Methods of Designing Digital Learning Technologies for Developing Primary School Pre-Service Teachers' 21st Century Skills

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Abstract. The survey looks into the issue of designing digital learning technologies for training primary school pre-service teachers. The paper discloses the authors' conception of designing digital learning technologies for training primary school pre-service teachers, based on the digital humanistic pedagogy, the multiple intelligence theory, and the theory of open education. The authors present the model of designing digital learning technologies for training primary school pre-service teachers and diagnostic tools, which includes the criteria and indicators of the development of skills to use digital technologies for fostering students' skills. The effectiveness of the authors' methods which have interdisciplinary character and can be implemented into the study of a number of courses, is proved while conducting learning and research projects in formal and informal education.

Keywords: Digital Competence, Primary School Pre-Service Teachers, Multiple Intelligence Theory, Digital Humanistic Pedagogy, Theory of Open Education, Project Learning.

1 Introduction

The modern world is continuously changing and characterized by everyday upgrading of information. To be knowledgeable about the current affairs and trends, teachers should follow innovations both in their pedagogical activities and in various spheres of social life. The reformation of education directs teachers to the necessity to constant professional self-improvement that is caused by the need of meeting the requirements of the dynamic environment. The modern trends of developing social, cultural, and information aspects of pre-service teachers' training are of priority concern of the government that is reflected in the legal and regulatory documents, which define the priorities in education policy of Ukraine: "Strategy of Information Society Development in Ukraine" [1], the Law of Ukraine "On Higher Education" [2], Project

"Digital Agenda of Ukraine – 2020" [3], the Concept of the Development of the Digital Economy and Society of Ukraine for 2018–2020" [4], the Law of Ukraine "On National Program of Informatization" [5] etc.

So one of the priority directions of professional development of pre-service teachers is to enhance their digital competence. Digital competence includes the skills to use different tools (computers, software, local and global networks) and skills to effectively implement them into the pedagogical activities [6]. The high level of the development of primary school teachers' digital competence becomes a key for the effective use of digital technologies in educational practices, as well one of the most important indicators of success of their activities and at the same time it is one of the conditions for further improvement of the level of teachers' professional competence.

In 2006, the European Commission issued the research "Digital Competence in Practice: An Analysis of Frameworks", which discloses that digital competence is an ability to confidently, critically and creatively use information and communication technologies for achieving the aims in the sphere of professional activities, education, leisure-time activities, and participation in social life [7].

As UNO document "Education Research and Prospects of Future Learning: What kind of pedagogies for the 21st century?" (2015) reveals, the framework of educators' competences in international learning environment combines learning and innovative skills, so-calls "4C": cognitive, creative, collaborative, and communicative skills [8].

The scientists of the united research center of the European Commission have developed the European system of digital competence on the base of consultations and active collaboration with a great number of stakeholders and law-makers of such spheres as industry, education, professional training, and social partnership. Christine Redecker and Yves Punie have developed the framework of digital competence for educators (DigCompEdu). European system of educators' digital competence describes the necessary tools for improving the level of teachers' competence development in the sphere of digital technologies. The system of DigCompEdu is developed for implementing the joint approach to defining the main spheres of educators' digital competence in European Union countries [9].

In the concept "New Ukrainian School: Conceptual Principles of Secondary School Reformation" (2016) it is stated that information and digital competence is one of the key competences for life [10].

The issue of pre-service teachers' awareness of implementing digital technologies for intellectual, communicative, and creative development is methodologically significant. One of the relevant ways of developing pre-service teachers' skills is using modern digital technologies and implementing project learning forms.

The implementation of project learning forms aims at the cognitive activities and creative self-realization of students that ensure the development of intellectual abilities, spiritual qualities, creative skills and, what is equally important, communicative and collaborative skills, as it is implemented by rationally combining theoretical knowledge and their practical use.

The analysis of domestic scientific sources provides the ground to assert that the theory and practice of education has accumulated a significant experience of upgrading the specialists' professional training. However, the issue of designing digital

technologies for pre-service teachers' training that may become the basis for improving and developing the 21st century skills, as well their pedagogical skills, needs further studying.

