

Methodical preparation as a means of developing prospective mathematics teachers' ICT competency

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Abstract. The purpose of the study is modeling of ICT competence formation of would-be mathematics teachers through the best practice application of effective ICT tools. The objectives of the study are to analyze the possibilities of creating conditions for the formation of competent mathematics teachers using ICT tools. The object of the study is the methodical preparation of students of pedagogical HEIs by means of ICTs. The subject of study is the peculiarities of the formation of a competent mathematics teacher in classes on methodical disciplines. The authors of the article analyze, summarize and systematize research on the issue of using ICT tools in the training students' activities in Universities of Teacher Education. The study determines the role of methodical training in the development of ICT competence of would-be mathematics teachers. The authors of the study developed a model for the formation of would-be mathematics teachers' competence, which consists of four components. There is the target, preparatory, procedural, and resulting components. The model describes a systematic approach to the organization of students' learning activities in the teaching of professional and practical training disciplines. Taking into account the integration nature of the methodical training of students, the organization of distance communication between students and teachers is also considered. This paper presents examples of the implementation of model components. It describes the implementation by students of course projects and degree projects on teaching mathematics methods using ICT tools. A pedagogical experiment was conducted to evaluate the effectiveness of ICT tools in the training of would-be mathematics teachers. The results of the study confirmed the effectiveness of modeling the organization of students' activities to develop their ICT competency. As the follow-up research directions, we consider summarizing recommendations on the usage of ICTs in the preparation of competent socionomic specialists.

Keywords: course project, degree project, ICT tools, training of would-be teachers

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1. Introduction

The information society requires the ability to see and understand the picture of the world, to identify and analyze various aspects of objects, processes and phenomena. Against this background, the aim of educational activities should be the training of specialists capable of making the transition from an industrial to an information society through innovations in education. This is emphasized in the state normative documents of Ukraine regulating education (“Law of Ukraine On Higher Education” [21], “National Strategy for Education Development in Ukraine for 2012–2021” [9]). Professional training of specialists in various areas of the information society requires research on the choice of innovations. This is necessary for the preparation of qualified competent specialists in the relevant field.

The International Society for Technology in Education (ISTE) has formulated directions for the use of information and communication technologies in the educational process and the main characteristics of ICT competence [8].

The analysis of scientific sources [8, 11, 15] on the definition of ICT competence makes it possible to understand the ICT competence of a future mathematics teacher as the ability to use information and communication technologies and resources for the conscious fulfillment of tasks in the chosen professional field.

The question arises as to how the training of a future mathematics teacher should be organized in order to form his/her ICT competence in the learning process. Currently, much attention is paid to substantiating the issues of involving ICT tools in the process of training future specialists in various fields. Occupying a certain place in the hierarchy of pedagogical innovations, the involvement of ICTs in the training of future teachers meets certain goals aimed at improving the indicators of the current state of professional training. For future teachers, ICTs are both a means of obtaining high professional qualifications and the aim of mastering ICTs involved in secondary education. This dual role of ICTs in the training of prospective teachers determines the nature of the use of ICT tools in the educational activities of students majoring in mathematical specialties of pedagogical HEIs. This, in turn, contributes to the formation of ICT competence of would-be mathematics teacher.

Many studies of recent years highlight various aspects of the problem of training qualified and competent specialists in HEI. Thus, the problems of personnel training for the use of ICTs in pedagogical activities are revealed (Bykov [1], Lovianova [5], Vlasenko, Rotaneva and Sitak [17], Vlasenko, Sitak and Chumak [18]); the content and models of formation of primary school teachers’ ICT competence (Shishkina and Tataurov [15]), mathematics teachers’ competence (Petrenko [11]) are substantiated; ICT competencies are distinguished as professional competencies in the field of education [14, 19]; the process of joint creation of a network educational community of teachers-practitioners to support the professional development of information and communication technologies is studied (Watson and Prestridge [20]); the role of the course model, which should help organize the learning process by promoting effective, holistic and focused practice of users (Porter [12]); the use of scientific approaches is emphasized, in particular the principles of: systematization, humanity and professional orientation, flexibility, dynamism and variability during modeling (Perogonchuk [10]); among the tools that ensure the professional growth of future teachers, researchers include ICT tools, and also insist on the importance of involving future teachers in the use of computer mathematics systems in the

preparing them for teaching (Karsenti et al. [3], Lovianova et al. [7]).

However, in our opinion, the pedagogical modeling of the process of formation of ICT competence of future specialists remains irrelevant for researchers.

The *purpose* of the article is to describe a model of methods for forming ICT competence of future mathematics teachers.

