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MODULAR-CYBERNETIC APPROACH FOR DEVELOPMENT OF DIGITAL COMPETENCE OF STUDENTS – FUTURE TEACHERS

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Abstract. The present research aims to investigate opportunities for the development of digital competence of future teachers through the application of a modular-cybernetic approach and a technological variant developed on its basis. The experimental research focuses on diagnosing the cognitive and practical achievements of students in order to identify the possibilities and limitations of the modular-cybernetic approach in the development of digital competence. The empirical research was conducted with a group of 86 students admitted to study Bachelor's degree in the professional field of Pedagogy. The system of criteria and indicators in the course of the empirical research is used as a "core of the competence" with an emphasis on the cognitive and practical achievements. The Wilcoxon's Test (Wicoxon) is utilized to compare correlating groups. The results of the Wicoxon application show that the modular-cybernetic approach for the development of students' competence has a greater than average impact on knowledge formation and also affects the development of cognitive skills to a small extent. On the other hand, the applied technological variant does not help the development of problem-solving skills and practical-applied skills.

Keywords: modular-cybernetic approach; digital competence; future teachers

Introduction

The recognition of a competence is often associated with a high degree of generality, which is understandable considering the wide range of activities that make up a teacher's professional profile. Of course, given the construction of a competence's invariant characteristics and the subsequent qualitative and situational understanding, this pilot conceptualization is needed. There are distinctive concepts with respect to the definition of digital competence, characterized by dimensions of "cognitive, relational and social nature" (Calvani et al. 2008). Considering the multidimensional structure of the digital competence of the teacher, its identification is commonly related with challenges such as: (1) insufficient knowledge of the necessary computer skills and the skills to work with different digital sources of information as a basis for digital competence, (2) impossibility for complete diagnostics, especially within short periods of time (?), (3) dependence on other skills, including metacognitive ones, complementing it, and giving it full personal expression, (4) contextual and subject-oriented dynamics, as well as social determinism.

This set of issues makes it essentially more difficult to identify the core competencies integrated into the teacher's digital competence. Digital competence, given its integral nature, is often seen as including technological, cognitive and ethical elements integrated according to the context of its existence (Calvani et al. 2008).

There are some contradictions regarding the content and structure of the digital competence of the teacher, which hinder its full formation and development during their university education. In educational theory and practice, these contradictions are most often reduced to: (1) misunderstanding of and hence inability to distinguish between systematic training of specialists (mainly from technical special-ties) in the field of information technology, the training of teachers of informatics and information technology and the training of future teachers of other subjects as users of these technologies; (2) failure to take into account the possibilities of the competence approach in the design of the goals and expected results of education, as well as the impossibility to identify the basic elements of each competence; (3) the ambiguity regarding the conceptual framework of the teacher's digital competence and the possibilities for its full inclusion in their professional profile; (4) the lack of a conceptual model for designing technological solutions for the formation and development of the digital competence of teachers, within their educational training (Tsankov & Damyanov 2017).

Digital competence is defined as a set of knowledge, skills and attitudes to perform tasks (related to problem solving, communication, information management, cooperation, content creation and sharing and building knowledge) using the tools of information and communication technologies and digital media. Digital literacy is shaped by competence in five main areas – information processing, communication, content creation, security and problem solving, which also forms the European Digital Competence Framework for Citizens (DIGCOMP) (Tsankov & Damyanov 2019).

Modular-cybernetic approach – scope and content of the concept, principles and technological variant for realization in the process of the development of digital competence

The modular-cybernetic approach is positioned in the initial research and conceptual grounding of a comprehensive model for the development of digital competence of students – future teachers. It takes into account the variety of existing views on the opportunities offered by modular learning, its continuity with other theories and concepts of learning that are evolving, especially in the systematic and targeted application of information and communication technologies in education. Additionally, it is related to the dynamics of the development of modern didactic theories as an opportunity to synthesize their features, which allows to combine different approaches in the selection of educational content more successfully, as well to organize and implement these in the educational process.

