in accordance with modern requirements, and supporting teachers' professional development. From this perspective, it is essential to implement these approaches in the education system in a consistent and phased manner, ensure their methodological support, and align their application with continuous professional development of teachers.

4. Discussion

The results obtained in this study are consistent with findings reported in recent international research on digital pedagogy and inclusive education. Specifically, the positive impact of UDL principles on student engagement and learning outcomes aligns with the conclusions drawn by Rose, Meyer, and Gordon (2014), who demonstrated that flexible instructional design significantly improves participation rates and knowledge

retention across diverse learner populations. Similarly, the observed gains in teachers' methodological competence are in line with findings by Bates (2019), who argued that teachers in digital learning environments must continuously adapt their pedagogical strategies to meet evolving learner needs.

A notable finding of this study is the synergistic effect produced by combining UDL principles with virtual collaboration models. While each approach independently demonstrated positive outcomes, their integrated application yielded a measurably stronger impact on both student learning and teacher professional development. This finding suggests that the two frameworks are not merely compatible but mutually reinforcing: UDL provides the structural foundation for inclusive content design, while virtual collaboration ensures dynamic and interactive delivery of that content. This synergy is particularly relevant in the context of Informatics education, where the subject matter itself demands both conceptual understanding and practical application.

However, the study also identified several challenges associated with the implementation of these approaches. First, some teachers initially reported difficulties in adapting existing lesson materials to conform to UDL principles, particularly in terms of providing multiple means of representation. This challenge was largely attributed to a lack of familiarity with UDL guidelines and insufficient access to appropriate digital resources. Second, the effective use of virtual collaboration tools required reliable internet connectivity and adequate technical infrastructure, conditions that were not uniformly available across all participating institutions. These findings underscore the need for targeted institutional support, including professional development training, resource allocation, and infrastructure investment, to ensure the sustainable implementation of UDL and virtual collaboration approaches.

Furthermore, the study's findings have important implications for teacher education programs and continuous professional development systems. The data indicate that a single training intervention is insufficient to produce lasting changes in methodological competence. Rather, sustained professional development embedded within communities of practice and supported by ongoing mentoring and peer collaboration is necessary for lasting pedagogical transformation. These conclusions echo those of Hattie (2009) and Fullan and Quinn (2016), who emphasized the importance of coherent, long-term professional learning systems in driving meaningful improvements in educational quality.

5. Conclusion

The effective integration of universal design and virtual collaboration approaches in a digital learning environment is a key factor in developing the methodological competence of Informatics teachers. The consistent implementation of these approaches contributes to improving the quality of education and fostering a modern digital pedagogical environment.

Based on the results of the study, the following practical recommendations can be proposed:

- a. To systematically integrate the UDL principles developed by CAST into professional development programs for Informatics and Information Technology teachers, and to introduce specialized training modules on this approach;
- b. To develop and implement practice-oriented methodological guidelines, digital resources, and instructional materials for the effective use of digital learning platforms (LMS and online collaboration tools);
- c. To gradually implement virtual collaboration-based teaching models (project-based learning, flipped classroom, and peer learning) in the educational process, as well as to establish mechanisms for evaluating their effectiveness and conducting regular monitoring;

- d. To design and implement a transparent and reliable assessment system for evaluating teachers' methodological and digital competences based on clearly defined indicators and criteria;
- e. To organize seminars, training sessions, webinars, and online collaboration platforms in educational institutions in order to disseminate innovative pedagogical practices and promote experience exchange among teachers;
- f. To systematically collect, analyze, and develop mechanisms for implementing best practices in the application of UDL and virtual collaboration approaches in digital learning environments.

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