2. Theoretical fundamentals of research

The use of ICTs in the professional activities of a teacher is provided by the comprehensive training: instrumental training (mastering the basics of office technology, multimedia, ICTs); psychological and pedagogical training (mastering the psychological and pedagogical features of students of different ages, the use of ICTs in modern schools); practical training. This approach allows you to master the ICT tools chosen for training comprehensively. Training for the use of ICT tools in future professional activities is both directly (content module “Information and communication tools for teaching mathematics” in laboratory classes on methods of teaching mathematics, preparation of presentations for lessons, development of interactive didactic materials during pedagogical practice) and indirectly as, for example, time of course work in methods of teaching mathematics. A generalizing role in the formation of the ICT competence of the prospective teacher belongs to methodological training. During this training, students in small groups under the guidance of a teacher perform activities such as practical and laboratory classes on methods of teaching mathematics, practice at school, course project.

Thus, it is possible to model the process of formation of ICT competence of the future mathematics teacher.

Descriptive, explanatory or prognostic models are used in pedagogical research, which allow: to formalize the designed processes; to make predictions about the relationships and the reasons that affect the events; to involve a list of recommendations; to give a brief description or abstract mathematical constructions.

According to Shtoff [16], models are simple substitutes for objects. The conditions for creating a model are such that it is separated and enshrined in its major elements and the connection between them significant and necessary links that form a completely appropriate structure.

Modeling is considered as a way of knowing reality, which consists in the reflection and reproduction of the object, phenomenon or process which are studied with the help of any system. The following features are distinguished in the model: a) imaginary representation or material realization of the system; b) display of the object of study; c) the ability to replace the object; d) study of the model to obtain new information about the object.

The modeling method is a general scientific method and is used to study objects of various nature. These can be natural organisms, objects, phenomena, processes, events of reality – both physical and social.

Modeling is also widely used in pedagogy. The specifics of its use in pedagogical theory and practice are revealed in the investigations of methodists. In practice, it is used in the vast majority of pedagogical research [13]. However, due to the extreme complexity of pedagogical reality, no model can be adequate to the simulated phenomenon and fully reproduce the object under study. Therefore, when developing a model, we need to determine which elements,

properties, dependencies can and should be reflected in it.

Regarding the use of the model in pedagogy, one should agree with Fridman [2], who points out that it is advisable to consider the model and modeling in a broad sense, if we keep in mind pedagogical aims. Presenting the definition of the model in a broad sense, Fridman [2] writes: “The model of some object A (original) is called object B, in some respects similar to the original A, selected or constructed by the subject (person) at least for one of the following purposes: 1) replacement of A in some mental (imagined) or real action (process), based on the fact that B is more convenient for this action in these conditions (substitute model); 2) creating an idea of object A (actually existing or imagined) with the help of object B (model-conception); 3) interpretation of object A in the form of object B (model-interpretation); 4) research (study) of object A with the help of object B, with the help of study of object B (research model)” [2].

According to Lodatko [4], pedagogical model is a thinking system that simulates or reflects certain properties, characteristics of the object which is studied or its internal organization and principle of functioning. This thinking system is presented in the form of a cultural form inherent in a particular socio-cultural practice.

In order for the model to be suitable for the specified purposes, it must meet these target characteristics.

Descriptive, explanatory or prognostic models are used in pedagogical research, which allow:

- to formalize the designed processes;
- to make assumptions about the correlations and reasons that affect events;
- to make a list of recommendations;
- to provide a brief description or abstract mathematical constructions.

With the help of models it is possible to design this or that area of knowledge, skills, abilities of any participant of the pedagogical system, which they should be in terms of the desired result. It provides knowledge of what needs to be formed. And the comparison of what forms the system with what should be formed, allows you to qualify the existing pedagogical system and make a conscious search for ways to improve it.

According to the nature of the reproduced sides of the original, different types of models are distinguished. The main ones are structural, functional and mixed models. Structural models imitate the internal organization of the original. A functional model is a model that imitates the behavior (function) of the original. The use of mixed models is due either to the impossibility of using one basis of modeling, completely abstracting from others, or by the natural feature of the models that the relationship between their nature and the nature of the basis of modeling is not unambiguous, or that most emerging problems are complex, multi-linear. This often combines structural and functional approaches. The mixed nature of the models in these cases is determined by the nature of the modeling method itself, which implies by establishing the similarity of the model and the original in one respect, to obtain information about the original in another respect. Thus, by establishing the structural similarity of the model and the original on the basis of information about the functions of the model we obtain information about the functions of the original. Establishing the similarity of functions, we obtain information about the structure of the original. Thus, we have two subspecies of mixed models of this kind: in the first case – structural-functional model, and in the second – functional-structural.

