Improving the learning environment for future mathematics teachers with the use application of the dynamic mathematics system GeoGebra AR

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Abstract

Immersive technologies and, in particular, augmented reality (AR) are rapidly changing the sphere of education, especially in the field of science, technology, engineering, arts and mathematics. High-quality professional training of a future mathematics teacher who is able to meet the challenges that permeate all sides, the realities of the globalizing information society, presupposes reliance on a highly effective learning environment. The purpose of the research is to transform the traditional educational environment for training future mathematics teachers with the use of the GeoGebra AR dynamic mathematics system, the introduction of cloud technologies into the educational process. The educational potential of GeoGebra AR in the system of professional training of future mathematics teachers is analyzed in the paper. Effective and practical tools for teaching mathematics based on GeoGebra AR using interactive models and videos for mixed and distance learning of students are provided. The advantages of the GeoGebra AR dynamic mathematics system are highlighted. The use of new technologies for the creation of didactic innovative resources that improve the process of teaching and learning mathematics is presented on the example of an educational and methodological task, the purpose of which is to create didactic material on the topic "Sections of polyhedra". While solving it, future teachers of mathematics should develop the following constituent elements: video materials; test tasks for self-control; dynamic models of sections of polyhedra; video instructions for constructing sections of polyhedra and for solving basic problems in the GeoGebra AR system. The article highlights the main characteristics of the proposed educational environment for training future mathematics teachers using the GeoGebra AR dynamic mathematics system: interdisciplinarity, polyprofessionalism, dynamism, multicomponent.

Keywords

augmented reality, GeoGebra AR, learning environment, teacher training, professional competences

1. Introduction

The rapid changes that are taking place in the post-industrial society require from the pedagogical higher educational institutions of the world and Ukraine a better provision of the

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educational process. Now, in the leading countries of the world, there is a sharp modernization of educational processes and a modern school, both higher and secondary, cannot stand aside.

The quality of mathematical training is an indicator of the readiness of the society for radical changes. New approaches to the organization of the educational process are substantiated in the main state documents of Ukraine that regulate the reform of the educational system:

- National doctrine of education development [1];
- Law of Ukraine on Education [2];
- State National Program "Education" ("Ukraine of the XXI century") [3];
- The concept of development of natural and mathematical education (STEM education) [4].

Today, reforming the education system is a strategic problem for all developed countries. Ukraine's integration into the international educational community, the need for urgent restructuring of existing industries in accordance with the requirements of the world market primarily requires improving the quality of education.

Mathematical knowledge, skills and abilities are considered not as an end in itself of education, but as a means of learning about the world, meeting cognitive and practical needs, as a universal language of science and technology that allows to model and explore the around world. Therefore, the national school, both higher and secondary levels, faces the task of forming a new paradigm of education, in which students develop a system of universal knowledge, skills, experience of independent creative activity, a set of key competencies that ensure dynamic adaptation of the individual to a new, rapidly changing information society and its full functioning in it.

In the emerging new educational space, a new system of values is emerging, where it is not knowledge, skills and abilities that dominate, but the ability to quickly navigate information flows, to respond to ever-changing challenges. The main qualities of the modern personality are the universality of all mental processes (thinking, memory, attention, motivational sphere), their dynamism and mobility. It is necessary to fundamentally rethink all the factors of the education crisis. Mathematical education, being the basis for successful participation in the modern information society, taking into account global trends and innovations is constantly updated. The quality of mathematical training is an important indicator of society's readiness to solve practical problems of the modern labor market, receive quality professional education and further education in the future.

Personality-oriented, activity, competence, technological, adaptive, environmental approaches, informatization, integration are the methodological basis of a qualitatively new educational process as a complex, nonlinear, multilevel, integrated education. Psychological and pedagogical science has accumulated considerable experience in the formation and development of educational space. The variability of the education system presupposes theoretical research on its structure and identification of the real subjects of the educational space, as a necessary and sufficient condition for its existence and continuous renewal.

2. Related work

The problem of the educational environment was studied in the works of the classics of psychology and pedagogy: Comenius [5], Locke [6], Rousseau [7], Pestalozzi et al. [8].