In previous century, the dissemination of the multiple intelligence theory by Howard Gardner started the revolution of the understanding and development of cognitive processes in education and became a certain catalyst, which encouraged educators to rethink the learning practices. The approaches to integrating the multiple intelligence theory with digital technology in learning process is presented only in foreign scientific space. Domestic scientists have never studied the issue of designing digital learning technologies on the basis of using the multiple intelligence theory in primary school pre-service teachers' training.

The purpose of the paper is to substantiate the authors' conception, model and methods of designing digital learning technologies in primary school pre-service teachers' training and to experimentally prove its effectiveness.

The subject of the study includes theoretical and methodological foundations of designing digital learning technologies in primary school pre-service teachers' training.

The target problems of the research are:

- to substantiate the concept of designing digital learning technologies in primary school pre-service teachers' training.
- to develop the model of the system of designing digital learning technologies in primary school pre-service teachers' training.
- to define the criteria and indicators of the development of digital competence as an ability to design digital learning technologies for developing primary school pre-service teachers' key skills.
- to develop and experimentally check the methods of designing digital learning technologies in primary school pre-service teachers' training.

2 Research methods

To achieve the purpose and to solve the target problems of the study, general scientific methods are used which complement and provide the reliability and the validity of the obtained results when they are implemented in a complex way.

The theoretical methods include: analysis, synthesis, and generalization of scientific, learning and methodological sources for defining the state of investigation of the studied issue in foreign and domestic educational space and the essence of main categories of the study, conceptual foundations of the multiple intelligence theory; *netnography* for analysing the papers and blogs which contain the description of foreign experience to implement the multiple intelligence theory in educational practices; *modeling* for studying the features and relationships between the structural components of the process of designing digital learning technologies in primary school pre-service teachers' training; *designing* for developing a model and methods of implementing digital learning technologies in primary school pre-service teachers' training.

The *empirical methods include: observation, survey, expert assessment, pedagogical experiment* for testing the study hypothesis; *methods of mathematical*

statistics for quantitative and qualitative analysis and testing the validity of the experiment results.

As the research has a theoretical and empirical nature, its effectiveness was tested while conducting the pedagogical experiment (2013–2019), which included some stages:

1. The **preparatory stage** of the experiment (2013–2014) involved the implementation of the following steps:

- studying the theoretical foundations of designing digital learning technologies in primary school pre-service teachers' training;
- studying the foreign experience of implementing the multiple intelligence theory in the educational process;
- substantiating the conceptual research principles;
- substantiating the model of designing digital learning technologies in the primary school pre-service teachers' training;
- developing the methods of designing the digital learning technologies for enhancing students' digital competence for ensuring the improvement of their cognitive, creative, communicative, and collaborative skills;
- defining the criteria and indicators of the development of pre-service teachers' digital competence that is determined as students' ability to use digital technologies for developing cognitive, creative, communicative, and collaborative skills.

The authors' conception of designing digital learning technologies in primary school pre-service teachers' training is based on the foundations of digital humanistic pedagogy (Valerii Yu. Bykov, Mariya P. Leshchenko [11]), the multiple intelligence theory (Howard Gardner [12], Thomas Armstrong [13], Walter L. Mckenzie, Jr. [14]), the open education theory (Valerii Yu. Bykov) and the theory of teaching mastery (Ivan A. Ziaziun [15]).

The key idea is that the development of human abilities and their ways of perceiving and learning the information world is considered in accordance with Gardner's multiple intelligence theory. The development of cognitive, creative, communicative, and collaborative skills, which are the 21st century skills, is claimed to be designed taking into consideration the types of intelligence (logical-mathematical, verbal-linguistic, bodily-kinesthetic, visual-spatial, musical-rhythmic, intrapersonal, interpersonal, and naturalistic) and realized by using digital learning technologies that create the conditions for their development.

Designing digital learning technologies in primary school pre-service teachers' training focuses on fostering their digital competence, based on humanistic-technological and intellectual-multiple approaches.

The humanistic-technological approach justifies the creation of the blended learning environment, which combines both bio and techno components to develop and apply students' skills through acquiring competence by using technological tools, designing and implementing digital learning technologies, and solving various technological problems.

The intellectual-multiple approach to designing digital learning technologies for enhancing students' cognitive, creative, communicative, and collaborative skills ensures the improvement of their digital competence and contributes to searching and forming the pre-service teachers' professional identity by making the reasonable choice of digital technologies, forms, and methods, depending on the dominant types of their intelligence and individual profile of each student for solving educational problems.