The initial typology of models according to Lodatko [4] is based on generalized subjects of modeling, which include content, structure and functionality. According to these subjects, the basic types of pedagogical models are: semantic, structural and functional. The derived types of models have a dual subject of modeling and the corresponding types: structural-semantic, structural-functional and functional-semantic.

Modeling in our own research the process of formation of ICT competence of the future teacher of mathematics, we will use pedagogical modeling, while the model will have a double subject of modeling and the type will be structural-semantic.

The component composition of the model of formation of ICT competence of the future teacher of mathematics is interrelated target, preparatory, procedural, and effective components.

The target component of the model is determined by the fact that the training of a competitive specialist who is able to confidently use information technologies in professional activities involves significant adjustments to the modern system of training future mathematics teachers. The target component of the model is aimed at forming a developed competent personality capable of development and self-development in a dynamically changing information space.

Motivational-value and intellectual-cognitive components are the elements of the preparatory stage, determine the level of students' motivation to master ICT tools in order to use them in future professional activities and study the level of students' awareness of ICT tools in education.

The procedural component consists of content-activity, organizational-activity and control-reflexive elements. Thus, the content-activity and organizational-activity components determine: the content, methods, forms and means of forming the ICT competence of the future mathematics teacher; a set of psychological and pedagogical approaches to the personality of students, aimed at the result of training. This result is a competent graduate of pedagogical HEIs in the field of ICTs with the appropriate level of preparation. The control-reflexive component involves constant two-way communication with the components of the model described above in order to control the formation process of ICT competence and make appropriate adjustments to this process.

The final component of the model involves determining the level of ICT competence of a future mathematics teacher and is constantly dependent on the target component.

The model of ICT competence formation with the complex of all its components provides a systematic approach to the organization of students' educational activities in teaching disciplines of the cycle of professional and practical training. This model assumes the organization of remote communication between teachers and students, as well as the integration nature of methodological preparation and reflection of the research result in the master's thesis (figure 1).

3. Methods

Let us describe the essence of the preparatory and procedural components of the model.

Motivational-value and intellectual-cognitive components of the model has provided a study of students' awareness of ICT learning, the level of their motivation to use ICT in future professional activities. The results of the survey of students who acquire the profession of teacher were as follows: 74.2% of respondents use information and communication tools for self-improvement in professional activities. At the same time they:

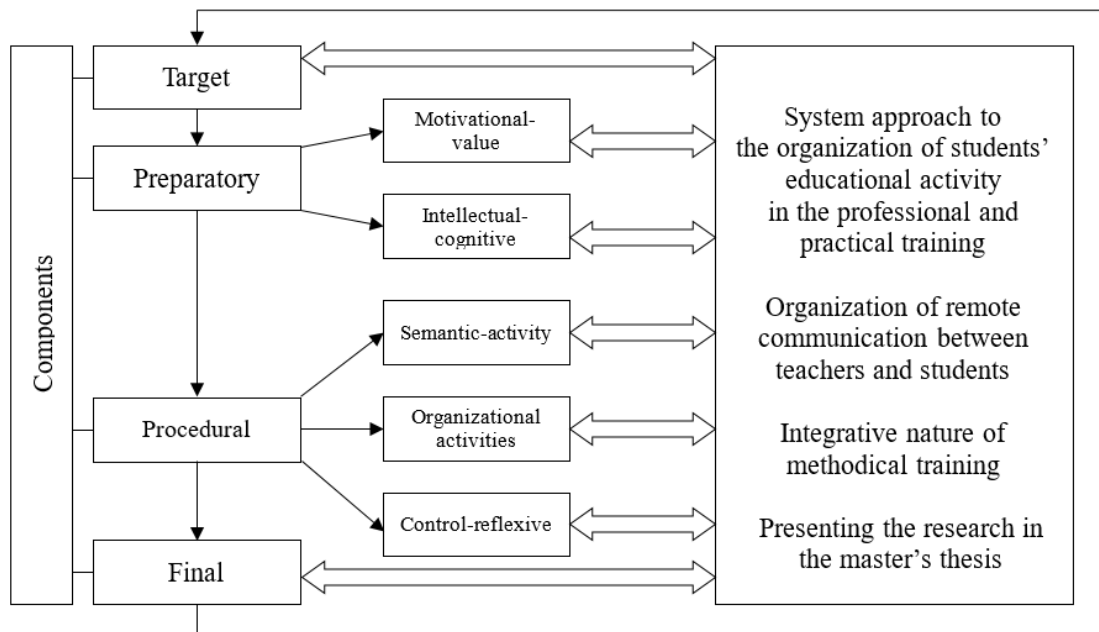


Figure 1: Structural and semantic model of ICT competence formation of a future mathematics teacher.