According to authors such as Daniukova, modular distance learning is one of the effective ways to intensify the educational process and provides a number of significant advantages, such as the ability to apply individual and functional-systemic approaches to course development and determining the content of training; increasing the level of consciousness, motivation, independence, cognitive activity of students; effective control; saving time resources (Daniukova 2021).

Authors such as Borisova see “the purpose of modular learning in creating the most favorable conditions for personal development by providing flexibility of the learning content, adapting to the needs of the individual and the level of their basic education by organizing educational and cognitive activities according to the individual curriculum” (Borisova 1999).

The theoretical analysis of modular training enables Borisova and Kuzov to distinguish between the following characteristics: (1) providing obligatory study of all components of the didactic system and their visual presentation in a modular program and modules; (2) presupposing clear structuring of the educational content, consistent presentation of the theoretical part, provision of the educational process with methodological tools and system for assessment and control of the acquired knowledge and skills, as well as a possibility for regulation and correction of elements of the educational process; (3) providing dynamism and adaptability of the learning process to the individual capabilities and requirements of the learners. According to the authors, these distinctive features of modular learning make it possible to identify its high adaptability, which is determined by structuring the learning content; the clear sequence of presentation of all elements of the didactic system (goals, content, methods for managing the educational process), in the form of a modular program; variability of structural, organizational and methodological units (Borisova & Kuzov 2005).

Comparing the modular training with the traditional one, Juceviciene brings out some of its main characteristics, considered as elements of its design: tasks, preparation of the study content, activity in the learning process, the role of the teacher, training method, training aids, student participation, individualization, pace of learning, time, freedom of action, mobility, learning conditions, assimilation of knowledge, organization of repetitions, consolidation of knowledge, control, student failure (lack of mastering), flexibility, and assessment of course preparation (Juceviciene 1989).

In the context of the development of the ideas of the modular education with different degree of generalization, the basic principles, perceived by Juceviciene as fundamental and defining the general direction goals, content and methodology of organization are considered: (1) modularity; (2) structuring the learning content into separate elements; (3) dynamism; (4) method of activity; (5) flexibility; (6) a conscious perspective; (7) versatility of methodological consulting; (8) parity (Juceviciene 1989).

According to Juceviciene the above-listed principles for modular training are closely related, but almost all of them (without the principle of parity) reflect the peculiarities of the construction of the teaching content, and the principle of parity characterizes the interaction between the teacher and the trainee in the new conditions, imposed in the realization of the principles of modularity, structuring of the teaching content as separate elements, the principles of dynamism, the method of activity, flexibility, the perceived perspective and the versatility of the methodical consulting. The manner of interaction between the teacher and the trainee is also determined by the principle of the versatility of methodological counselling (Juceviciene 1989).

Indeed, the priority orientation related to the structuring of the curriculum in deriving the principles of modular learning stands out. It is this rationale that allows Borisova and Kuzov (despite the different approaches to structuring the learning content) to claim that they are all based on the same principles, to attempt to identify principles for its structuring, in the context of modular learning, namely: (1) The principle of arranging the content of an academic course around basic concepts and methods; (2) The principle of systematic and logical sequence of the exposition of the educational content; (3) The principle of integrity and practical relevance of the content and (4) The principle of visual presentation of the educational content (Borisova & Kuzov 2005). Drawing on earlier concepts suggested by Juceviciene, Borisova and Kuzov formulate the following basic principles: (1) the principle of structuring; (2) the principle of problematic nature; (3) the principle of variability; (4) principle of adaptability; (5) principle of application of feed-back (Borisova & Kuzov 2005).

The dynamic system of modular training formed along increasing orders of complexity has specific requirements for its management, i.e. inherent in cybernetic systems (with their dynamism, openness – complete or partial, their complexity and selectivity with respect to possible states). The search for optimal functional arrangement of the main units in the modular training, through the potential of the cybernetic approach to treat them as subsystems, depending on their functional characteristics, is reflected in the framework of the proposed technology of modular-cybernetic type (Fig. 1).

