ABSTRACT

of the dissertation submitted to qualify for
the degree of Doctor of Philosophy (PhD) in
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Development and Application of Augmented Reality Technology Models in Physics Teaching in General Secondary School

General description of the work. The main goal of the Education 5.0 is to study the level of implementation and use of new technologies like augmented reality in the context of complete digital transformation using three basic theoretical models: technology acceptance model, task technology fit model, and unified theory of acceptance and use of technology model. The technology adoption model is the first and most common model, which determines the user's intention to adopt a new technology. The task-oriented technology compatibility model focuses on the compatibility of technology capabilities with the requirements of the task at hand. The model based on a unified theory of technology adoption and use is a more comprehensive model that combines the above models and several other theories. The synthesis of these three models allows us to scientifically prove the effectiveness of augmented reality in teaching physics. They justify students' perception of technology not only as "entertainment" but also as a valuable tool that facilitates learning. The dissertation aims to develop and study digitalization models for the implementation, compatibility, and use of augmented reality technology in physics education.

Relevance of the dissertation theme. The use of augmented reality technology for teaching physics in secondary schools is important, since the unique advantages of this technology are that it can actively provide integrated visualizations to clearly explain to students the phenomena of physics, as well as its laws in general, the properties and structure of matter, and the laws of its interaction. Thus, ensuring the adoption, compatibility, and use of augmented reality technologies in teaching physics reveals the importance of this research. The results of the study show that the systematic introduction of augmented reality technologies in physics teaching is a key condition for raising the quality of education to a new level. The importance of this study lies not only in demonstrating the technical capabilities of the technology, but also in comprehensively substantiating its acceptance by students, its compatibility with the curriculum, and its real practical application. Studying the level of acceptance of augmented reality technologies in physics teaching opens the way to implementing digital transformation in modern schools on a scientific basis. This study is distinguished by the fact that it provides not only theoretical conclusions, but also specific methodological guidelines for future physics teachers.

The purpose of the dissertation work: To investigate the acceptance, compatibility, and use of augmented reality technology in teaching physics in general education schools, as well as to assess the impact of its application on students' motivation and academic performance.

To achieve this goal, it is necessary to solve the following tasks:

1) To study the characteristics of students' acceptance of augmented reality technologies in physics teaching in secondary schools;

2) To study the compatibility of augmented reality technology with the tasks of teaching physics.

3) To study the unique possibilities of applying augmented reality in physics teaching.

4) To determine the impact of augmented reality technology on students' learning of physics through a pedagogical experiment.

Research methods: The following methods were used to solve the identified tasks: general scientific methods of theoretical research (analysis, synthesis, formalization, modeling, classification, generalization, literature review); empirical research methods (study of teaching practice, observation, interviewing, questioning, testing); object-oriented design and programming methods; development of visual models and augmented reality tools; pedagogical practice and statistical methods, didactic concepts.

The object of the research: augmented reality technologies and their application in a comprehensive secondary school.

The subject of the research: teaching physics in a general secondary school using augmented reality technology.

The hypothesis of the research: If we introduce augmented reality technology into physics teaching in general secondary schools as a teaching tool and for interactive communication, then:

− In teaching physics, the effectiveness of teaching increases by integrating a high degree of integration of aesthetically pleasing virtual models and the real world, including modeling of physical phenomena and other didactic elements;

− Due to the possibility of conducting practical work that was previously inaccessible, physics in high school can be made visually understandable;

− By using augmented reality visual aids in practice, students can achieve better results in physics lessons.

The novelty of the research: for the first time,

1. Technology acceptance model was developed, evaluated, and implemented into a general secondary school process based on factors such as usability, enthusiasm, effectiveness, enjoyment, and intention to use augmented reality technologies in the educational process.

2. In accordance with the task of using augmented reality technology, a task technology fit model was developed, evaluated, and studied in the process of a general secondary school.

3. Taking into account the specifics of teaching students in general secondary schools by generation, an integrative model based on the unified theory of

acceptance and use of technology model was developed in accordance with the features and advantages of augmented reality technologies.

4. Using augmented reality in the GeoGebra mobile app, physics assignments for general secondary schools were developed in Kazakh, using augmented reality technology as a teaching tool.

Theoretical significance of scientific research:

– reveals the theoretical foundations of the use of augmented reality technologies in teaching physics

– demonstrates the ability of a teacher to integrate modern technologies into his/her pedagogical activities and contributes to improving his/her innovative competence;

– expands the goals and content of teaching physics in general secondary schools through the use of augmented reality technology;

The practical importance of scientific research:

The results obtained in the study contribute to improving teachers' digital and innovative competence, as well as providing students with a deeper understanding of the subject, increasing their interest, and improving their academic performance. In addition, the findings of the study can be used in secondary schools, in higher education institutions that train future physics teachers, and in the system of professional development for teaching staff.

