Didactic Terms of Shaping Pedagogical Universities Students' Digital Competence in the Process of Teaching Informatics Courses

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Abstract: In this study the results of the conducted theoretical and experimental research on determining, grounding and testing of didactic terms of shaping pedagogical universities students' digital competence in the process of teaching informatics courses have been presented. The object of the research is the process of shaping digital competency of pedagogical universities students. The subject of the research is the didactic terms that contribute to the shaping of digital competence of pedagogical universities students in the process of teaching informatics courses. The article provides insight into the essence of the conducted pedagogical experiment on the assesses of the effectiveness of didactic terms of shaping pedagogical universities students' digital competence in the process of teaching informatics courses. The conducted quantitative, qualitative and statistical analyses have identified a positive and statistically significant dynamic in the levels of formation of the competence in question in accordance with the defined criteria; in the degree of the system acquisition of this phenomenon; in general levels of the formation of digital competence of students from the experimental group.

1 INTRODUCTION

The current pace and vector of the evolution of the post-industrial world community necessitate a rethinking of the structure of professional competencies of the students of pedagogical specialities, the inclusion in their list of the ability and readiness to function effectively in a digital society, the development and improvement of skills to competently and appropriately use models, methods and tools of informatics, the latest information technologies in professional activities and social practice.

The Strategy for the Development of the Information Society in Ukraine (Cabinet of Ministers of Ukraine, 2013) set a course for creating an education system focused on the use of the latest ICTs in forming a well-rounded personality and ensuring the continuity of education. The Concept of the New Ukrainian School (Elkin et al., 2017) calls the information and digital competencies key and essential competence for living in modern society. The Regulation on the National Educational Electronic Platform (Ministry of Education and Science of Ukraine, 2018) emphasizes the need to develop them for participants in the educational process. The concept of the Digital Agenda of Ukraine (Adz, 2016) recognized the digitalization of society, which includes future teachers, as an object of attention and integrated public administration. In the quarantine restrictions context, it is digitalization that has become the primary tool for distance and blended learning, and digital competence has been the guarantee of effectiveness.

The researches which are the basis for the study of the problem are the works examining the theoretical and methodological foundations of teachers' professional preparation as agents of social change (Honcharenko, 2012; Chernilevskyi et al., 2010; Sultanova et al., 2021; Hrynevych et al., 2022; Semychenko, 2004; Slastenin et al., 1997; Falfushynska et al., 2021; Rybalko et al., 2020; Ziaziun, 1989; Madzigon and Vachevskyi, 2011; Havrilova and Topolnik, 2017; Kuts and Lavrentieva, 2022), ways of modernizing of higher pedagogical education and updating its content and organizational forms (Aleksiuk, 1993; Bespalko,

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1960; Kodliuk et al., 2021; Lozova, 2003; Ogneviuk et al., 2020), the source developing the competence approach and reveal the essence of the teacher's professional competence (Khutorskaya and Korol, 2008; Raven, 2020; Zimnyaya, 2021; Ovcharuk, 2020; Pometun, 2003; Dakhin, 2012; Morze et al., 2022).

A lot of theoretical and experimental works of domestic and foreign scientists are devoted to the problems of implementation and effective use of ICT in education, in particular (Bespalko, 2018; Burov et al., 2020; Gershunsky and Pullin, 1990; Honcharenko, 2000; Gurevych et al., 2020; Kademiya and Kobysia, 2017; Hurevych et al., 2012; Robert et al., 2016; Sysoieva, 1998; Zhaldak, 2012). The issues of digitalization of the educational space are thoroughly considered by foreign scholars in their publications (Manovich, 2001; Polat, 2004; Stommel, 2014; Vuorikari et al., 2016) and Ukrainian researchers (Balyk et al., 2019; Kukharenko et al., 2022; Bilousova et al., 2022; Spivakovsky et al., 2013; Rakov, 2005; Teplytskyi et al., 2019; Trius and Sotulenko, 2017; Zhaldak et al., 2012).

The analysis of the current state and directions of reforming science education (STEM education) has led to the conclusion that its digitalization requires the modernization of computer science training and the cross-cutting integrated systematic design of advanced content for teaching computer science to students of pedagogical universities based on a competence approach. These problems are comprehensively addressed in the works of Hrynevych et al. (Hrynevych et al., 2021), Ramsky and Rezina (Ramsky and Rezina, 2005), Semerikov et al. (Semerikov et al., 2022).