- expect from innovative technologies unique knowledge and experience in project implementation with the help of innovative technologies (51.6%);
- want to expand their knowledge in the field of ICTs – 43.5% of respondents;
- want to get an interesting job that requires knowledge in the field of ICTs (41.9%).

Data on students' awareness of certain software and use of mathematical software in their own learning activities, obtained during the survey, are presented in table 1 and table 2.

Table 1

Data on students' awareness of software and its facilities.

Software used by students	Number of respondents	Percentage
Presentations (PowerPoint, Google Slides)	56	90.3%
Spreadsheets (Excel, Google Sheets)	45	72.6%
Electronic manuals	43	69.4%
Test tasks (Google Docs, Google Forms)	40	64.5%
Programming environment (Visual Studio, Delphi, Scratch)	28	45.2%
Virtual laboratory	7	11.3%
Video (CamtasiaStudio)	7	11.3%
Software for creating a game product (Construct 2, Unity 3D, Game Editor)	3	4.8%

The obtained results and their analysis has led to develop the procedural component of the ICT competence formation of a future mathematics teachers. This involves a systematic

Table 2

Data on the use of mathematical software in educational activities.

Mathematical software	Number of respondents	Percentage
GeoGebra	50	80.6%
GRAN	31	50%
MATLAB	28	45.2%
Mathcad	14	22.6%
Sage	12	19.4%
DG	5	8.1%

approach to the organization of students' educational activities in their professional and practical training.

The purpose and objectives of teacher's ICT competence are to provide methodical preparation of prospective teachers, to form professional competence of graduates, which combines mathematical knowledge, psychological, pedagogical and methodical training. Personal qualities, a conscious attitude to self-improvement and the ability to organize the educational process at the level of modern requirements complement the content of this competence.

ICT competence of the prospective mathematics teacher is acquired by students in lectures, practical and laboratory classes, during active pedagogical practice. This is how the content-activity stage of the procedural component is realized.

The organizational-activity stage involves independent work of students and remote communication with the teacher, for instance, during active pedagogical practice and writing a course project. The writing of course projects is one of the types of independent work of students in the discipline [6], so the writing of course projects on methods of mathematics teaching will be an effective means of methodical training of prospective teachers and the formation of their ICT competence. Therefore, the topics of student's research should be aimed at highlighting the methodical features of studying some content lines of the school mathematics course by means of ICTs. Moreover, the effectiveness of the work can be seen in the processing of certain course sections according to a specific scheme.

Here is the algorithm of student's actions when completing a course project on the methods of mathematics teaching in the formation of their ICT competence:

1. Analysis of programs and textbooks.
2. Highlighting of the main concepts of the topic (section), conducting a logical and didactic analysis of those concepts that are considered in the topic.
3. Substantiation of the methodical features in teaching rules, algorithms and theorems of the considered section.
4. Analysis of exercises aimed at mastering the topics of the section, which are contained in the current textbook.
5. Studying the possibilities of implementing interdisciplinary connections and using information and communication technologies in the learning process.
6. Providing examples of mastering some topic of the school mathematics course by students using ICT tools known to them or developing alternatives.

Therefore, there was a proposal during the course project on methods of mathematics teaching to use both known mathematical software, thoroughly processed in previous stages of learning, such as GeoGebra, and those services that they should develop independently at the stage of course project. An example of such tools is Construct 2 (a designer of two-dimensional games for Windows) or a similar tool of the student's choice.

4. Results

Let us consider examples of the implementation of the procedural component of the model. Thus, the student demonstrates the use of the GeoGebra dynamic mathematics system completing a course project on the topic "A formation of students' logical thinking in solving of the cutting problems".

Let us describe the content of paragraph 6 of the student's action algorithm when writing a course project. The project presents the task: Three identical triangles are cut by different medians. Is it possible to make one triangle out of six triangles formed in this way?

To solve this problem, you can prepare a blank for a multimedia board, developed in GeoGebra. This development will be especially effective if students can move and rotate cut triangles on their own. As a result of several attempts, students will be able to get a solution to the problem (figure 2).

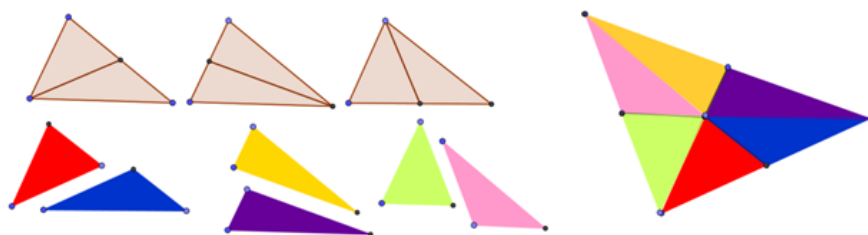


Figure 2: The process and result of solving the problem using GeoGebra.