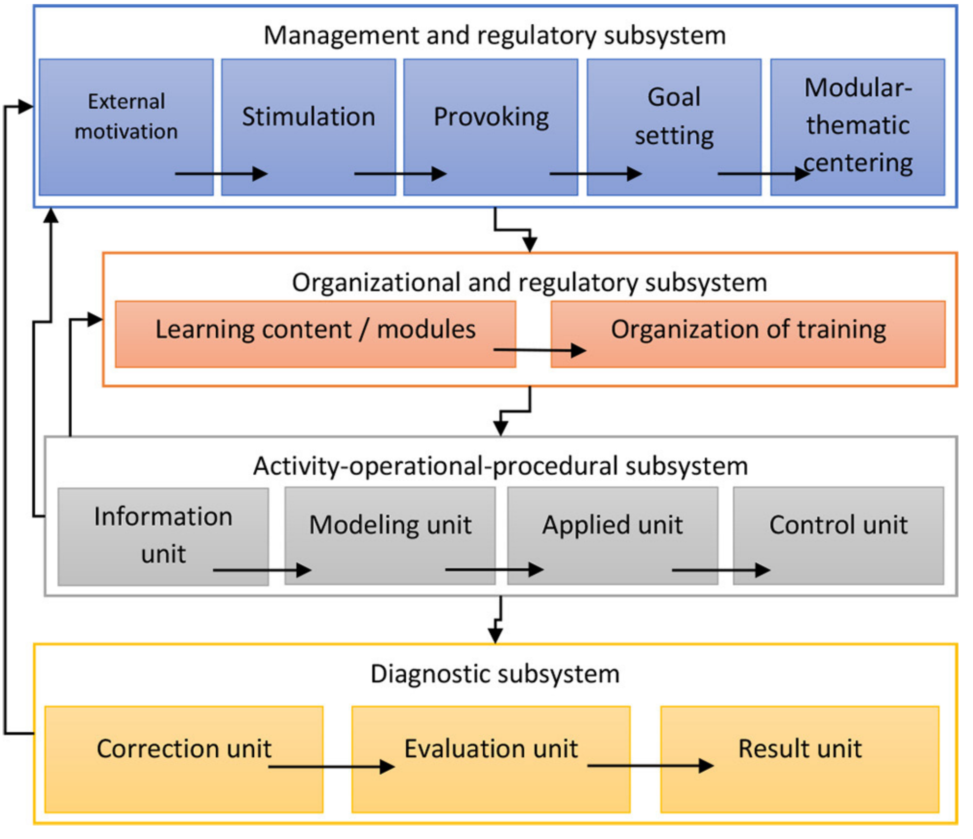

Figure 1. Learning design – modular cybernetic approach

Thus, in essence, the requirements for training are met, as a complex dynamic system: (1) the units are arranged in systems (training and trainee) and subsystems; (2) the elements of which the systems consist to perform the same functions; (3) the exchange of information between the separate systems and subsystems to be carried out through the channel for feedback.

Although it is argued that the application of the specific principles of modular learning gives its most important characteristic – flexibility (of content and/or structural), which penetrates into all major components of the didactic system, opportunities are sought to optimize this type of self-regulation of the system, which implies the presence of positive feedback. The flexibility of the content is reflected primarily in the possibility for both differentiation and integration of the curriculum, and the structural flexibility is provided for by the dynamism and mobility of the structure of the modular program; the ability to design a flexible schedule of the educational process and establish flexible management of the educational process. Management flexibility provides for the procedural aspect of modular learning, including variability of teaching methods and tools, flexibility of the monitoring and evaluation system, individualization of students' educational and cognitive activities (Borisova & Kuzov 2005).

In the conceptual grounding of this basic part of a model for growth design and development of the digital competence of the students from professional field "Pedagogy" training to acquire the professional qualification "pre-school teacher" and/or "primary school teacher", and in the context of the application of the modular-cybernetic approach to this development against the background of the awareness that "through the specifics of its result, developmental regulation has the most expressed anti-entropic nature by ensuring not only that the entropy is kept within the given values, but also that it is reduced by generating forms of organization with increasing information capacity and resilience to disturbances" (Golu 1983).