Meanwhile, the analysis of primary sources revealed a terminological inconsistency in the use of the term "digital competence". The scientific researches which comprehensively studies the categorical and terminological field of informatics, information and communication competencies in line with our study are valuable in this context (Ovcharuk and Ivaniuk, 2021; Ovcharuk et al., 2022; Spivakovsky et al., 2022; Soroko, 2021; Vakaliuk et al., 2021a; Martyniuk et al., 2021; Bondarchuk et al., 2022; Vakaliuk et al., 2021b; Prokhorov et al., 2022; Pinchuk and Prokopenko, 2021; Riezina et al., 2022; Moiseienko, 2020; Moiseienko et al., 2020a,b).

It has been established that the Digital Competence Framework for Citizens (Carretero et al., 2017) and the Digital Competence Framework for Educators (European Commission et al., 2017) developed within the European Research Center of the European Commission have become reference models, clearly defined guidelines for creating conditions for the development of educational space, forming the digital competence of participants in the educational process, and they also laid the foundations for building an educational institution's digital learning environment. However, despite the significant achievements in the field of research, there are still contradictions such as:

- between the socially determined and state-regulated need for a high level of digitalization of all spheres of society and the insufficient level of digital competence of the key actors of the information society – students of pedagogical specialities;
- between the need for students to acquire critical thinking skills, lifelong learning, and mobility to changing technologies as the basis for their sustainable professional and personal growth and traditional approaches to teaching computer science at pedagogical universities;
- between the didactic findings, forms, methods and techniques accumulated in science and practice and the degree of substantiation and experimental verification of the didactic terms for the formation of students' digital competence in teaching computer science disciplines.

The aim of the study is to identify, theoretically substantiate didactic terms, develop and experimentally test a model that promotes the formation of digital competence of pedagogical universities students during the study of computer science disciplines.

2 THEORETICAL ASPECTS OF SHAPING PEDAGOGICAL UNIVERSITIES STUDENTS' DIGITAL COMPETENCE

Taking into account the results of the analysis of the procedural and content aspects of the competence approach as a leading educational paradigm of higher pedagogical education, the role, place and significance of digital competence have been clarified which are a key and essential component of the teachers' professional competence in a modern globalized society. It has been found that such competence allows them to creatively introduce ICT innovations into professional and pedagogical activities, to promote the development of relevant ICT competencies in students.

It has been established that in its essence, digital competence is a personality's dynamic characteristic

determining the ability to secure information interaction, communication and collaboration, design digital educational resources and solve complex professional problems with the use of ICT and tools. From this point of view, it performs *motivational and incentive, gnostic and transformative, activity and methodological, evaluative and reflective, and communicative and procedural functions* in the professional activity and social practice of pedagogical institutions' students.

Given the peculiarities of informatics as a complex scientific and engineering discipline, the object of which is information processes of any nature, the subject – new information technologies, and the methodology – computational experiment, we define digital competence as a separate phenomenon that is directly related with the information competence, as well as computer, information and technological, and informatics competencies of pedagogical universities' students.

The analysis of the key and related concepts made it possible to formulate the author's vision of this multi-dimensional category. *Digital competence* is determined as the subject's ability and capacity to purposefully use ICT to create, search, process, and exchange information in the virtual space, to demonstrate information and media literacy, to comply with Internet security and cybersecurity rules, to understand and consciously adhere to ethics in working with information.

It has been found, that by its structure, digital competence is a complex and multidimensional personal formation, a professionally and personally significant integrative quality covering a set of competencies necessary for orientation and activity in the information space. These include *functional literacy in information and data, communication and collaboration competence, digital content competence, digital security competence, and problem-solving competence* (figure 1). It has been established the digital competence of pedagogical universities students can function at two qualitative levels. One is the basic level making it possible to solve educational problems by means of general-purpose computer technologies, and yet another is subject-oriented allowing the introduction of specialized digital technologies and resources into educational activities.