In modern education, the essence of the concept of "educational environment" and its various aspects were studied by Aars and Christensen [9], Abed et al. [10], Alahmadi [11], Al-Maroof et al. [12], Andersson [13], Berrani et al. [14], Bondarenko et al. [15], Camacho et al. [16], Chrysafiadi et al. [17], Dotsenko [18], Fuentes-Moreno et al. [19], Horbatiuk et al. [20], Huh [21], Kerimbayev et al. [22], Kyslova et al. [23], Lechthaler et al. [24], Lawless and Riel [25], Lee et al. [26], Morze and Kucherovska [27], Mousavi et al. [28], Orlando et al. [29], Sahu et al. [30], Shapovalov et al. [31], Smogorzewska et al. [32], Stratulat et al. [33], Tleubay et al. [34], Uchitel et al. [35], Yang et al. [36] and others. The educational environment is considered as a factor of education from the standpoint of understanding education as a special sphere of social life.

A thorough analysis of models of the educational environment and its components was carried out by Bykov [37].

The concept of information and communication learning environment, current issues of organization of open and distance learning systems are covered in the research of Bobyliev and Vihrova [38], Bykov et al. [39], Gergei and Mashbits [40], Glushkov [41], Mintii et al. [42], Monakhov et al. [43], Monakhov [44], Polhun et al. [45], Shokaliuk et al. [46], Spivakovsky et al. [47], Syvyi et al. [48], Yershóv [49], Zhaldak and Franchuk [50], Zhaldak et al. [51] and others.

Book et al. [52], Cook [53], Freedy et al. [54], Hardin et al. [55], Ji-Ping and De Diana [56], Kaltenborn et al. [57], Linstead [58], Mendiburo and Biswas [59], Mevarech [60], Milne and Rowe [61], Morris [62], Pagano et al. [63], Pizzutilo and Tangorra [64], Porta [65], Rowe and Gregor [66], Sambrook et al. [67], Semerikov et al. [68], Shubin et al. [69], Sleeman and Hartley [70], Tait and Hughes [71], Wegner et al. [72] and others have studied the creation and implementation of computer-based learning systems.

Various aspects of using the GeoGebra dynamic mathematics system are studied by Abánades et al. [73], Bhagat and Chang [74], Botana et al. [75], Diković [76, 77], Drushlyak et al. [78], Flehantov and Ovsiienko [79], Hohenwarter and Preiner [80], Jacinto and Carreira [81], Jelatu et al. [82], Kovács and Parisse [83], Kramarenko et al. [84], Reis [85], Reis and Ozdemir [86], Saha et al. [87], Takači et al. [88], Tatar and Zengin [89], Velichová [90], Verhoef et al. [91], Zengin et al. [92], Zulnaidi and Zakaria [93], Zulnaidi and Zamri [94].

Hrybiuk [95], Hrybiuk and Yunchik [96], Rakuta [97, 98, 99] consider the issues of organization of the learning environment with the use of the system of dynamic mathematics GeoGebra for professional training of future specialists.

The solution to the problem of informatization of the educational process using the BYOD (Bring Your Own Device) approach and subject-oriented cloud services using GeoGebra is considered in the work [100].

The relevance of the issues of organizing the learning environment is confirmed by a large number of publications devoted to this problem (702 issues results for Learning Environment in link.springer.com) [101, 102, 103].

Important aspects of the learning environments organization are discussed at numerous international conferences: Transforming the Teaching & Learning Environment 2021 [104], Augmented Reality in Education (AREdu) 2018-2021 [105, 106, 107, 108], Learning Environments 2019 [109] and others.

International associations such as International Association of Smart Learning Environments [110], Association for Learning Environments [111] contribute to the creation of effective learning environments that reflect the unique capabilities of the community.

3. Problem setting

The purpose of the paper is to improve the traditional learning environment for training future mathematics teachers through the use of the GeoGebra AR dynamic mathematics system, the introduction of cloud technologies into the educational process for their use in mixed and distance learning of students.

