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Development of Digital Competence of a Future Teacher in the Context of Informatization and Digitalization of Modern Teacher Education

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Abstract

The relevance of the research lies in fact that the digitalization of modern teacher education, according to the adopted national program "Digital Economy of the Russian Federation", should ensure the preparation of highly qualified staff, who will be able to apply modern and advanced information technologies with a high level of digital skills and competencies, that correspond to social needs and the requirements of the digital economy. Based on these requirements, it becomes necessary to develop the digital competence of the future teacher, in particular, in the field of using augmented reality technologies in professional activities.

The aim of the article is to create a technology developing digital competence of a future teacher and methods for using augmented reality tools for teaching physics. The main research methods are: studying the experience of Russian and foreign scientists connected with the problem of future physics teacher's digital competence formation, questioning, conducting an experiment, which allows us to explore the process of using augmented reality technology as one of the components of digital competence formation. The article revealed that first-year graduate students, on the one hand, are interested in using augmented reality technology in the educational process. On the other hand, they do not have a sufficient level of knowledge and practical skills in this area.

The digital competence formation technology for future physics teacher is developed. A technique for diagnosing of formation level of digital competence is proposed and its effectiveness is experimentally proven.

Keywords: digital competence, digitalization of teacher education, augmented reality technology, professional preparation of a future physics teacher.

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Introduction

The process of transition to the digital economy has special requirements not only for the formation competencies level of future specialists, but also for their individual and personal development level, intellectual and social mobility. The formation of new ways of human interaction with the digital world connected with serious changes in the education system. As a result of education digitalization, the studying process becomes more flexible, personal characteristics of each student are taken into account, who themselves form a request for knowledge and are included in the learning process at a convenient time for them (Shagrova et al., 2019).

The pace of development of the digital economy in Russia currently requires the implementation of appropriate technologies in the education system and necessitates the preparation of teachers using modern digital technologies in their professional activities. This contributes to the search for innovative ways to develop the digital competence of the future teacher, which implies, in our opinion, conscious and methodically competent mastery of modern information management skills and digital tools by teacher.

Purpose and objectives of the study

The purpose of the study is to develop a technology for the development of digital competence of a future teacher and methods of using augmented reality tools for teaching students physics.

Literature review

A lot of works of both Russian and foreign scientists are devoted to the problem for teacher's digital competence formation. In the works of Lapchik (2013), Yachina et al. (2016), Fernández and Yachina (2018), the attention is drawn to the relevance of digital preparation of teachers in the context of informatization and digitalization of modern teacher education, the need to form a certain level of the future teacher's digital competence in the field of digital technologies. The authors emphasize the importance of communication and network technologies, show the expediency of mastery mobile and interactive educational technologies. Quarles et al. (2018) believe that the use of the latest digital tools and mobile technologies in pedagogical activity should increase the effectiveness of education and students' interest in mastering new material. Maxwell et al. (2017) emphasize that the format of educational activity is constantly changing. In this regard, the knowledge of modern digital technologies is necessary for the future teacher. Jones and Bennett (2017) warn that the digitalization of education can adversely affect the formation of basic methodological foundations of teaching and educating students. Demarle-Meusel et al.

(2017) talk about the necessity of creating a digital educational environment at the university, which will help a future teacher to master skills and competencies of working with modern digital tools.

During preparing a future teacher in order to form an appropriate level of digital competence, it is necessary to focus students on the necessity to master modern and perspective software and hardware tools of information technology for the development of interactive digital content, in particular, educational resources in the format of augmented reality applications (AR-applications).

This is due to the fact that augmented reality technology (AR-technology), as a powerful visualization tool and an effective way to provide educational information to students, modernizes the education technologies themselves, enriching them with new tools and methods, expanding their didactic and cognitive capabilities. Placing virtual objects in a specific environment, in which they are initially absent, allows us to simulate unusual educational practices.

The study of augmented reality technologies will provide the future teacher with an opportunity to identify the advantages and disadvantages of these pedagogical tools, master them and determine the degree of their effective use in professional pedagogical activity (Poddubnaya & Kulikova, 2018).