It has been fixed that the digital competence content reflects the structure of activities for consistent, literate and multidimensional work with information and is determined by the relevant following structural and criterion components (figure 2):

- *motivational-value component* contains the goals, motives, interests, value orientations, special abilities, focus on self-realization in professional and pedagogical activities and self-realization in the information space;
- *cognitive-informational* one as a set of knowledge and experience that ensures information processing and work with information objects on the cybersecurity and ethical behaviour foundation;
- *operational-activity* one – a set of skills and abilities for the active usage of information technology and computer equipment in professional activities as tools of learning and development, self-improvement and creativity;
- *personal-reflexive* one – features and qualities determining the student's personal reflective attitude towards themselves as a subject of activity in the information space, as well as their self-awareness, self-control, self-assessment of actions and responsibility for their results.

The article proposes to assess the formation of digital competence of pedagogical university students by the degree of manifestation of relevant indicators at four levels – elementary, intermediate, sufficient and advanced ones.

3 DIDACTIC SUPPORT FOR THE SHAPING OF STUDENTS' DIGITAL COMPETENCE

The analysis of scientific sources and the results of practical activities made it possible to clarify the essential characteristics of the educational process in pedagogical universities, to identify key disciplines and to determine didactic means (forms, methods, techniques, technologies) for the formation of components of students' digital competence in the process of studying computer science disciplines. According to the results of the analysis of educational programs, the content of teaching informatics disciplines has been presented in three content areas:

- algorithmization and programming (Fundamentals of algorithmization and data structure, Object-oriented and event-driven programming, Web programming);
- software of computer systems (Fundamentals of office technologies, Numerical methods and modelling, Multimedia);
- computer technologies in the professional activity of a teacher (School course of informatics, Methods of teaching informatics, Olympiad in informatics, Modern lesson of informatics).

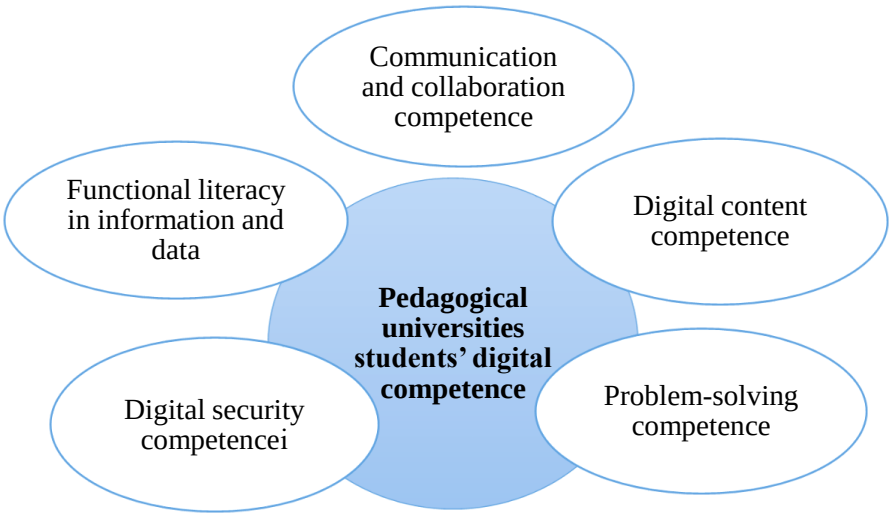

Figure 1: Components of the digital competence.

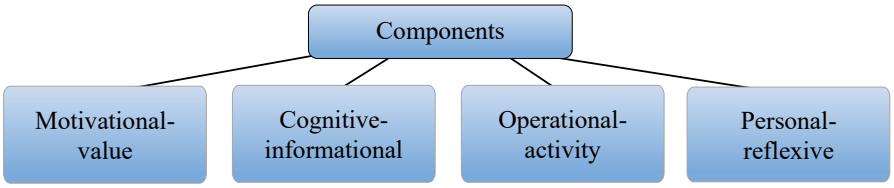

Figure 2: Structural and criterion components of the digital competence.

It has been recorded that in order to improve the students' digital competence and its separate components, the practice of pedagogical universities widely uses the possibilities of a variable block of computer science disciplines (Fundamentals of Media Literacy, Educational Smart Technologies, Network Communities, etc.), as well as the LMS of HEIs, MOOCs and open educational resources.

It has been substantiated that increasing the efficiency of the process of shaping the digital competence of pedagogical universities students is ensured by the creation of certain didactic terms that are educational procedures specially modelled as a result of the systematic selection, design and implementation of elements of content, as well as methods, techniques and organizational forms of computer science disciplines. The complex of *didactic terms* includes: the motivational conditionality of interaction of subjects' educational process in the information and digital learning environment; structuring of educational information in the form of problematic, heuristic and integrative models of learning and its translation into the project activities mode; ensuring the systemic complicating nature of students' study activities, diagnosis and timely correction of its products on the basis of modern ICT.