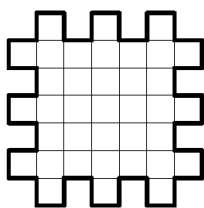


Figure 3: Figure for problem 2.

The student also has demonstrated the use of GeoGebra to solve the following problems:

1. Cut a 4x9 rectangle into two equal parts to form a square.
2. What is the smallest number of rectangles you can cut the figure shown in figure 3, if the cuts are allowed only on the sides of the cells?

To work effectively in the lesson, the teacher can prepare models for the tasks in advance. Moreover, it can be electronic dynamic models. These are becoming widespread in the modern educational space due to the high level of clarity and ease of use. The student offers to teach school students the topics of stereometry using the capabilities of this tool. This idea is the basis of the master's thesis "Problem based approach to the formation of logical thinking of high school students in teaching Mathematics".

Here is an example of the task. At the base of the pyramid is an isosceles triangle with angle β at the vertex and radius R of the circumcircle. The plane of each side face of the pyramid forms an angle α with the plane of the base. Find the area of the side surface of the pyramid.

Methodical commentary to the task. In order to deeply analyze the conditions of the task and the statement to be proved, as well as further generalization, we propose to use the capabilities of GeoGebra. It is convenient to organize work with two canvases of the program – 2D and 3D (see figure 4).

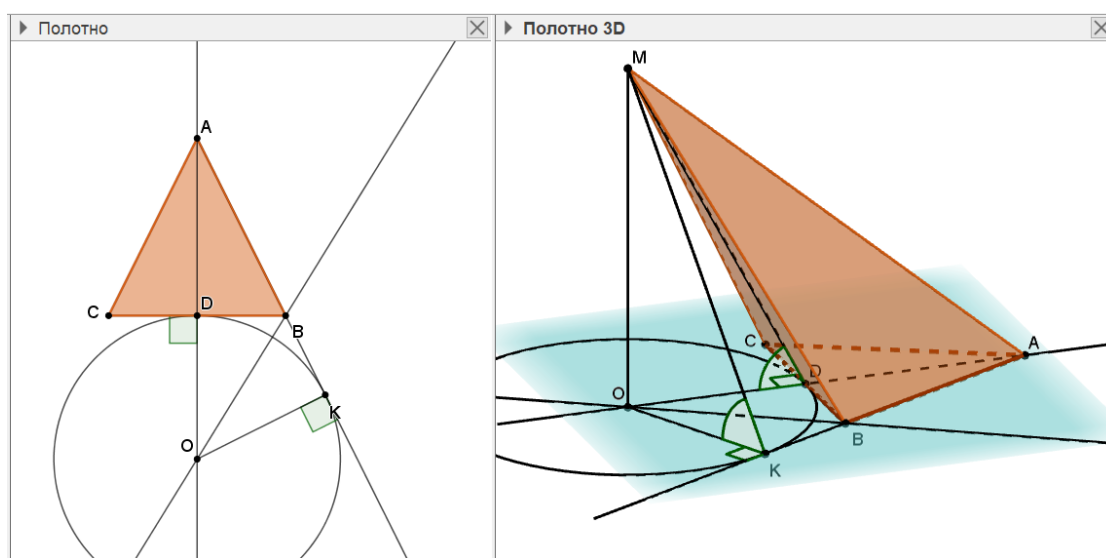


Figure 4: Dynamic model for the task, performed on a multimedia board in GeoGebra during the lesson.

Thus, on the plane you can perform the construction of the triangle underlying the pyramid, determine the position of the center of the inscribed circle of this triangle. At this time, on another canvas is automatically built the appropriate spatial drawing, on which you can complete the pyramid and conduct study. Thus, organized work with the task allows you to perform a mental comparison operation.

Tasks of course and diploma projects also involve independent mastering of ICT by students, for example, in studying the topic "An organization of didactic games in Mathematics lessons by ICTs". The student in his thesis involves not only known services he mastered during classroom classes, but also chooses additional ICT tools, justify their use and develop tasks within the course project. The algorithm of the student's actions was as follows:

- 1) find an ICT service that can be freely used by the teacher in the professional activity;

- 2) learn how to work with the selected service;
- 3) substantiate the expediency of its use in education;
- 4) use the service to reveal the topic of own research within the course project;
- 5) give examples and recommendations for using the service.

For example, point 3 of the action algorithm provides the following description of the selected service: Construct 2 is an HTML5-based 2D video game engine developed by Scirra Ltd. Construct 2 allows anyone to create 2D games of any complexity and any genre, even without programming skills. Games made on it are easily imported to all major platforms – Windows, Mac OS, Linux, browsers with HTML5 support and others.

