3D Modeling and Printing in Physics Education: The Importance of STEM Technology for Interpreting Physics Concepts

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ABSTRACT: In accordance with the requirements of STEM education, a physics teacher must know the principle of operation, the device of the equipment and be able to effectively apply it in physics lessons. If, during a physics experiment, students do not know the principle of operation of the installation, then they also remain unclear how the physics phenomenon occurs in the experiment. If the experimental textbooks in the physics classroom are old, unusable, or there are no physics overloads, it is necessary that the teacher can consider a way to solve this problem and quickly make a decision using modern technologies (for example, 3D printing) to eliminate or alleviate the problem. The aim of this study is to address the challenges faced by physics educators in using outdated or unavailable laboratory equipment. The purpose of this study is to determine the importance of 3D modeling and printing based on STEM technology for performing physics laboratory work. In addition, it is necessary to determine the features of the use of 3D modeling and printing in the interpretation of physics concepts. This study employs a descriptive correlational approach, utilizing both a meta-analysis of relevant literature and a student questionnaire. In the course of the study, a meta-analysis of scientific papers based on the PRISMA method was conducted and a student questionnaire method was obtained. Based on 3D computer programs, a modeling method and constructive printing methods were chosen. These results underscore the need for integrating modern technologies into physics education to foster a deeper understanding and engagement with scientific phenomena. The results of the responses of 64 surveyed students significantly expand the teaching experience - using 3D modeling and printing technologies compared with traditional forms of education. The results of the study are recommended for use in the field of STEM education and are a necessary document for a large audience of researchers in the future.

Keywords: Physics teaching, STEM education, 3D Modeling, STEM technology, Physics concepts.

I. INTRODUCTION

Along with developed countries, the Republic of Kazakhstan began to use STEM technologies as a way to achieve success in the natural and technical-engineering fields. In the Republic of Kazakhstan, as in many developed countries, there is a concerted effort to incorporate these technologies into secondary and higher education curricula to improve the quality of education. In recent years, scientists have begun to study the problem of improving secondary and general education programs through programming languages, taking into account 3D printing [1, 2]. The results of the study indicate the need to equip the physics room with digital interactive tools and experiments created using a 3D modeling program.

Since the 19th century, specialists in the natural sciences have considered laboratory work to be an important tool [3, 4]. Teaching based on laboratory work is a direct practice of observing scientific materials and shows that it is superior to other methods of understanding and evaluating the material. However, the effectiveness of these laboratory sessions is often limited by the quality and availability of experimental equipment.

There are many positive results from research on the role of the laboratory in teaching physics. Laboratory classes seem to be useful for students whose academic performance is assessed as average or low according to the indicators of preliminary control work [5]. However, the practical learning process in laboratories can be improved through the use of computer software tools, through the introduction of more effective teaching methods. One of the main aspects of science is the modeling of complex phenomena of the real world. The physics model is based on the basic principles of science, and the purpose of the physics model is to predict or explain the most important aspects of a particular situation [6]. Modeling makes it easier to identify and master assumptions that necessarily allow a detailed analysis of the system [7-9].

In this direction, scientists of the Department of Physics of Khoja Akhmet Yassawi International Kazakh-Turkish University are working within the framework of the state grant order.

In this direction of research, two doctoral students and four undergraduates performed dissertation research works at the Department. As a result, applications "Physics Handbook" were launched, some elements of robotics were developed using 3D printing, STEM classrooms were opened, and equipment was developed [10, 11]. Other digital resources and teaching materials were published. Most of the unusable physics equipment was upgraded and launched using 3D printers.

This study aims to determine the importance of 3D modeling and printing in performing physics laboratory work and interpreting physics concepts. By addressing the following research questions, this study seeks to fill the gap in existing literature and provide practical recommendations for educators. However, there are not enough studies on the methodology for using the capabilities of 3D modeling and printing in the development of students' knowledge on specific problems of physics in accordance with the research topic. In particular, in the teaching of disciplines in the technical and natural sciences, engineering, in particular physics, specific didactic systems have not been developed, 3D modeling and printing technologies in teaching are not integrated. Therefore, in accordance with the purpose of our study - to determine the importance of 3D modeling and printing based on STEM technology in the performance of physics laboratory work, to identify the features of the use of 3D modeling and printing in the interpretation of physics concepts is relevant. To achieve this goal, it is necessary to be guided by the following research questions:

- What is the impact of STEM education based on 3D modeling and printing on the interpretation of physics concepts?
- Does the use of STEM technology in teaching physics increase the effectiveness of learning compared to traditional methods?
- Does the educational process based on 3D modeling and printing affect the performance of students?