In the authors' opinion, the development of a structural and functional model contributes to the identification, theoretical substantiation and implementation of the didactic terms. In the model, each structural component (target, theoretical and methodological, content and procedural, criterion and diagnostic, and resulting blocks) has a specific function: orientation, analytical, formative and corrective ones serving to optimize the organization of activities for the shaping of students' digital competence during the study of computer science disciplines (figure 3).

The *target of the modelling* is to build a system of pedagogical work on the shaping digital competence of pedagogical university students during the study of informatics courses. The didactic model is based on the principles of comprehensive information support, optimality and pedagogical expediency, interactivity, comprehensive differentiation, controllability, effectiveness, proceduralism, diagnostics, gamification, adaptability, and ergonomics. The *target block* of the didactic model reflects the sequence of steps in defining goals and objectives, so it performs an orientation function in the formation of students' digital competence at each segment of the educational material. The *theoretical and methodological block* describes the content of the information and digi-

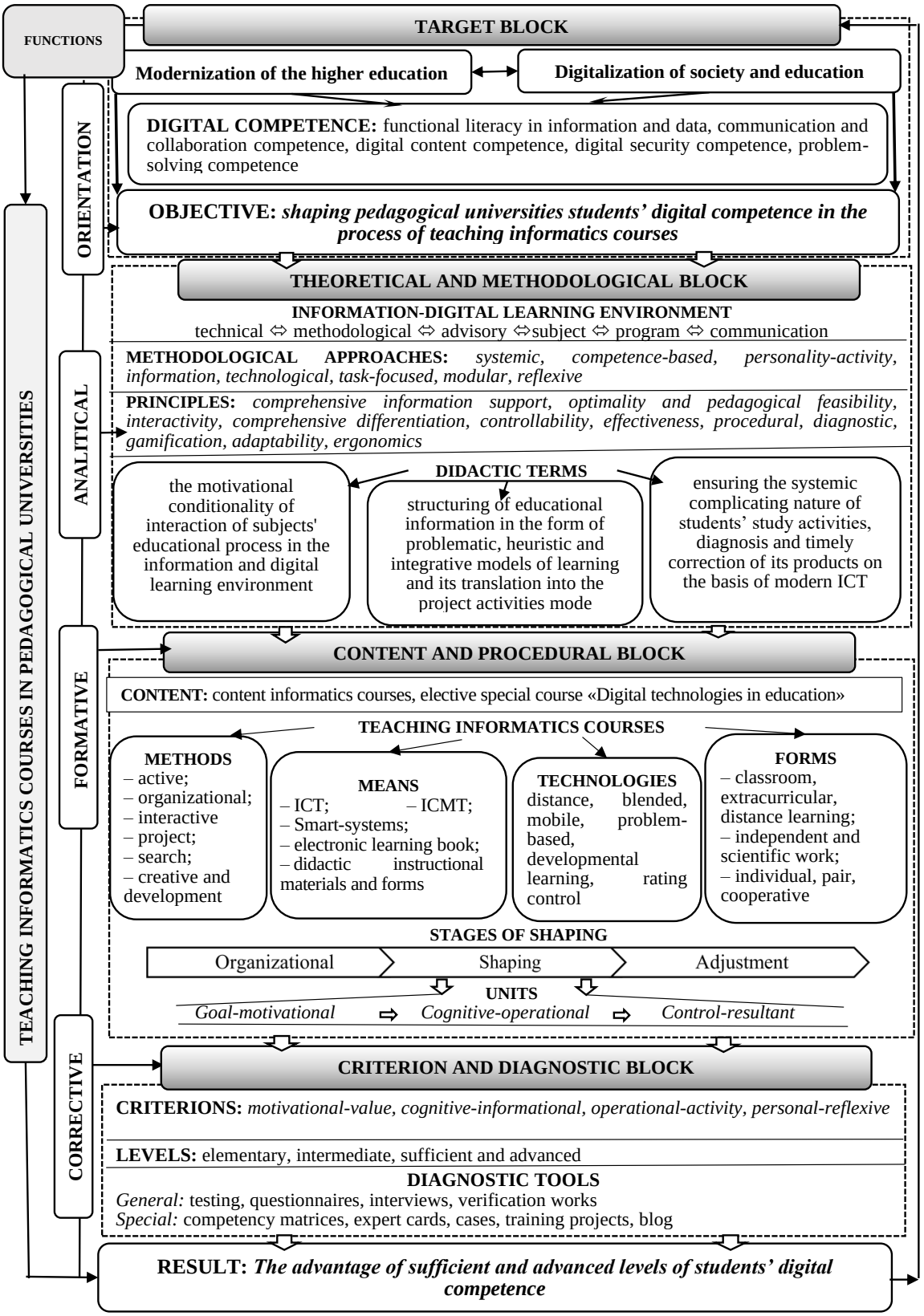

Figure 3: Didactic model of digital competence development of pedagogical university students.

tal learning environment, methodological approaches, principles and didactic terms that are the subject of analysis when designing the research process. The *content and procedural block* reflects the complex of didactic support (selected forms, methods, technologies, tools), as well as the logic and stages of forming students' digital competence and its components. The *criterion and diagnostic block* perform a corrective function, so far as shows the criteria, levels, and diagnostic tools for determining the level of students' digital competence during the study of computer science disciplines. The *result of the model implementation* is the achievement of the advantage of sufficient and high levels of digital competence at each stage of mastering computer science disciplines.

4 ORGANIZATION AND METHODOLOGY OF EXPERIMENTAL WORK

The investigation of the state and analysis of the problem in the practice of pedagogical universities made it possible to diagnose the goals and content of teaching computer science disciplines at the bachelor's level. First of all, it has been found that mastering the basics of algorithmization and programming, software of computer systems is provided only for the main or additional speciality "Informatics" (15% of the total curriculum). For the rest students, elective and integrated courses are offered covering the issues of computer technology in the professional activities of a subject teacher. Evidently, it does not contribute to the full and purposeful digital competence formation as one of the key competencies for a teacher. At the same time, other contradictions and a number of objectives, conceptual and procedural difficulties have been identified, and the superiority of the primary and secondary levels of digital competence in more than 52% of students has been stated both by separate criteria and in general.