The developed model of designing digital learning technologies in primary school pre-service teachers' training includes target, content-technological, operational-technological and resulting components.

The *target* component of the model characterizes the focus of the students' learning system on designing digital learning technologies to develop their key competences of the digital society. The target component is presented in the purpose specified in the defined targets.

The purpose is teaching to design digital learning technologies by improving the digital competence for developing cognitive, creative, communicative, and collaborative skills of future Bachelors of primary education.

Specifying the purpose of the development process, its target problems are identified:

- to develop students' ability to design digital technologies for developing their cognitive skills;
- to develop students' ability to design digital technologies for developing their creative skills;
- to develop students' ability to design digital technologies for developing their communicative skills;
- to develop students' ability to design digital technologies for developing their collaborative skills.

The *cognitive skills* are defined as an ability to conduct the cognitive activities, based on designing digital learning technologies in terms of opportunities of their implementation for developing dominant intelligence types and expanding the opportunities of non-dominant ones, which are typical for a certain intelligence profile, as well as to predict the further designing of digital technologies for the cognitive development of learning process participants.

The *creative skills* are interpreted as an ability to realize creative activities, based on designing digital technologies in terms of the opportunities of their implementation according to individual intelligence profiles and to predict the further designing of digital technologies for students' creative development.

The *communicative skills* are determined as an ability to use digital learning technologies for reception and reproduction of information messages while communicating with other people; to adhere to the ethics of network communication; to deepen knowledge about new digital technologies and the opportunities of their use to foster interpersonal interaction.

The *collaborative skills* are considered to be an ability to use digital technologies for providing the interaction with other people who, having different personal characteristics (age, gender, education, social status, experience, and professional

knowledge), are grouped together to fulfil a collaborative learning assignment; to support a positive emotional atmosphere while conducting group interpersonal activities.

The next component of the authors' model is the content-technological one which contains the universal and special digital learning technologies, whose choice is realized on the basis of the multiple intelligence theory by H. Gardner. According to this theory a personality has a number of intelligence types (logical-mathematical, verbal-linguistic, bodily-kinesthetic, visual-spatial, musical-rhythmic, intrapersonal, interpersonal, naturalistic). Each of them represents the special ways of processing and interpreting information messages, informing how a person learns the world.

Digital learning technologies are rapidly developing in both quantitative and qualitative aspects. For achieving the purpose and solving the target problems of the authors' model, two main groups of digital technologies are singled out: universal and special.

The *universal digital technologies* are regarded as learning technologies which can be used for activating the overwhelming majority of intelligence types (four intelligences and more) simultaneously. The universal digital technologies include: electronic social networks, multimedia presentations, game-based learning platforms, computer and video games, video conferences, digital narratives (storytelling) [16].

The *special* digital learning technologies are considered to be those which can activate one, two or three intelligences while being used. The special digital learning technologies include: chat, guest book, blog, forum, e-mail, photo, audio and video editors, resources for creating crosswords, rebus, augmented reality, spreadsheets, databases, online search tools for analysing and collecting data, online tools and applications, which design digital or printed graphic reproduction of time slots (timelines), etc.

The *operational-technological* component of the authors' model implies the realization of the process of teaching students to design digital learning technologies for developing the 21st century key skills in formal and informal education.

The procedure of designing digital learning technologies implies the definition of its opportunities for developing every student's cognitive, creative, communicative, and collaborative skills, depending on his or her unique intelligence profile. The choice of digital learning technologies in accordance to students' unique intelligence profiles is made in two ways. The first one includes the selection of technologies that can activate students' dominant intelligences; the other one is aimed at the compensating role of digital technologies; it means that a digital technology is chosen in the way that improves students' abilities in different types of activities which also require well-developed types of intelligences that are not dominant in this intelligence profile.

For example, if verbal-linguistic and visual-spatial intelligences are dominant for a student's intelligence profile, one should choose digital learning technologies that stimulate these intelligence types (digital narratives, text and graphic editors etc.). If it is necessary to make musical arrangement of information product, those digital technologies should be used that help students whose level of development of musical intelligence isn't high and increase students' expressive capacities.

Thus, digital learning technologies can perform the following functions: activating

and entertaining, activating and compensating.