Tasks:

- Investigate the concept of future mathematics teachers learning environment;
- Analyze the educational potential of the GeoGebra AR dynamic mathematics system in the system of professional training of future mathematics teachers;
- Analyze of main features and benefits of Dynamic Mathematics GeoGebra AR system for future Math teacher's training;
- Illustrate the technology of creating didactic innovative resources to improve the teaching and learning process of mathematics on the example of the educational and methodological task of creating didactic material on the topic "Sections of polyhedral";
- Transformation of the traditional learning environment for the preparation of future mathematics teachers, the introduction of cloud-based and immersive technologies into the educational process in order to form professional competencies of future mathematics teachers in the field of information and communication technologies.

4. The concept of learning environment for future mathematics teachers

Qualitative professional training of a future mathematics teacher, who is able to respond to today's challenges that permeate all sides, the realities of the globalizing information society, provides a reliance on a highly effective learning environment [112].

At the present stage of functioning of a pedagogical institution of higher education, the learning environment is designed to stimulate higher education students to acquire professional knowledge, skills and experience, awareness of the need for emotional and volitional regulation of educational and cognitive activities through a system of attitudes, reflection and successful professional self-realization.

We interpret the learning environment for future mathematics teachers as an open, complex, multilevel, dynamic, branched, multi-component, holistic, objectively existing, purposeful system, characterized by a certain set of material subjects, on the background of which educational professional programs, the content of educational components, the length of the educational process over time.

A necessary and sufficient conditions for such composition are the subjects of the educational space, material objects that change during their life, as well as the intangible components of life processes, subjects of the natural and socio-cultural environment as habitats, which makes it possible to enrich and update the content of education, turn their properties into personalized experience of future mathematics teachers, necessary for successful self-realization both in the learning environment itself and in the environment where the graduate will go. The learning environment is characterized by interdisciplinarity and polyprofessionalism, the dynamic movement of the future mathematics teacher from educational activity to professional activity, personal inclusion in all types of activities and their design as a step-by-step independent work [113, 114, 115].

The modern information society requires the creation of a sufficiently effective learning environment in the pedagogical institution of higher education to train future mathematics teachers, which is an artificially constructed system aimed at achieving a set of different goals and nature of higher education, providing not only certain knowledge, skills, abilities, but also mastering of professional competences, ability to act quickly in various professional situations [116].

The development of society, science, technology, technologies leads to appropriate changes in the methodological system of education. This in turn forces the learning environment to change constantly. Both individual components and the whole structure of the learning environment need to be changed.

As the structure of the learning environment becomes more complicated or updated, both the educational and cognitive activity of the future mathematics teacher and the system of actions through which it is carried out and which is mastered by the applicant of higher education become more complicated. Changing the elements and characteristics of the learning environment leads to change, expanding the area of immediate activity of the subjects of the educational process, ways of their behavior, the system of educational goals [117, 118].

5. Analysis of the possibilities of the dynamic mathematics system GeoGebra AR in the system of training future mathematics teachers

In practical classes on methods of teaching mathematics, considerable attention should be paid to the use of digital technologies to prepare future mathematics teachers to visualize the teaching material of school mathematics, which will greatly improve the quality and effectiveness of teaching, diversify teaching aids and forms. As digital media become more widespread and accessible, the focus of the educational process is shifting toward individual, blended, and distance learning [119, 120].

Prospective math teachers should be introduced to existing programs that they can use to visualize and teach math. Such programs include Maple, Derive, Mathematica, Geometry Expressions, Live Geometry, Mathcad, Blender, GRAN and more. Each of these programs has its drawbacks and its strengths [121].

Today, many educators and methodologists pay attention to the possibilities of the GeoGebra AR program as a system of dynamic mathematics, which is constantly improved and updated.

GeoGebra is powerful Math Applications which includes Suite Calculator; 3D Calculator; CAS Calculator; Geometry; Graphing Calculator; Scientific Calculator; GeoGebra Classic; Testing [122].

Graphing Calculator released GeoGebra is used for Windows, Android and iPhone tablets and phones. The environment provides the organization of the process of teaching natural sciences and mathematics the design of dynamic graphic objects and conducting research using augmented reality. The GeoGebra community's collection of teaching and learning materials consists of more than 300,000 free and dynamic worksheets and books. For convenient organization of the educational process and cooperation between students and teachers GeoGebra provides for the creation of classes and the use of groups.