Currently, the development of engineering education is declared one of the priorities of government policy in the field of education. On the one hand, measures are being taken to popularize engineering education, attracting young people to the field of science, the formation of motivation for a conscious choice of engineering and technical professions, the demonstration of the latest scientific developments and achievements in the field of breakthrough technologies of science and technology. On the other hand, there is a decrease in the motivation of high school pupils to study natural sciences and physics in particular.

The possibility of teaching physics using augmented reality was previously considered by scientists, for example, conducting virtual laboratory work in physics with pupils (Sannikov, 2014). Visualization, using augmented reality, phase diagrams, solving equations of mathematical physics, according to researchers, allows students to look deep into the processes, motivating them to a deeper study of physical theories. A number of scientists believe that the use of augmented reality in the study of physical phenomena by pupils increases the visibility and enhances interest in the subject (Kurzayeva et al., 2017). Therefore, how to use augmented reality technologies in the educational process for future physics teachers is currently an urgent task.

Education in the master's course on the direction of 44.04.01 Pedagogical education, profile Physical education assumes the future teacher has a serious substantive base obtained from the course of general

physics in undergraduate studies. It should be kept in mind that one of the most important functions of the course of general physics is to strengthen the professional motivation of the future physics teacher, aiming it at applying special knowledge in order to assist for developing a pupil's personality (Agibova & Fedina, 2019).

The knowledge and skills acquired by students during the education process of the discipline "Digital Technologies in Science and Education" and the course of general physics are used by us to prepare the future teacher for organization of the educational process in physics using augmented reality technology.

During studying the discipline "Methods of Teaching Physics in Secondary School" in practical classes, we train students to develop and use interactive educational resources with augmented reality.

Methodology

Research methods

In the research process, the following methods were used: study and theoretical analysis of psychological, pedagogical, methodological literature; generalization of Russian and foreign experience in training a future teacher in order to form his/her digital competence; observational, experimental, praximetric methods.

Experimental base of research

The experimental base of the research is the North-Caucasian Federal University.

Research stages

Implementation of the created technology for the development of digital competence of the future teacher in the conditions of informatization and digitalization of modern teacher education was carried out in three stages.

The first stage involved the analysis of scientific, psychological and pedagogical literature, research of the current state of the problem, synthesis of Russian and foreign experience in preparing future teachers to form their digital competence. The second stage was to develop the content of educational and methodological materials for students for the disciplines: "Digital Technologies in Science and Education" and "Methods of Teaching Physics in a Secondary School", which is part of the system of preparing master's students in the direction 44.04.01 Pedagogical Education, profile Physical education, in order to form an appropriate level of digital competence; the mastering of modern and perspective software and

hardware information technology for interactive digital content development and educational resources in the format of AR-applications; development of digital competence of the future physics teacher in the field of application of augmented reality technologies in professional activities; competent use during the lesson, in extracurricular and project activities of educational AR-applications. The third stage was devoted to checking the effectiveness of using the developed technology for the formation of digital competence of a future physics teacher.

Results

Digital competency development technology

The approach we used to develop the digital competence of the future physics teacher has a certain unification and is considered by us as a pedagogical technology. By this technology we understand the purposeful and personality-oriented process of subject-subject interaction between the teacher and the student, during which the teacher, taking into account the level of students' readiness to use augmented reality technologies, motivational-value relationships, applies modern teaching methods and tools, activates students' productive cognitive activity.

The formation of the digital competence of the future physics teacher begins with studying the discipline "Digital Technologies in Science and Education", which is aimed at developing ideas about educational opportunities and hardware-software technology of augmented reality.

The structure of the discipline consists of the following sections.

Section 1. Technologies of augmented reality in the educational process

The essence of augmented reality technologies, methods for their implementation and application area. The work principles and functionality of AR-applications. Classification and comparison of virtual and augmented reality systems. Analysis of practical experience in using augmented reality systems in the educational process.