The activating and entertaining functions are aimed at developing students' skills and abilities, contributing to activating dominant intelligences of an individual intelligence profile.

The activating and compensating functions can increase students' opportunities for creating information messages, strengthening and enabling the definition of this individual intelligence profile.

By combining different forms and methods of formal and informal education (lectures, seminars, laboratory works, trainings, discussions, projects, etc.), the open blended learning environment is developed that is characterized by high potential of developing students' cognitive, creative, communicative, and collaborative skills.

The *resulting* component of the authors' model is characterized by the development of digital competence that is distinguished by primary school pre-service teachers' ability to design digital learning technologies for developing cognitive, creative, communicative, and collaborative skills of all the participants of educational process.

The authors' model of designing digital learning technologies in primary school pre-service teachers' training belongs to individual learning models, as its developing and implementing are based on the idea of defining the opportunities for designing digital learning technologies in the educational process for developing every student's cognitive, creative, communicative, and collaborative skills, depending on his or her intelligence profile.

The model has a variable nature that is caused by the choice of digital learning technologies and has exactly defined characteristics, depending on the features and functions, defined for using digital learning technologies and a type of learning activities (see fig. 1).

Based on the conception and model, the methods of designing digital learning technologies in primary school pre-service teachers' training are developed.

The specificity of the methods is concretizing the choice of digital learning, based on the number of factors:

a. defining by an educator a target problem on improving students' ability to design certain digital technologies for developing key skills;
b. distinguishing students' individual intelligence profiles and, based on them, defining the activating and entertaining, activating and compensating functions of exactly chosen digital learning technologies;
c. implementing project learning that has both monodisciplinary and interdisciplinary nature and is realized in such projects: "Interactive Book", "Interactive Poster", "Making Video Clips", "Prevention of Primary Schoolchildren's Computer Addiction", "Student Scientific Conference", etc.

The *target* component includes the improvement of students' abilities to design exactly chosen digital technologies for developing primary school pre-service teachers' cognitive, creative, communicative, and collaborative skills.

The *diagnostic-motivating* component implies the definition of students' intelligence profiles and their motives for using digital learning technologies in professional activities and in everyday life.