Future math teachers should emphasize the benefits of this program: dynamism, constant updating, a wide range of functionality, intuitive interface, the ability to work in different modes, the ability to install on mobile devices, multilingual, free, the ability to interact at a professional level, the possibility of use at different levels of education, the possibility of organizing the management and correction of learning, the possibility of creating educational content directly in the learning environment, the possibility of sharing with the environment, which is a source of contextual enrichment and updating the content of education, cognitive activity, which leads to a reduction of the digital divide between the subjects of the learning environment, the ability to create high-quality dynamic computer models (creating a visual spatial image and tracking the state of the created model due to changing parameters of its elements), the ability to use program material and its adaptation to specific learning conditions.

The modern learning environment provides for the transition from informative to active methods and techniques of teaching. Emphasis shifts from the predominantly educational function of the teacher to enhancing the cognitive activity of the student. An important aspect is to ensure the connection between education and professional practice [123].

The learning environment of dynamic mathematics GeoGebra AR should be used in teaching the following mandatory and optional components of professional training of future mathematics teachers:

- Methods of teaching mathematics;
- Elementary mathematics;
- Analytical geometry;
- Linear algebra;
- Mathematical analysis;
- Projective geometry and image methods;
- Methods of teaching mathematics in the profile school;
- Methods of distance education;
- Methods of STEM-education;
- Use of learning environments in mathematics.

The learning environment of dynamic mathematics GeoGebra AR provides more effective than in traditional learning the formation of competencies:

- Integral competence: The ability to solve complex professional problems and practical problems in education, which involves the application of theories and methods of psychology, pedagogy and mathematics and is characterized by complexity and uncertainty of pedagogical conditions of the educational process in educational institutions of different levels.
- Special (professional, subject) competencies:
  - Ability to apply the results of research and / or innovation activities in a practical way, which correspond to the latest achievements.
  - Ability to apply interdisciplinary approaches in critical thinking of professional problems.
  - Ability to use the principles, methods and organizational forms of research and / or innovation to make optimal decisions and interpret their results.
  - Ability to develop an education system and determine the role of the mathematical component in it.
  - Ability to independently develop experimental and observational research and analyze the data obtained on their basis, through the creative application of existing and generating new professional ideas.
  - Ability to improve existing and develop new methods of analysis, modeling, forecasting, problem solving in new areas of education.
  - Ability to self-educate and improve skills on the basis of innovative approaches in the field of education.
  - Ability to master and apply the psychological and didactic foundations of teaching mathematics.
  - Ability to initiate and conduct research in a specialized field of education [124].

6. An example of educational and methodical task of creating didactic material on the topic "Sections of polyhedra" using the system GeoGebra AR

Here is an example of an educational and methodological task, the purpose of which is to create didactic material on the topic "Sections of polyhedra". In solving it, future math teachers should develop the following components:

1. Video material "Learn more about polyhedra".
2. Test tasks for self-control of information assimilation of video material.
3. Dynamic models of a cube, parallelepiped, prism, pyramid with the possibility of demonstration in the dynamics of changes in the states of these objects when changing the parameters of their elements [122, 125, 126, 100].
4. Video tutorial "How to build images of polyhedra of different types in GeoGebra?".
5. Video tutorial "How to explore polyhedrons in Augmented Reality in GeoGebra?".
6. Video material on solving the basic problem in parallel and central projection of such content.