For this purpose, a technological model of training was tested through the discipline "Information and communication technologies in training and work in a digital environment", initially seen (training) as a cybernetic system (com-plex; consisting of elements in non-random interaction; relatively open; dynamic and scholastic (subject to regularities, but with a probabilistic character, with unpredict-able behavior), and subsequently dynamically upgraded and improved according to the possibilities (time, resource and subject) in the context of developmental learning.

Despite all the possibilities of the modular-cybernetic approach, its limitations are observed, which are closer to the objectivist and instructivist – traditional model, where to some extent teaching continues to be too structured, to be dominated and controlled by the teacher, knowledge continues be separated from cognition, the learning content/information is divided in part and subordinated to a whole concept and, despite the focus on student activity, elements of cooperative activity, dialogue and problems in learning are not excluded. Rather, students continue to expect instructions from the teacher, instead of activating their experience, integrating and reconstructing it in the conditions of learning a new experience, creating their own cognitive meaning of situations and creating their own meanings, self activizing knowledge and trying to expand the limits of their cognitive and practical possibilities.

Results

The empirical research was conducted with a group of 86 students admitted to study Bachelor's degree in the professional field "Pedagogy". The aim of the research is to establish the degree of development of the digital competence of the students - future teachers through the application of a modular-cybernetic approach in education. The system of criteria and indicators presented in Table 1 in the course of the empirical research is used, with an emphasis on the cognitive and practical achievements, as a "core of the competence".

Table 1. System of criteria and indicators

Criteria	Indicators	Evaluations
Cognitive achievements	Knowledge	– volume (completeness) – thoughtfulness – durability – applicability
	Cognitive skills	– skills for critical analysis and synthesis; – skills for understanding relationships (part – whole, single – total, cause – effect, purpose – means, determinism); – skills for classification and definition; – modeling skills; – skills for self-initiative variations of actions / activities; – assessment skills.
Practical achievements	Practical skills	– reproductive (standard) solving tasks according to instructions; – research solving tasks/problems by recreating constructs; – creative transfer of skills in problematic situations through the development of new constructs.
	Problem-solving skills (solution requiring selection and combination of ICT opportunities, assessment of opportunities)	– identifying the main elements of the problem; – selection of information and technologically possible solutions needed to solve the problem; – generating ideas for solutions; – deciding; – (self) evaluation of the decision.

Within the framework of the students' education towards receiving their Bachelor's Degree, after establishing the stat of their digital competence in the preliminary experiment (operands – the initial values of the state of the system; the established mode in the cybernetic system) elements are applied of author's educational technology, which is based on a system of educational cognitive and practical tasks on a modular principle (operators – impact factors) in order to realize transformation (, transient mode in the cybernetic system), while at the intermediate and final stages in the training images are diagnosed (states of the cybernetic system after the transformation, seen as the development of digital competence).

In accord with Petrov and Belcheva's conception of modular education as a version of and an improvement of syllabus-type and block-type education, a training was designed which was conducted preeminently on the basis of a syllabus (composed of modules), which allows student to apply the knowledge ac-quired to the solution of cognitive and practical tasks: The technology of the modular training is applied according to the view that each module consists of the following components: (1) clear and well-formulated goal – goal setting; (2) information bank: presentation of the learning content; (3) methodological guidance for achieving the goal; (4) practical exercises (solving cognitive and practical tasks) to form the necessary skills; (5) cognitive and practical tasks which track students' achievements and strictly correspond to the goals set in the respective module (Petrov & Belcheva 2013).

Within the training of students, the learning content is initially divided into three main content panels / modules, which are mixed in essence (integrating, theoretical (informational) and practical (operational) aspect). The thematic content areas are: Spreadsheets, Computer Presentations and Interactive Technologies and Educational Software.

Based on the concept that each image obtained from a previous trans-formation becomes an operand for the next transformation, in the course of the experiment an attempt was made to follow the differences between two transformations (amplitude), as well as to outline the personal trajectory for the development of the digital competence of each student (described by the values of the transformation from the initial to the final state), while a concurrent summary is made of the phase portrait (the set of consecutive transformations (transitions) considered in a certain time interval). This in turn allows for some determination at the time intervals for each individual conversion. The process learning, supported by the functionalities of the electronic platform Blackboard Learn™ for Academic Collaboration, whose effectiveness and capacity have been evaluated in research motivating the development of the described technological model of education in a course in "Information and communication technologies in learning and working in a digital environment".