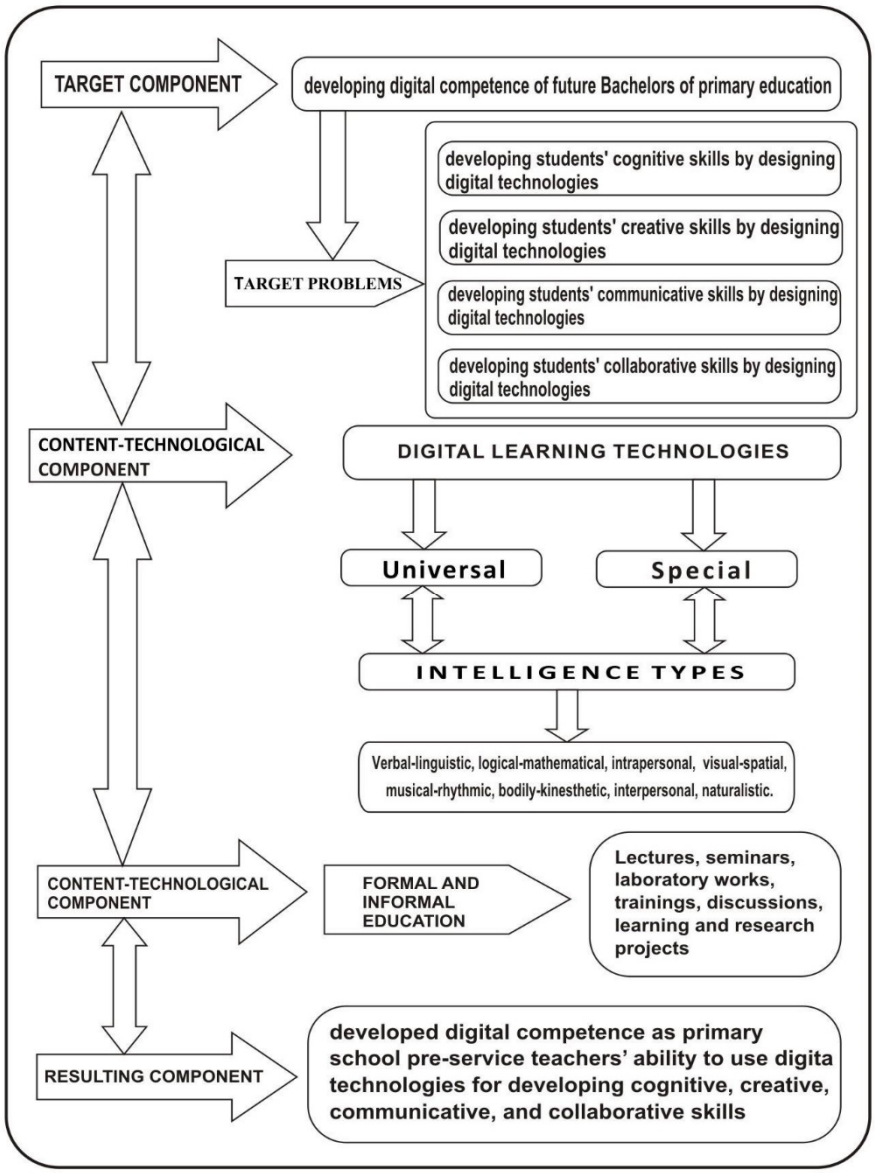

Fig. 1. The model of designing digital learning technologies in primary school pre-service teachers

The *content-technological* component involves creating learning content that is characterized by different digital learning technologies and their opportunities which contribute to developing cognitive, creative, communicative, and collaborative skills, as well as skills to act safely in information environment. The component contains the

characteristics of digital learning technologies which primary school pre-service teachers should use in educational process for developing different types of intelligence and key skills. While implementing different projects, a complex of universal and specific digital learning technologies is used, such as:

"Interactive Book" includes the use of universal (multimedia presentation and digital storytelling) and special (tools for online search, photo, video, audio, graphic and musical editors – by students' own choice) digital technologies [17];

"Interactive Poster" is based on using multimedia presentation as a universal digital technology and a number of special digital technologies (tools for online search, photo, video, audio, graphic and music editors, resources for making crosswords, rebus, online tools and applications for digital or printed graphic reproduction of time slots (timelines) – by students' own choice);

"Making Video Clips" requires the use of special digital technologies (tools for online search, photo, video, audio, graphic and music editors) and universal digital learning technologies – electronic social networks for disseminating the digital products;

"Prevention of Primary Schoolchildren's Computer Addiction" is implemented by the use of universal digital learning technologies (multimedia presentation, digital storytelling, electronic social networks, game-based learning platforms, video conferences); as well a number of special digital learning technologies (e-mail, tools for online search, photo, video, audio, graphic and music editors, resources for making crosswords, rebus, etc.);

"Student Scientific Conference" is held on the basis of using universal digital learning technologies (multimedia presentation, digital storytelling, electronic social networks, video conferences) as well special digital learning technologies (e-mail, chats, tools for online search, text, photo, video, audio, graphic and music editors).

The *operational-technological* component is characterized by active forms and methods of learning, in particular, interdisciplinary project learning in formal and informal education.

The process of designing digital technologies for developing a digital learning resource that can be used in future teaching activities includes eight functionally interrelated stages:

1. Designing the project of digital learning resource, taking into consideration the learning content, students' individual characteristics, their cognitive interests and needs and the definition of its teaching potential.
2. Choosing digital learning technologies for realizing the creative ideas according to the quality of digital learning resources, the development of digital skills and students' individual intelligence profiles.
3. Making digital learning resources.
4. Sharing digital learning resources in the network and analysing their teaching potential, based on the proposals for improving their qualities.
5. Making necessary changes in digital learning resources.
6. Experimental implementation of digital learning resources in the practice and evaluating of its effectiveness.

7. The final designing of digital learning resources.
8. Making recommendations for its implementation.

The *resulting* component is defined by the development of digital competence as an ability to design digital learning technologies for developing cognitive, creative, communicative, and collaborative skills.

2. The **research stage** involves confirming, forming and controlling experiment (2014–2018) which provides for the experimental testing the effectiveness of the authors' model and methods of designing digital learning technologies in primary school pre-service teachers' training.