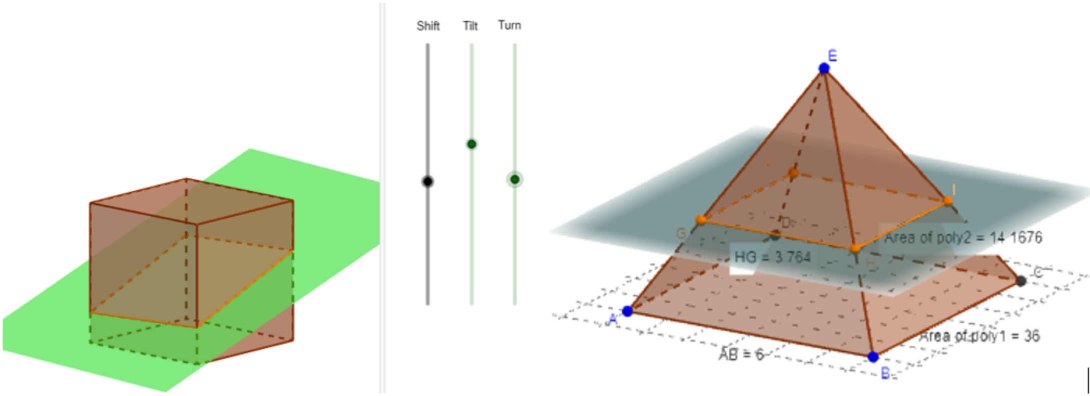

Figure 1: Dynamic models: Cross Sections of a Cube. Pyramid section.

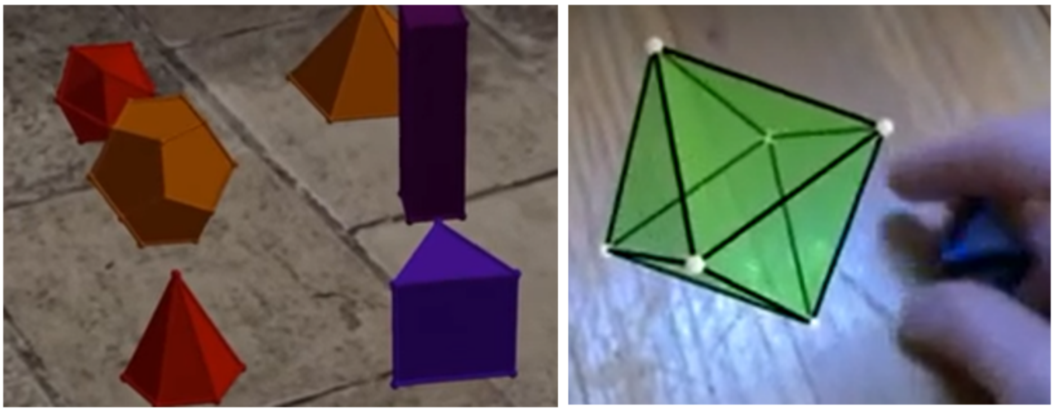

Figure 2: GeoGebra Augmented Reality (https://www.youtube.com/watch?v=nmIIO9KZNww). Octahedron (https://www.youtube.com/watch?v=kZvdDPWhLmY).

Given:
α – plane,
$A(A1)$, $B(B1)$, $C(C1)$ – points and their projections,
$D1$ – projection of an unknown point D.
Find: D.
The solution of this basic problem by a method of traces and a method of conformity both at parallel, and at the central projection, leads to the corresponding algorithms.

1. Example of construction of a section of a cube with dynamic reproduction of algorithm of construction by a method of traces.
2. Example of construction of a section of a triangular pyramid with dynamic reproduction of the algorithm of construction by the method of traces.

3. Example of construction of a section of an arbitrary prism with dynamic reproduction of construction by the method of correspondence.
4. Example of construction of a section of an arbitrary pyramid with dynamic reproduction of the algorithm of construction by the method of correspondence.
5. The task that will help consolidate the acquired knowledge and skills: to build the specified section of a cube or triangular pyramid in GeoGebra and find its area.

Task 1. Determine the cross-sectional shape of the cube with a plane that is drawn through the middle of the edges AB, $AA1$ and $A1D1$ find the cross-sectional area if the edge of the cube has length a.