Section 2. Technology of development of educational AR-applications

Approaches to developing applications using augmented reality technologies. Overview and comparative characteristics of development tools for AR-applications. Comparative characteristics of AR-content development tools in browsers.

Section 3. Tools for creating educational AR-applications

Software and technology for the development of augmented reality elements and their use in the educational process. Designing educational AR-content using various software tools.

Students get acquainted with the methodological features of the application of augmented reality technologies in the physics teaching during studying the discipline "Methods of Teaching Physics in a Secondary School". In practical classes, we teach students to develop and use interactive maps with augmented reality (pupil's interactive AR-map).

Depending on purpose, the pupil's interactive AR-maps can be two types: "Interactive AR-maps for fixing lesson's material with the teacher" and "Interactive AR-maps for homework".

"Interactive pupil's AR-maps for fixing lesson's material with the teacher" are handouts with assignments (unfinished definitions, tables, partially formulated formulas, graphs or drawings that need to be completed or colored). AR-maps are filled in by pupils during the lesson while the teacher explains a new topic, and used at home to consolidate the material studied at school. The augmented reality function is superimposed on the map, which allows to embed digital content on it.

The full-scale experiment in the lesson can be replaced by a video demonstration, but when the pupil is left alone with the difficult material of the textbook, accompanied by gray illustrations, he/she may not overcome the difficulties encountered in completing homework. The gaps appear in the theory that can accumulate and cause a misunderstanding of the subject or unwillingness to study it.

Demonstrations in textbooks are usually represented by two-dimensional images and pupils cannot always imagine such an object as voluminous, which leads to a misunderstanding of the principle of operation of a physical device or an experimental setup. Therefore, the opportunity provided by augmented reality allows us to present the device or technical device in three-dimensional space, which contributes to a better understanding of their work.

A video attached to an interactive AR-map will help the pupil while doing homework to keep in mind the experiment showed by the teacher and conclusions from it. Re-watching the video will enable the pupil to make out moments that were not clear in the lesson. Teachers can create a video of experiment by themselves or use a ready-made file downloaded from the Internet.

The study of technical devices, such as a hydraulic press (grade 7), an internal combustion engine (grade 8), an alternator (grade 11), a transformer (grade 11), etc. is often not easy for pupils. For example, explaining

the principle of the internal combustion engine's operation during the lesson, the teacher demonstrates the model of the device. At home repeating material on an interactive AR-map, the pupil thanks to the technology of augmented reality will be able to see the engine model and the principle of its operation, which will help the pupil to understand in details the operation of the technical device.

The pupil's work with "Interactive AR-map for fixing lesson's material with the teacher" is carried out according to the following algorithm: to remember the new material told at the lesson by the teacher; read the material in the textbook; retell textbook material using an AR-map; tell material without using an AR-map.

The pupil's homework can be divided into the following types: working with educational literature; exercises execution; making observations or performing an experiment; performance of a creative research assignment.

"Interactive AR-map for homework with the educational literature" includes questions that need to be answered by reading certain pages of the manual or textbook. The AR-map can also contain training exercises that will help pupils analyze the material they read, organize, summarize and consolidate it. For teacher, organizing a homework of this kind, is necessary to think through the difficult moments of the text and select small videos for them, which will help to prevent the difficulties and help pupils complete the task successfully.

To teach pupils to execute exercises on their own is not easy. Indeed, the success of solving a physical exercise lies not only in understanding its physical content, but also in the ability to use the mathematical apparatus. It is difficult for pupils to imagine how the puck moves along a plane inclined at an angle to the horizontal if it had a non-horizontally directed initial speed, or where the action of forces is directed on a rod moving along an inclined plane with a current in a magnetic field, etc. Therefore, voluminous "live" drawings, attached using augmented reality technology to the "Interactive AR-map for homework", can help a pupil to visualize the exercise condition.

Most physics textbooks include reading materials describing curious historical facts, interesting phenomena, and fascinating experiments in order to interest by the subject and prepare pupils for reading non-fiction. Illustrations to the text are not always demonstrative. The use of AR-technology allows to eliminate this drawback, which will increase the interest and motivation of pupils.