The research and experimental activities were held at the Faculty of Primary, Technological and Vocational Education at Donbas State Pedagogical University (Sloviansk, Ukraine). The research engaged 90 primary school pre-service teachers, aged between 19–29, who were gaining their first higher education in specialty "Primary Education".

The purpose of *confirming* experiment is to define the actual level of skills of future Bachelors of education to design digital technologies according to the criteria determined and to study the dominant type of intelligence.

The diagnostic of skills is conducted through the survey which includes self-assessment of the skills to design digital technologies for learning activities and everyday life.

The diagnostic of dominant types of intelligence is held, using the methods of defining the multiple intelligence of Walter L. Mckenzie, Jr.

The results prove that the dominant intelligence types of the majority of students, who are gaining the specialty "Music", are musical-rhythmic, intrapersonal and interpersonal. The dominant intelligence types of students of the specialty "Choreography" are bodily-kinesthetic, visual-spatial and interpersonal. The dominant intelligence types of students of the specialty "The English Language" are verbal-linguistic, interpersonal and intrapersonal. The dominant intelligence types of students of the specialty "Computer Studies" are logical-mathematical and interpersonal.

According to the results of the confirming experiment, the program of forming experiment is developed which implies practical implementation of methodical system of designing digital learning technologies. The activities are conducted within the courses "Information Technologies in Teacher Professional Activities", "Modern Information Technologies", "Foundations of Scientific Research", "Pedagogical Informatics" and others while realizing interdisciplinary projects, teaching practices and informal teaching activities in extracurricular work during four-year study.

The forming experiment is aimed at testing the research hypothesis about that the implementation of methodical system of designing digital learning technologies in training of future Bachelors of education ensures the improvement of the level of development of students' digital competence that contributes to enhancing their cognitive, creative, communicative, and collaborative skills.

The following target problems should be resolved during the formal experiment:

- to experimentally check the feasibility of implementing the methodical system of designing digital learning technologies in the process of primary school pre-service teachers' training;
- to study the influence of implementing the authors' methodical system and the development of students' cognitive, creative, communicative, and collaborative skills;
- to test the feasibility of the content and components of the methodical system in the process of primary school pre-service teachers' training.

3. The **controlling experiment** includes the diagnostic and analysis of the level of development of students' skills to design digital technologies, studying the dynamics of increasing the indicators of digital competence of future Bachelors of education to design digital learning technologies.

The criteria and indicators for testing the development of digital competence have been defined and described in details in our previous research [18].

4. **Processing and interpretation** of research data, making conclusions, making recommendations and defining the directions of further research (2018–2020).

3 Results

The results of the experiment, focused on training in designing digital learning technologies, are implemented in the development of digital competence as an ability to design digital learning technologies for developing primary school pre-service teachers' cognitive, creative, communicative, and collaborative skills, presented in comparative analysis of indicators, obtained at the initial and final stages of research (2018).

Comparing the development of pre-service teachers' skills to design digital technologies shows that at the initial stage of research 80% of participants have low or sufficient level and only every fifth has the high level. After implementing the pedagogical experiment, the distribution of students according to high, sufficient and low levels and criteria-based characteristics has significantly changed. The level of students (17,8%) has considerably increased, so the indicators of low level have significantly (twice) decreased, as well as indicators of the high level have improved (see fig. 2).

The least noticeable changes opposed to the other skills have been registered when comparing the indicators of the development of an ability to design digital learning technologies for improving creative skills. The quantitative indicators confirm the positive changes, but they are not so significant as, for example, results, gained while investigating cognitive skills. 4 students have upgraded their status (proceed to higher level), but this progress has been made by moving from the low level to the sufficient one. This fact proves the complexity of training to design digital learning technologies for developing creative skills (see fig. 3).

The conducted research gives us an opportunity to conclude that at the initial stage the majority of future Bachelors of education have low (17,8%) and sufficient (57,8%) level of development of an ability to design digital learning technologies for developing

communicative skills according to the criteria defined and every fourth of the students (24,4%) have high level.