The interface of the program is intuitive and easy to master, thanks to the visual WYSIWYG-editor. Game logic in Construct 2 is created using a system of events and related actions.

This game designer allows you to easily create game prototypes, demos, presentations and interactive training programs. Since Construct 2 is free and open source, anyone who wants to master it has open access to the world of video game design, with easy learning.

The student also gives a detailed description of the game project for the Mathematics lesson (point 4 of the algorithm).

1. *Creating a project.* Run Construct 2 and select the menu item “File” → “New”. Let’s make an empty project based on screens with a large resolution. Select the template “New empty HD portrait 1080p project” (the game will work in portrait orientation) and click “Open”. In the properties panel we set the data about the project: name, version, description, author (company name or name and surname of the developer), e-mail address and website address (figure 5).
2. *Create a game menu.* After creating the project, tabs “Layout” and “Event sheet” appear. The first tab is the layout of the screen or scene that the player will see. The second tab is the event page. The layout model has already been created, so it is used for the game menu. After editing the properties of the menu screen, create a scene with the button “Pass the test”.
3. *Creating objects.* In the course project, the objects of the game are planets of different colors (three planets correspond to three levels of the game). These objects were created in Adobe Photoshop. After adding an object to the layout, it appears in the “Projects” panel. To add another instance of The Planet to the layout, drag it from the Projects panel to the menu layout. After dragging, there will be two objects on the layout, similarly add the third object. This way, you can create any number of game objects. There are three such objects in the described course project, these are the planets called “The Planet of Viète”, “The Planet of Archimedes”, “The Planet of Newton”. The next stage is programmed operations that allow you to proceed to the tasks of the game, the calculation of correct and incorrect answers to questions and display this information on the screen.

Figure 6 shows what the first level of the game in action looks like on the screen.

The program provides additions, improvements and editing. Therefore, the proposed project can be improved by the student at the next stages of learning.

You can diversify the forms of work in Mathematics lessons by conducting interactive exercises developed using the online services [Kahoot!](#) and [LearningApps.org](#). For example, an alternative

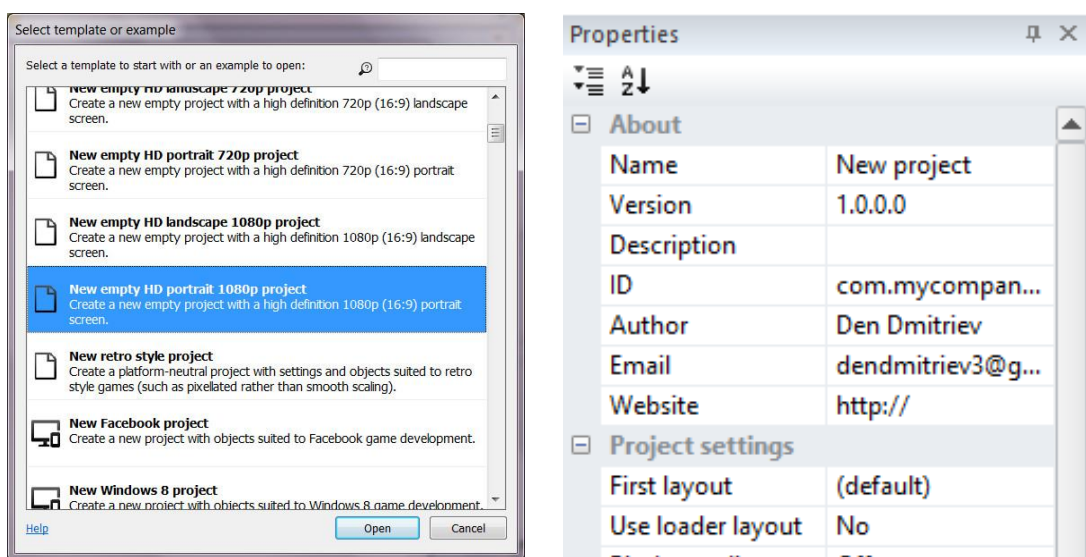


Figure 5: Start creating a project in the Construct 2.