Within the organization and implementation of student training and given the time horizon of training (for the specific target group) what is taken into account are the conclusions Vasileva made on the basis of a theoretical analysis of modular training which result in highlighting the following features: "(1) modular training provides a study of each component of the didactic system as a relatively independent, functionally oriented fragment of the learning process with its own syllabus-target and methodological support; (2) the modular training presupposes clear structuring of the educational content of the training, consistency in its teaching and learning, provision of the educational process with methodical means; availability of a system for assessment and control of the acquired knowledge and skills, allowing correction of the training process; (3) modular learning provides for variability of learning and adaptation of the learning process to the individual capabilities and needs of learners" (Vasileva 2016).

According to Petrov and Atanasova in accordance with the system-activity approach, the module as an independent part of the training includes "introductory, cognitive and control stage, as they function in a linear sequence and manifest themselves as a guiding, executive and evaluation component of the activity" of the teacher and students (Petrov & Atanasova 2001).

In its original design, the training of students in the Bachelor's degree is planned as modular, taking into account the following advantages, derived by Vasileva: "(1) an optimal balance between theory and practice is achieved in the structure of the modules; (2) the quality of the acquired knowledge and skills increases; the quality of teaching increases; (3) the cognitive load when covering the modules is higher, but the quality of the achieved results is also higher; (4) there is no subjectivity in the evaluation; the evaluation system is accurate and objective; there is a rhythm and completeness of the assessment; (5) each element of the modular vocational training process is clearly defined; (6) the motivation for continuous methodical and specialized qualification of the trainers increases; (7) the share of practical classes is higher than in traditional training; (8) there is a need to keep the evaluation tools up to date" (Vasileva 2016).

In the application of the technological variant discussed above based on the modular-cybernetic approach for development of the digital competence of the students from the professional field Pedagogy in the formed group of Bachelor's Degree students for the comparison of the results by indicators "knowledge" and "cognitive skills" is used Wilcoxon's Test (Wicoxon) to compare two correlated (related) samples (groups). The results of its application show the associated significance level given in the Asymp line. Sig. (2-tailed), for the indicator "knowledge" $p = 0.015 < 0.05$ and for the indicator "cognitive skills" $p = 0.045 < 0.05$. In both cases, it is the basis for the conclusion that the difference between the two estimates is statistically significant, which is the basis for accepting the alternative hypothesis.

Despite the statistically significant difference between the two indicators in the interpretation of the magnitude of the effect of the applied technological variant, where the coefficient d is used, it was found that the indicator "knowledge" $d = 0.62$, while the indicator "cognitive skills" $d = 0.28$, which is the reason for the conclusion that the modular-cybernetic approach – as a basis for the chosen technological option for the development of students' competence at this stage as a priority, has a greater than average impact on knowledge formation and much more to a small extent affects the development of cognitive skills.

The Wicoxon Test was also used to compare the results of the "practical skills" and "problem solving" indicators, and the results of its application show the associated level of significance given in the Asymp line. Sig. (2-tailed) for the indicator "practical skills" is p = 0.055> 0.05 and for the indicator "problem solving skills" is p = 0.065> 0.05, which leads to the conclusion that in both cases the difference between the two assessments is statistically insignificant, which is a reason for accepting the null hypothesis, namely that the applied technological variant does not help the development of problem-solving skills and practical-applied skills.

Conclusions

Based on the conducted empirical research in the application of the developed technological variant, based on the modular cybernetic approach, a statistically significant difference was found between the initial and final state of the achievements on indicators "Knowledge" and "Cognitive skills", but no such difference was registered on the indicators "practical-applied skills" and "problem-solving skills". It is necessary to look for opportunities to combine other approaches in the development of the digital competence of students - future teachers to provide opportunities for the functioning of knowledge in favor of solving cognitive and practical problems.

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