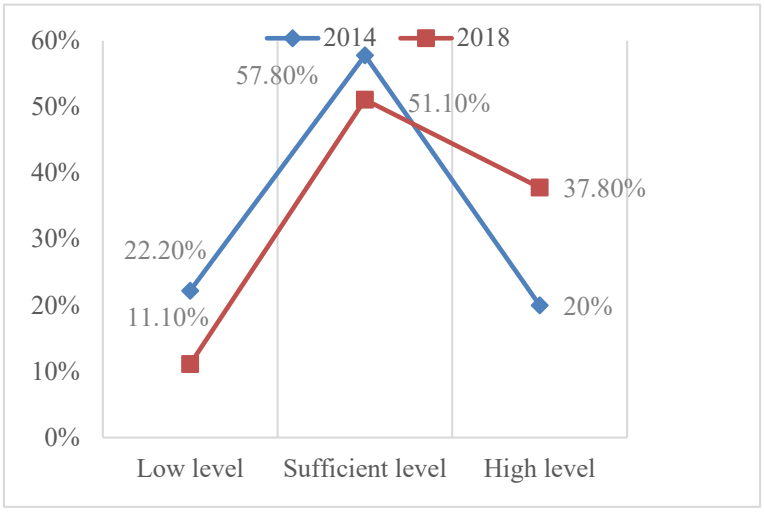

Fig. 2. Comparing the levels of the development of digital competence in designing digital technologies for enhancing cognitive skills in 2014 and 2018

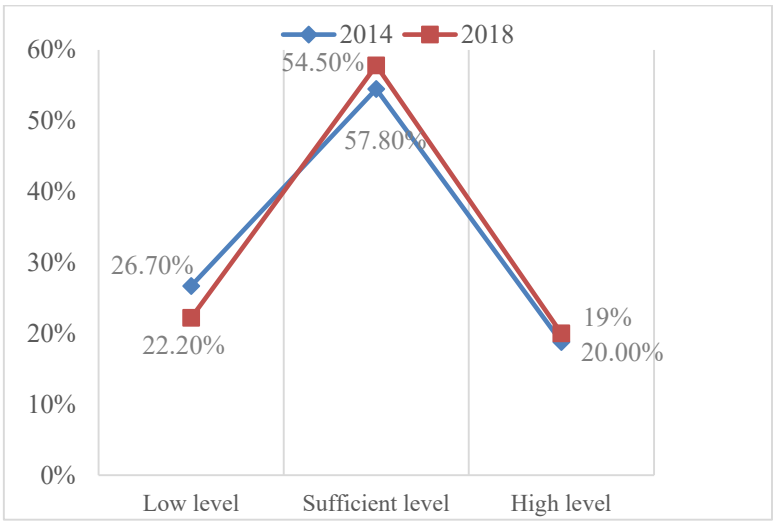

Fig. 3. Comparing the levels of the development of digital competence in designing digital technologies for enhancing creative skills in 2014 and 2018

The conducted research gives us an opportunity to conclude that at the initial stage the majority of future Bachelors of education have low (17,8%) and sufficient (57,8%) level of development of an ability to design digital learning technologies for developing

communicative skills according to the criteria defined and every fourth of the students (24,4%) have high level.

After conducting the pedagogical experiment, the distribution of the students according to low, sufficient and high level and criteria-based characteristics has significantly changed. The number of students, who have low and sufficient levels of communicative skills, have decreased by 5,6% and 3,3% respectively. So the number of students with high level has increased by 8,9% (see fig. 4).

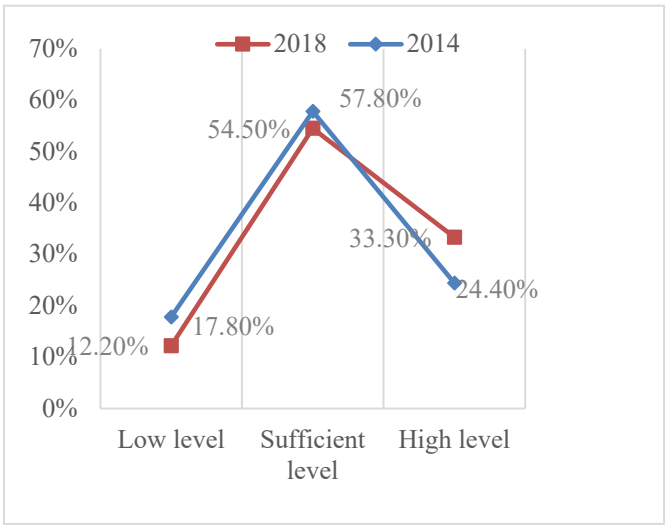

Fig. 4. Comparing the levels of the development of digital competence in designing digital technologies for enhancing communicative skills in 2014 and 2018

The results of research give us an opportunity to assert that at the initial stage of the research the majority of students (more than 75%) have not the skills to design digital learning technologies for developing skills to work efficiently in teams.