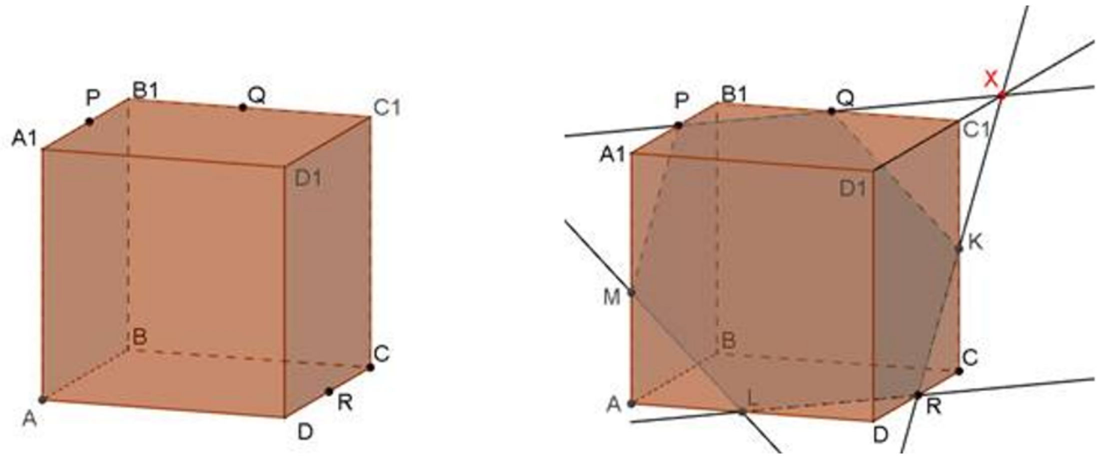

Figure 3: Cross-section of the cube.

Task 2. On the edges $AA1$ and $CC1$ the parallelepiped are the corresponding points M and N so that $AM : AA1 = m$, $CN : CC1 = n$. Construct a section with a plane passing through the points M and N parallel to the diagonal BD of the base. Determine in what ratio this plane divides the edge $BB1$.

The use of the GeoGebra AR package in the pedagogical specialties of the university is a joint activity of all subjects of the educational space, aimed at developing in future mathematics teachers the ability to search in the creation of educational and methodological tasks according to the plan offered by the teacher, the ability to carry out independent professional intelligence and interdisciplinary research with the assistance of teacher, the skill of conducting an independent search for a trans disciplinary plan based on active interaction and creating conditions for success.

In the process of using the GeoGebra AR package, the teacher coordinates the educational and cognitive activities of students, aimed at acquiring new knowledge and experience in relation to this software, encourages them to explore new professional knowledge and the formation of special competencies.

The introduction of the system of dynamic mathematics GeoGebra in the process of training future teachers of mathematics changes the place and role of higher education in the educational process, the way they acquire new knowledge and experience in methods of teaching mathematics.

Advantages of using GeoGebra: activation of the educational process, the formation of deep internal motivation, within which there is a shift from the focus on results to the focus on ways of learning and cognitive activity and their improvement. Moreover, the more valuable the use of software, the more significant tumors occur in the motivation to learn. In addition, there is space for self-realization, self-improvement of future mathematics teachers.

Introducing the use of GeoGebra AR, the teacher thus demonstrates to students innovative forms of teaching, teaches future mathematics teachers to use the acquired professional knowledge, skills and abilities in future activities [113].

In connection with the introduction to the training of future teachers of mathematics laboratory and practical work on methods of teaching mathematics, focused on the GeoGebra AR package, provides for the gradual involvement of students in mastering these tools, to explore objects in mathematics, pedagogy, psychology. Due to this, students are involved in the development and implementation of GeoGebra model, GeoGebra projects, their own GeoGebra researches, are involved in scientific and methodological studies of teachers.

Using GeoGebra AR reveals the personal professional potential of a future math teacher.

7. Conclusions and outlook

The analysis of scientific publications made it possible to determine the concept of an learning environment for the training of future mathematics teachers, its structure and models.

The use of the GeoGebra AR dynamic mathematics system, the introduction of cloud and immersive technologies into the educational process makes it possible to form the professional competencies of future mathematics teachers more effectively, in particular in the field of information and communication technologies.

The examples show that the use of the GeoGebra AR system allows making the teaching of mathematics practice-oriented, applying research methods, and increasing the motivation of students' learning. Opportunities to create and study interactive dynamic models in the learning environment GeoGebra AR increase the efficiency of the learning process of natural sciences and mathematics, promote the development of logical thinking and increase the level of motivation of students.

In the future, we are planning development and implement a special course "GeoGebra AR for future teachers of mathematics and physics".

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