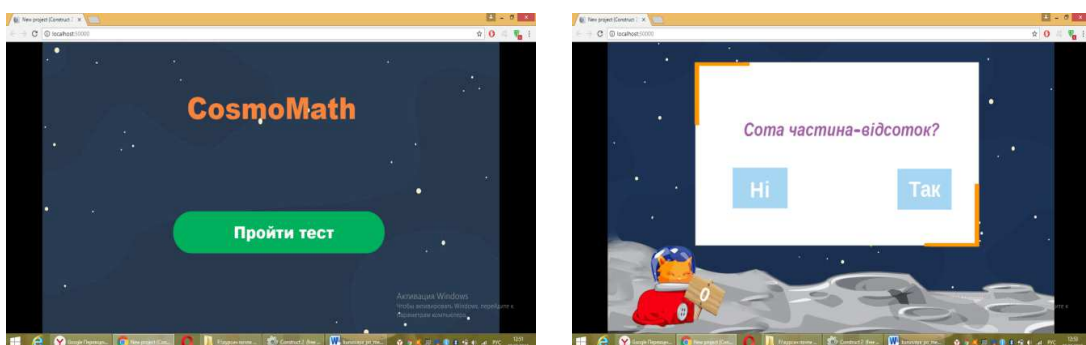


Figure 6: The work of the program “CosmoMath” and the first level of the game.

to the face-to-face survey may be to conduct an interactive quiz test on “Dihedral Angle”, a test developed using Kahoot!. To participate in the quiz, students follow the link <https://kahoot.it/> on smartphones to the page with the field for entering the PIN code of the game, which is reported by the teacher. At the end of the quiz, the winners are automatically determined – they are participants of the game who gave the most correct answers. The tasks are demonstrated on the board or teacher’s computer screen. Students use their smartphones as “voting consoles” (figure 7, figure 8).

The students’ developments describe how to use interactive exercises for independent homework. For example, such task on the topic “Combinations of bodies” as an interactive exercise developed in LearningApps.org (figure 9).

In this way we present the implementation of the procedural component of the proposed

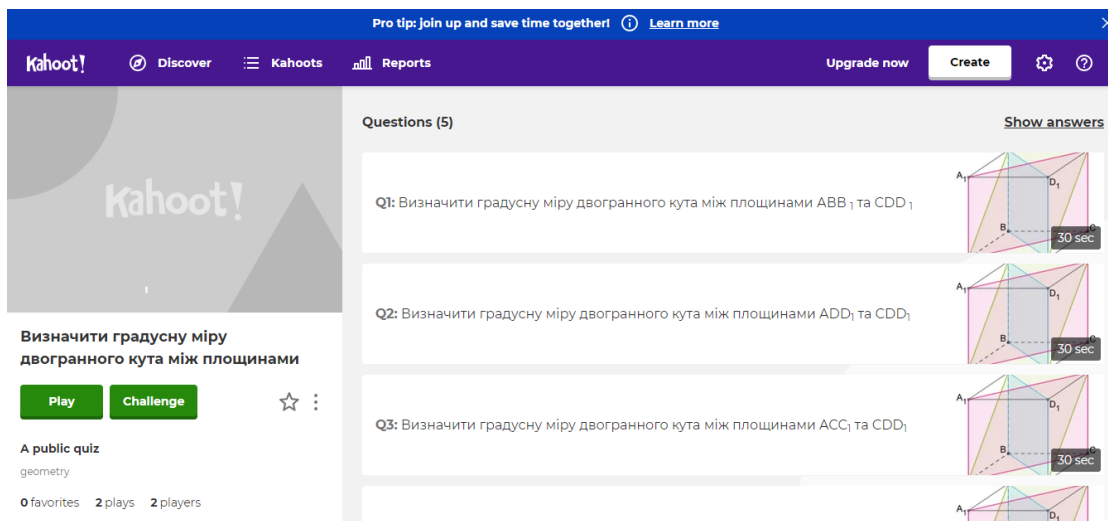


Figure 7: Kahoot interface.