The implementation of the methodical system of designing digital learning technologies in training of future Bachelors of education contributes to improving the levels of development of an ability to design digital learning technologies for developing collaborative skills as 70% of students have achieved sufficient and high level, whereas the number of students with the high level has tripled (see fig. 5).

Thus, the main purpose of the experiment has been achieved as we gain comparative figures of the levels of development of digital competence of future Bachelors of education whose dynamics of changes is a reason to state the tendency of improving the effectiveness of educational process through implementing the methodical system of designing digital learning technologies.

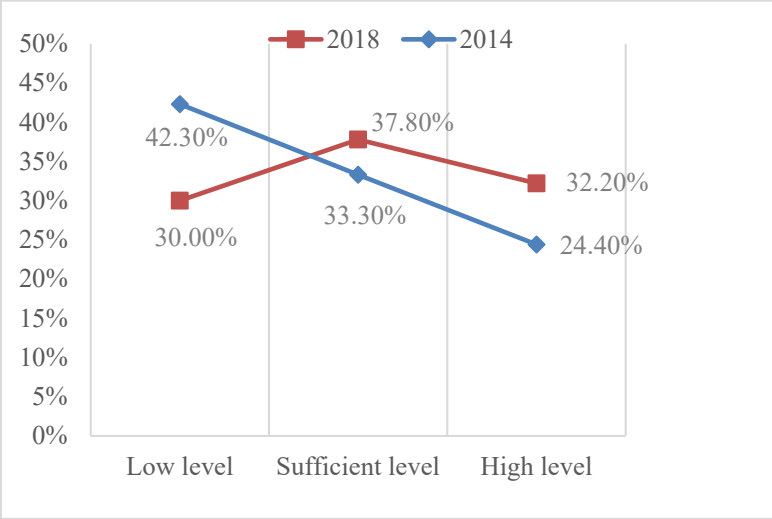

Fig. 5. Comparing the levels of the development of digital competence in designing digital technologies for enhancing collaborative skills in 2014 and 2018

4 Conclusions

In the article the methods of designing digital learning technologies in primary school pre-service teachers' training are substantiated and experimentally testified, which are aimed at using technologies for supporting the development of ways to perceive and produce information messages, improving cognitive, creative, communicative, and collaborative skills of all the participants of educational process.

The theoretical framework of the methods is the authors' conception of the feasibility of using the multiple intelligence theory by H. Gardner for choosing digital learning technologies, as their implementation creates conditions for developing all the types of intelligence, namely: logical-mathematical, verbal-linguistic, bodily-kinesthetic, visual-spatial, musical-rhythmic, intrapersonal, interpersonal, and naturalistic.

For studying the opportunities of reproducing the authors' conception in the educational process, the model is developed, whose specificity is explained by the fact that the blended learning environment is developed due to training primary school pre-service teachers to design digital learning technologies. In this environment the abilities of every participant are revealed, critical thinking, creativity, communicability, and collaborativity – the key skills of modern people – are developed.

The authors' model to design digital learning technologies in primary school pre-service teachers' training belongs to innovative individualized learning models. It has also interdisciplinary and variable character, as well as it gets certain features according to the specificity and functions, provided for using digital learning technologies and types of learning activities.

Based on the conception and model, the methodical system for designing digital learning technologies in primary school pre-service teachers' training is developed.

The methodical system includes five interrelated components: target, diagnostic-motivating, content-technological, operational-technological and resulting ones. The structure of each component is defined by the content of target problems, type of students' individual intelligence profiles, monodisciplinary or interdisciplinary character of project learning.

The dynamics of changes and gained comparative figures of the development of digital competence of future Bachelors of education are the reasons to state about the tendency of improving the effectiveness of educational process through implementing the methodic system of designing digital learning technologies.

In our opinion, the opportunities of designing digital technologies for developing citizens' competences in conditions of informal education requires the further research.

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