Experimental testing of the effectiveness of the identified didactic terms was carried out in stages. At the organizational stage, on the basis of systemic, competence, personal activity, information, technological, task-focused, modular, and reflective approaches, the empirical research program was developed, the content was clarified and the electronic educational content of computer science disciplines ("Event-driven programming" and "3D modelling") was updated, the author's electronic special course "Digital Technologies in Education" (3 ECTS credits) was prepared, didactic support for teaching computer science disciplines (lectures, multimedia presentations, electronic textbooks, instructional materials and forms, tests, a system of educational tasks for the formation of digital competence and its components) was selected.

The components of the information and digital learning environment – methodological, consulting, subject, programmatic, and communication were developed and filled with content in accordance with the components of the didactic model of students' digital competence formation. The guideline was the prepared structural and logical scheme of teaching computer science disciplines with a system of classroom work and independent and self-educational activities of students with the support of the LMS of HEIs, open educational resources, specialized departmental websites and teachers' personal websites (blogs, pages, etc.), and digital communication tools.

The testing of such didactic term as the *motivational conditionality of interaction of subjects' educational process in the information and digital learning environment* carried out at the formative stage of the experimental work provided for the use of the advantages of such an environment to organize effective cooperation and co-creation in the system "teacher-student-class" during the study of computer science disciplines. The development of students' learning motivation in mastering digital competence was facilitated by the use of problem-based and developmental learning technologies, the creation of success situations, the introduction of emotional stimulation, and rating control with elements of gamification. The projects implemented (individual or group) were aimed at developing motivation, forming cognitive readiness for digital activities, practising leading digital activities, and integrating computer science knowledge.

Students' progression from motives in mastering digital activities to knowledge, skills, abilities, and evaluative judgments to digital competence was ensured by creating a didactic term such as *structuring of educational information in the form of problematic, heuristic and integrative models of learning and its translation into the project activities mode*. Based on the logic and stages of the studied activity, a technological scheme for the formation of students' digital competence was developed, namely:

entrance and introductory diagnostics $\rightarrow$ *goal-motivational module (formation to students of a system of motives and an approximate basis for activities in the virtual space)* $\rightarrow$ *cognitive-operational module (solving a system of educational tasks to develop components of digital competence, forming of constituent elements of digital competencies, inputting them into*

Table 1: Comparative results of experimental work.