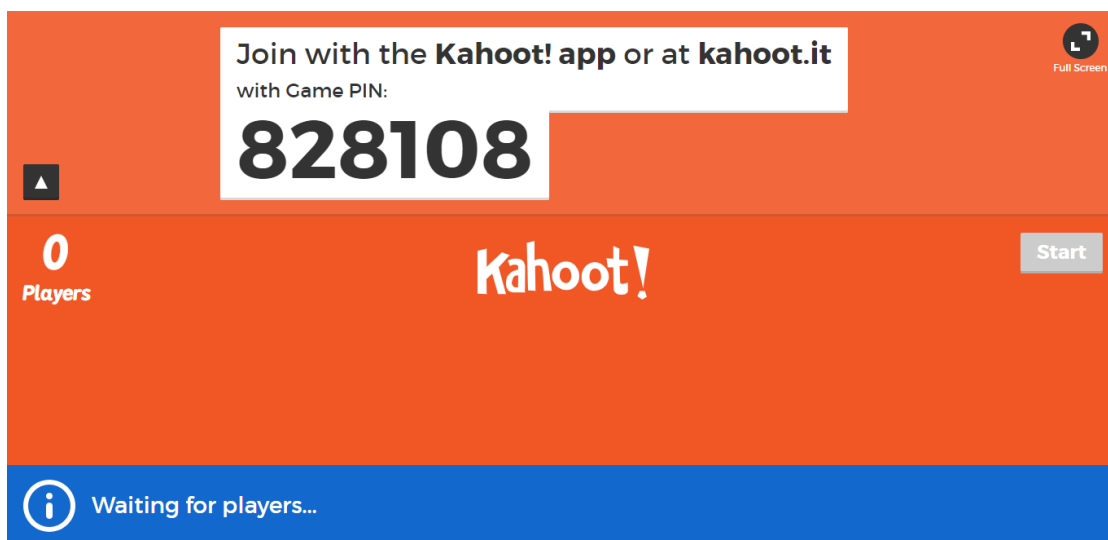


Figure 8: Expecting new participants in the game.

model.

5. Conclusions

The study made it possible to draw the following conclusions.

The preparation of the prospective teacher for the use of ICTs in professional activities is complex, which allows to model the process of ICT competence formation of a future mathematics teacher.

The screenshot shows the LearningApps.org interface with the following problems:

1. Навколо куба описано циліндр. Ребро куба дорівнює 8 см. Обчисліть об'єм циліндра. $V = \dots\pi$ см³.
2. Циліндр вписано в куб. Об'єм куба дорівнює 125 см³. Обчисліть об'єм циліндра. $V = \dots\pi$ см³.
3. Правильна чотирикутна призма вписана в циліндр. Висота призми дорівнює 13 см, а сторона її основи дорівнює 10 см. Обчисліть об'єм циліндра. $V = \dots\pi$ см³.
4. Правильна чотирикутна піраміда вписана в конус. Січна конуса дорівнює 6 см і утворює з площиною основи кут 60 градусів. Обчисліть об'єм конуса. $V = \dots\sqrt{3}\pi$ см³.
5. Конус вписано в циліндр. Діаметр циліндра дорівнює 10 см, а його висота дорівнює 12 см. Обчисліть площу бічної поверхні конуса. $S = \dots\pi$ см².
6. В тіло, утворене при обертанні квадрата площею Q навколо однієї зі сторін, вписано правильну шестикутну призму. Визначте площу її бічної поверхні. $S = \dots Q$.
7. Площа діагонального перерізу куба дорівнює $6\sqrt{2}$. Знайдіть площу бічної поверхні циліндра, описаного навколо куба. $S = \dots\sqrt{6}\pi$.
8. Рівносторонній конус вписано в кулю. Знайдіть радіус кулі, якщо січна конуса дорівнює 24 см. $R = \dots\sqrt{3}$ см.

Figure 9: Home independent work in the service LearningApps.org.

The analysis of possibilities of pedagogical modeling allowed to allocate basic types of pedagogical models: semantic, structural and functional. There are also derived types of models that have a dual subject of modeling: structural-semantic, structural-functional and functional-semantic. A structural-semantic model was chosen to model the process of forming the ICT competence of a future mathematics teacher.

The constructed model of formation of ICT competence of the future teacher of mathematics will be effective if to allocate certain means of ICTs and to analyze their possibilities in creation of conditions of formation of competent mathematics teachers. It is important to provide a systematic approach to the organization of students' learning activities in the process of professional and practical training and use the generalizing role of methodical training in the ICT competence formation of the prospective teacher. The structural-semantic model of ICT competence formation is multicomponent in the composition of the target, preparatory, procedural and final components. Each of these components has its own structure and content. The content of the components provides actions aimed at forming the ICT competence of the future mathematics teacher. The actions of motivational-value and intellectual-cognitive components of the model explore students' awareness of ICT learning, the level of their motivation to use ICT tools in future professional activities. The content of the procedural component of the model is developed on the basis of this research. Thus, the content-activity component is responsible for building the content of education, the mastery of which contributes to the

formation of ICT competence of students and justification of student activities in the learning process. The organizational-activity component is aimed at the implementation of student activities in the real educational process. The control-reflexive component involves constant two-way communication between the components of the model in order to control the process of formation of ICT competence and make appropriate adjustments to this process, as well as developing algorithms for students to acquire ICT competence. The final component of the model involves determining the level of ICT competence of the future teacher of mathematics and is in constant dependence on the target component.

The implementation examples of the proposed model are presented, on which the students performed experimental course projects on the methods of teaching mathematics with the involvement of ICTs.

The results of the study testify to the effectiveness of the process of modeling the organization of students' activities in order to form their ICT competence.

The prospect of this study is a pedagogical experiment that will summarize the recommendations for the choice of ICTs in the training of competent mathematics teachers and clarify the components of prospective teachers' ICT competence of other disciplines.

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