Working with texts in the seventh and eighth grades is a propaedeutic of completing tasks for understanding texts with physical content that pupils will meet when passing the exam in the ninth grade.

To complete them, you need to read the text, understand it, and then execute the exercise. Typically, in such exercises, a diagram of the experimental setup is presented, a description of the experiment (for example, Hilbert's experiment with a terella) or physical phenomenon (for example, the appearance of the lower and upper mirages) is given. For teaching how to execute this kind of exercises, technology augmented reality can be used, which will cause a desire to read physical texts in the future and will contribute to executing exercises of understanding a text with physical content.

The particular interest is the organization of personal observations or experiments conducted by pupils at home. Such activities contribute to: increasing interest to a subject; the formation of such character traits as curiosity and observation; development of cognitive abilities; teaching methods of scientific knowledge; the formation of the ability to consciously absorb knowledge; the development of the need for self-education; preparation for scientific activity.

Processes, observation of phenomena or conducting experiments at home should be carried out purposefully and organized. The teacher needs to highlight moments that can cause difficulties and think about how to help pupils overcome them. In this case, the homework of the pupils will be successful and productive. "Interactive AR-map for personal observations and experiments" will help the pupil formulate the goals and objectives of the research, determine the stages of the work. The questions or exercises contained in the map will allow the pupil to analyze, make generalization, and formulate conclusions. Augmented reality technology will turn the process of doing homework from routine into an exciting activity.

Let us give an example of a fragment of "Interactive AR-map for personal observation and experimentation" for eighth grade pupils on the topic "Electrification of bodies in contact. Interaction of charged bodies" (Fig. 1).

The map contains exercises of different difficulty levels: basic (first, second, third) and advanced (fourth). While completing task 1, to view the experience demo, the pupil should point the smartphone or tablet at the AR-task icon. To homework, such as an observation of the phenomenon, was targeted, pupils are invited to highlight the features of electrified bodies and draw a conclusion. Observation of the phenomenon will prepare the pupil for the second and third tasks, in which it is necessary to independently conduct experiments on electrification.

Eighth grade pupils are taking their first steps in experimental physics. It is necessary to teach them to set up experiments and formulate conclusions. In case of difficulty, the pupil can view the theoretical material by activating the AR-help icon.

To complete tasks of an increased level of complexity, a pupil may need knowledge from related subject areas, in this case from chemistry. By activating the AR-help icon, the pupil will be able to quickly receive additional information. If the pupil still could not cope with the task, the video, launched using the AR-SOS icon, will allow him/ her to find out the answer to the question of the fourth task.
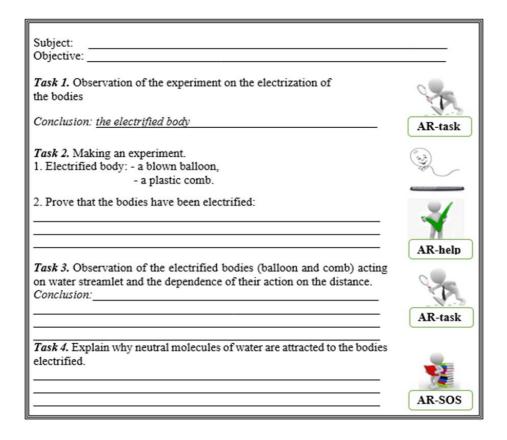

Fig. 1. The fragment of "Interactive AR-map for independent observation and experience"

The implementation of developed interactive AR-maps in the education process of pupils was made by students during pedagogical practice. Pedagogical practice was the final stage in the formation of digital competence of the future physics teacher.

Experiment Stages

The ascertaining stage

To assess the level of digital competence of students, we highlight the willingness of a future teacher to use AR-technologies in professional activities. Therefore, during the ascertaining stage of the pedagogical

experiment, the students' readiness was evaluated according to the following components: motivational, cognitive, technological.