Criteria and indicators	Experimental group	Control group
Motivational-value criterion	*+25.26%*	*+10.75%*
Formation coefficient / χ^2 – Pearson's criterion	+0.09 / 79.28	+0.04 / 7.43
Cognitive-informational criterion	*+35.79%*	*+13.98%*
Formation coefficient / χ^2 – Pearson's criterion	+0.11 / 143.48	+0.04 / 9.54
Operational-activity criterion	*+23.16%*	*+7.53%*
Functional literacy in information and data	+0.11%	+0.04%
Effective communication and cooperation competence	+0.11%	+0.02%
Creation of digital content competence	+0.07%	+0.01%
Security competence	+0.08%	+0.03%
Problem-solving competence	+0.07%	+0.02%
Formation coefficient / χ^2 – Pearson's criterion	+0.09 / 63.58	+0.03 / 3.21
Personal-reflexive criterion	*+17.89%*	*+13.98%*
Formation coefficient / χ^2 – Pearson's criterion	+0.06 / 31.73	+0.04 / 9.95
The level of digital competence	*+26.32%*	*+10.75%*
Elementary	–17.89%	–9.68%
Intermediate	–8.42%	–1.08%
Sufficient	+16.84%	+8.6%
Advanced	+9.47%	+2.15%
Formation coefficient / χ^2 – Pearson's criterion	+0.09 / 113.95	+0.04 / 9.74

the metastructure of digital competence during the creation, search, processing, exchange of information) $\rightarrow$ *control and result module (control, evaluation, self-assessment, correction of the formed constructs via information and digital learning environments).*

This work was supported by a system of study tasks, contextual, game and problem situations, and web quests created by, which in their content covered motivational and value, cognitive and informational, operational and activity, and personal and reflective aspects of students' activities in the virtual space. The content of the tasks was aimed at both understanding, comprehension, and memorization, structuring the learned tools in the student's memory, actualization and reflection on their own activities.

Ensuring the systematic complication of students' study activities, diagnostics and timely correction of its products based on modern ICTs, as the next didactic term, involved the introduction of virtual space tools that together optimized and intensified the learning of students of computer science disciplines. These include new ways of organizing classes, technological models of mobile, distance, and blended learning, game design, video and teleconferencing, web forums, and workshops in synchronous and asynchronous modes.

The corrective stage involved monitoring and correcting the results of students' learning activities using both general (testing, questionnaires, interviews, tests) and specific methods (competency matrices, expert cards, cases, learning projects, blog).

According to the results of quantitative, qualitative and statistical analysis of the experimental work results, a tendency towards positive changes in the levels of students' digital competence formation both by separate criteria and in general has been established (table 1).

The comparative analysis revealed a positive dynamic of achievements of pedagogical university students of both groups, which, however, is more pronounced and statistically significant for students of the experimental group. According to the research results, the cognitive-informational (+35.79%) and motivational-value (+25.26%) structural-criterion components have turned out the most developed. Changes in the control group's indicators are due to the influence of the educational process and the overall development of students. The non-randomness of the obtained changes was proved with the use the mathematical statistics methods.

5 CONCLUSIONS

1. The study analyses the procedural and substantive aspects of the competence approach as a leading paradigm of higher pedagogical education, clarifies the role and importance of informatization and digitalization in the development of the educational space, highlights the need for digitalization of science education (STEM education) and the urgency of end-to-end

integrated systematic design of advanced content of teaching computer science disciplines to students of pedagogical universities. On this basis, the place of digital competence in the structure of the professional competence of future teachers is determined as a key and essential component in performing motivational and incentive, gnostic and transformative, activity-methodological, evaluative and reflective, and communicative and procedural functions in their professional activities and social practice. At the same time, it is established that the problems in the formation of students' digital competence during the study of computer science disciplines in traditional approaches are associated with the prevalence of a knowledge-oriented paradigm in the organization of the information and digital learning environment, the focus on the one-sided mastery of the basics of algorithmization and programming and software of computer systems. Yet another reason is the insufficient level of educational innovations introduced in the teaching of computer science disciplines.