The main provisions for defense are:

1. The developed model of technology adoption in physics teaching in general secondary schools shows that the determining factor for students' adoption of augmented reality is perceived intention, with a coefficient of determination $R^2 \approx 0.83$.

2. The developed model of technological compatibility “task-technology-fit” demonstrates that the correspondence between tasks and the selected technology has a positive effect on the quality and accessibility of the technology, which is summarized by a regression coefficient $\beta \approx 0.628$.

3. The developed integrative model, based on a unified theory of acceptance and use of augmented reality technologies, is reliable, as confirmed by statistical analysis at overall fit of the research model GoF=0,95.

4. The use of augmented reality technologies in physics education contributes to improving students' academic performance and enhances their motivation to learn, with a Fisher coefficient F=7.01.

The reliability and validity of the results: The results obtained correspond to the control data. The reliability of the dissertation work is confirmed by articles published in foreign journals with a high impact factor and in publications recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Education and Science of the Republic of Kazakhstan.

The author's personal contribution: The author personally carried out the entire research process from start to finish, including the literature review and all numerical calculations. This work was carried out in consultation with his supervisors. The author was directly involved in the research and analyzed the results together with his supervisors.

Approbation of the dissertation: During the process of writing the dissertation, 30 works were published. Of these, 5 articles were published in prestigious journals recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Education and Science of the Republic of Kazakhstan, and 2 articles were published in international journals with a high impact factor included in the Web of Science and Scopus databases.

The results of the research, the educational and cognitive tasks developed during the research, and recommendations for their use were implemented in secondary schools in physics lessons using augmented reality technologies. They were included in the educational process of secondary schools No.30 and No.46 in the city of Alatau, Almaty region.

The following two articles have been published, indexed in the international scientific publication databases Scopus and Clarivate Analytics.

1**. Arymbekov B.S.,** Turekhanova K. M. Turdalyuly M. The Effect of Augmented Reality (AR) Supported Teaching Activities on Academic Success and Motivation to Learn Nuclear Physics among High School Pupils // International Journal of Information and Education Technology. – 2024. – №5. – P.19–31. https://doi.org/10.18178/ijiet.2024.14.5.2099

2. **Arymbekov B.S.,** Turekhanova K.M. Augmented reality in Physics education: A tool for intellectual learning. Contemporary Educational Researches Journal. – 2025.– Vol.15, No.1. – P.33–44. https://doi.org/10.18844/cerj.v15i1.9629

Articles in journals recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan:

1. **Arymbekov B.S.,** Turekhanova K.M. Observation of Augmented Reality in Teaching Physics as a tool of Intelectual Teaching// Journal of Educational Sciences – 2022. – Vol.73, No.4. – P.128-141. https://doi.org/10.26577/JES.2022.v73.i4.12

2. **Arymbekov B.S.,** Turekhanova K.M. Study of using methodology of augmented reality application for physics designed for high school// Journal of Educational Sciences – 2023. – Vol.76, No.3. – P.125-145. https://doi.org/10.26577/JES.2023.v76.i3.011

3. **Arymbekov B.S.,** Turekhanova K.M. Methodology of application of augmented reality in physics laboratory experiments // Bulletin of Toraighyrov University. Pedagogics series. – 2023. – No.3. – P.157-169. https://doi.org/10.48081/POLK7321

4. **Arymbekov B.S.,** Turekhanova K.M., Fedus K. Methodology of using interactive visualization through augmented reality in teaching physics // Bulletin of Karaganda University. Pedagogy series. – 2024. – Vol.113, No.1. – P.29-47. https://doi.org/10.31489/2024ped1/29-47

5. **Arymbekov B.S**., Turekhanova K.M., Fedus K., Suprapto N., Tursanova E.R., Turdalyuly M. The effect of applying Geogebra software for augmented reality

visualization to teach physics in high school // Journal of Educational Sciences 2024. – Vol.79, No.2. – P.60-82. https://doi.org/10.26577/JES2024790206

In addition, the results of the dissertation work were published in reports at several prestigious international and domestic scientific conferences, in particular: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences Conference, IEEE International Conferences on Smart Information Systems and Technologies, E3S Web of Conferences, "Farabi World" scientific conference, "Abdildin Readings" conference, "Modern Trends in Education and Language Teaching" scientific symposium, "XXIV Satpayev Readings" conference, "SCIENCE. EDUCATION. YOUTH" conference, "ǴYLYM JÁNE BILIM - 2024" conference, "Development of Natural Science Education in the Republic of Kazakhstan: Problems and Prospects" conference, "Shokan Readings-28" conference, "Baitursynov Readings - 2024" scientific and practical conference, "Modern Science: Current Issues and Ways to Solve Them" international scientific and practical conference, and etc.

Structure and scope of the dissertation

The dissertation consists of an introduction, 3 chapters, a conclusion, and a list of references and appendexes. The work includes 40 tables, 21 figures, 23 formula, 203 references, and 151 pages.