To determine the motivational component of student readiness, a questionnaire was conducted, during which it was found out that for most first master's course students a positive attitude towards the use of AR-technologies in teaching pupils is characteristic.

The cognitive component of readiness was evaluated in the course of monitoring students' work according to the following parameters: the ability to independently determine the need for using digital technologies in the lesson; correctly select digital instruments, depending on the purpose of the lesson; ability to work with educational and popular science literature; the ability to independently apply the knowledge of AR-technology in practice.

The technological component of readiness is assessed by the necessary knowledge, skills and abilities to use the hardware and software of AR-technologies in the education process at school.

The level of formation of all the indicated components individually for each student made it possible to diagnose the initial level of readiness in general for first master's course students.

An analysis of the data obtained at the ascertaining stage showed that first master's course students have not high enough formation level of digital competency.

There was a contradiction between the interest shown by students in augmented reality technologies and a low level of knowledge in this area. This also confirmed our conclusion about the necessity of experimental training, taking into account the level of readiness of students, and justified the choice of appropriate technology.

The formative stage

The formative experiment was aimed at clarifying the role, place and didactic capabilities of augmented reality technology tools in the development of digital competence of a future physics teacher, the development of formation technology of digital competence in the conditions of informatization and digitalization of modern pedagogical education.

We agree with the researchers, Grebenyuk (2000), Kraevsky and Polonsky (2001), who believe that in a pedagogical experiment it is quite difficult to achieve equalization of the composition of parallel groups taking into account the level of initially available knowledge and initially formed skills to distinguish the
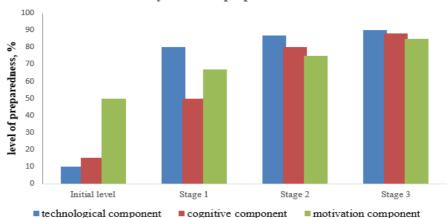
experimental and control groups. Therefore, in our research, we found it possible to abandon the comparative experiment and evaluate the effectiveness of the technology of independent work of students, fixing the changes that occur at individual stages of the study.

The control stage

Diagnostics of digital competency formation level was determined by the results of a series of control slices. For the obtained quantitative data, was used the $\chi 2$ - criterion, which allows to compare the percentage distribution of the data. The boundary value of $\chi 2$ - the criterion, corresponding to two degrees of freedom (m = 3) and a probability of an admissible error of 0.05, is 5.99, which allows us to conclude that there are significant changes in the level of digital competence and confirms the validity of the research hypothesis.

Monitoring the development of digital competence was divided into three stages, the results were compared after studying each of the disciplines and after passing pedagogical practice.

The dynamics of the readiness level of a future teacher to use AR-technologies in professional activities is shown in Fig. 2. This allowed us to conclude that the proposed technology is effective.

Fig. 2. Diagram showing the dynamics of the preparedness of future teachers for the application of AR-technology in professional activity

An empirical research made it possible to verify the effectiveness of the developed technology for the development of digital competence of a future physics teacher in the conditions of informatization and digitalization of modern pedagogical education.

Discussions

The formation of the digital culture of the future teacher has become a focus of many research studies. The possibilities of forming digital competence of future teachers of higher educational institutions have been identified in the work of Fernández & Yachina (2018). An analysis of the digital competence of Russian educators was done by Lapchik (2013). The foreign experience of developing a profile of digital teacher competencies was considered by Quarles et al. (2018), Demarle-Meusel et al. (2017). However, there are practically no comprehensive researches devoted to the development of digital competence of future subject teachers in the use of AR-technology in professional activities, which allow contributing to the formation of professional competencies among students.

Conclusion

At present, due to the rapid development of the digital space, the digital competence of the teacher requires constant improvement. In order to develop digital competence, a modern teacher must have a sufficiently high level of mastering digital pedagogical instruments.

The technologies considered serve as a means of achieving new educational results, envisage the appropriate level of teachers' professional activity, determined by new functions and types of these activities, as well as contribute to the implementation of the Federal State Education Standards of the next generation.

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