2. It has been found that the digital competence of pedagogical university students is inherently a dynamic characteristic of a personality determining the ability and capacity to purposefully use ICT to create, search, process, and exchange information in the digital space, to demonstrate information and media literacy, to comply with Internet security and cybersecurity rules, to understand and consciously adhere to ethics in working with information, to creatively introduce ICT innovations in professional and pedagogical activities, to promote the development of relevant their students' digital competence.

Digital competence is an integrative quality that encompasses a set of competencies necessary to navigate and operate in the information space in order to fulfil personal and social needs and carry out professional activities. These include functional literacy in information and data, communication and collaboration competence, digital content competence, digital security competence, and problem-solving competence.

The structural and criterion components of digital competence are motivational-value (indicators: interest in mastering information in the subject area; motivation to use ICT to search for information), cognitive-informational (indicators: knowledge of information sources, methods of working with information, methods of presenting information, knowledge of security and cybersecurity), operational-activity (mastery of methods of obtaining, storing, processing and transmitting information, ability to use information technology in working with sources), and personal-reflexive (indicators: a reflection of information activities, the ability to evaluate information differently and critically select it). It allows monitoring of their formation during the study of informatics disciplines according to the signs of elementary, intermediate, sufficient and advanced levels.

3. The didactic support of shaping pedagogical university students' digital competence in the process of teaching informatics courses has been developed. By analyzing educational programs, the content basis for the formation of the studied phenomenon is represented by three areas in the study of computer science disciplines (algorithmization and programming, computer system software, and computer technologies in the teacher's professional activity), as well as the possibilities of a variable block of the curriculum, in particular, using the LMS of HEIs, MOOCs and open educational resources.

The set of didactic terms for shaping pedagogical university students' digital competence in the process of teaching informatics courses has been determined and justified. Among them are the following ones: 1) motivational conditionality of interaction of subjects' educational process in the information and digital learning environment; 2) structuring of educational information in the form of problematic, heuristic and integrative models of learning and its translation into the project activities mode; 3) ensuring the systemic complicating nature of students' study activities, diagnosis and timely correction of its products on the basis of modern ICT.

4. The effectiveness of creating the system of didactic terms is ensured by the substantiation and experimental verification of the didactic model, which schematically reflects the system of work on the formation of the digital competence characterizing the hierarchy, sequence, components, stages, blocks and applied tools, connections between them and performs orientation, analytical, formative and corrective functions in the organization of teaching students of computer science disciplines.

The implemented didactic modelling led to the content, specification and correction of the educational goals of the components of teaching the pedagogical universities students (target, theoretical and methodological, content and processual and criterion and diagnostic blocks), structuring of educational material into functional modules (goal-motivational, cognitive-operational and control-resultant ones); made possible the logic and gradual introduction of didactic terms for the formation of digital competence in the educational process, in the classroom and students' independent study work.

The motivational conditionality of the interaction of the subjects of the educational process in the infor-

mation and digital learning environment contributed to a shift in emphasis from the mentoring model of communication between teachers and students to the partnership model.

Structuring educational information in the form of problem-based, heuristic, and integrative learning models and transferring it to the project activity mode made it possible to transform students' reproductive activities into creative ones, which contributed to the skills development to navigate the information space, generalize and integrate knowledge, and choose effective ways and methods of solving problems.

Ensuring the systematic complication of students' study activities, diagnostics and timely correction of its products based on modern ICTs made it possible to gradually increase the complexity of the learning tasks performed, contributed to students' confidence in their abilities and building-up motivation and interest in learning.

Apart from traditional study means additional academic modules were created including special and elective courses in Digital Technologies and 3D Modelling.

According to the results of the empirical research in the experimental groups, there is a statistically significant dynamics in the levels of students' digital competence, namely a 17.89% decrease in the number of students with an elementary level, an 8.42% reduction in the number of students with an intermediate level, 16.84% increase in the number of students with a sufficient level, 9.47% – with a high level. The cognitive-informational, operational-activity and structural-criterion components of digital competence have developed the most.

The paper does not exhaust all aspects of this problem. Further research is reasonable to update the content of educational programs of pedagogical universities in accordance with the needs of the information society and the goals of STEM education; modernization of computer modelling training based on the use of modern tools and software, factors of improving the content and mechanisms for organizing students' activities in the information and digital learning environment, ways to develop and apply educational SMART systems.

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