The work is investigating the integration of 3D printing and modeling technologies into physics education. It aims to achieve many significant objectives, which include:

1. To investigate the effectiveness of using STEM technology-based 3D modeling and printing to enhance the instruction of physics.
2. To examine the impact of virtual reality simulations on students' understanding of physical phenomena.
3. To identify the most efficient techniques for integrating 3D printing and modeling into STEM-focused educational programs.
4. To assess the attitudes and academic performance of students who use these tools in contrast to those who employ traditional methods.
5. To provide evidence-based recommendations for educators and policymakers.

Despite the potential benefits, there are some hurdles that must be addressed in order to effectively integrate 3D printing and modeling technologies into physics education. Insufficient training and resources for educators to effectively employ new technology is a significant challenge they encounter. Additionally, it is possible that there might be resistance to adopting new teaching practices due to a preference for more traditional methods. Moreover, overcoming the challenge of providing all students with access to crucial technology and software may be a significant hurdle. Ultimately, to effectively gauge the impact of these technologies on student learning outcomes, it is essential to carry out research that are meticulous and well-planned, which may need significant resources.

This study offers significant insights and contributions to the field of physics education and the incorporation of STEM disciplines, including the subsequent:

1. This research presents empirical evidence that shows how the use of STEM technology for 3D modeling and printing enables students to enhance their understanding of physics fundamentals.
2. The study outlines optimal methods for instructors to include virtual reality simulations and 3D modeling into their educational methodologies.
3. We provide policymakers specific advice on how to facilitate and fund the use of these technologies in educational institutions.
4. The report offers valuable insights for future research and development endeavors by highlighting the present hurdles and gaps faced in the implementation of these technologies.
5. The outcomes have the capacity to influence educational policy and the distribution of resources, therefore facilitating the wider use of innovative teaching instruments in the educational system.

II. LITERATURE REVIEW

Currently, developed countries consider modeling in education to be a valuable tool for supporting conceptual understanding through the visualization of invisible processes [12]. Constant interaction with educational material is an important factor in learning through modeling and virtual worlds [13]. Virtual reality (VR) technologies allow you to interact with a virtual environment with a high intensity of immersion [14, 15].

In line with global trends, the "Institute of Electrical Engineering and Electronics Engineers" in the United States has been working on the Maroon VR platform for teaching physics for more than five years. Previous results with the help of Maroon showed that virtual reality has a high potential for students and teachers, and also found solutions to potential problems in terms of design, use of virtual reality experiences and pedagogical concepts [16].

In the process of teaching physics, there is a need to create the most realistic experience [17, 18]. And if the necessary tools are not in the physics room, it is necessary to be able to choose alternative solutions that can replace it. If the construction of the equipment is simple, then the necessary device can also be forged.

No matter how much the Physics Room provides physical tools from special plants, it cannot be said that it is sufficient in the course of teaching physics [19, 20]. The use of simple handmade physics tools in physical practice has a number of pedagogical advantages. This is because the construction of a homemade tool is simple, and the physical process that takes place on it also takes place before the eyes of students [21].

One of the most prescriptive areas of application of STEM technologies in physics education is the modeling of physical phenomena and processes [22]. Computer modeling of some equipment is the same as creating and assembling the same thing with your own hands. After all, when modeling an object, each particle and its movement are created by the student himself, using theoretical knowledge. To complete these tasks for the student, the teacher must have computer modeling skills [23]. That is, knowledge in the field of computer modeling is of great importance in improving the practical training of future physics teachers [24].

It is more efficient and cheaper to print using a 3D printer the instruments necessary for the missing physical practice in the physics room or the parts of the failed accessories. For example: in case of failure of a part of the equipment necessary for laboratory work in physics, the unit becomes unsuitable for Operation. Considering that physical installations are expensive and parts of it cannot be found in ordinary stores, it is known that it is more profitable to print them using a 3D printer. To eliminate many of the problems that arise when performing a physical experiment, the 3D printer was supported by several scientists [25, 26].

Since physics is an experimental science, each lesson must be conducted through a physical experiment [27]. However, at present, sufficient attention is not paid to the organization of a physical experiment in the process of teaching physics. One of the reasons is the poor quality of the equipment in the Physics Room. It is known that one of the main research methods of physics is experimentation, and the equipment necessary for modern physics practice is constantly updated, the construction and characteristics are improved and become more complex. However, the quality of the equipment that comes to the modern physics room is not critical. This, in turn, makes it even more difficult to organize a physical experiment, leaving the physical experiment unfulfilled. This leads to a decrease in the level of interest and knowledge of students.

III. MATERIAL AND METHOD

To identify problems related to the use of STEM technology in teaching physics, a meta-analysis of the literature based on the PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) was carried out (Figure 1). The PRISMA flow diagram (Figure 1) illustrates the process of identifying, screening, and including studies.

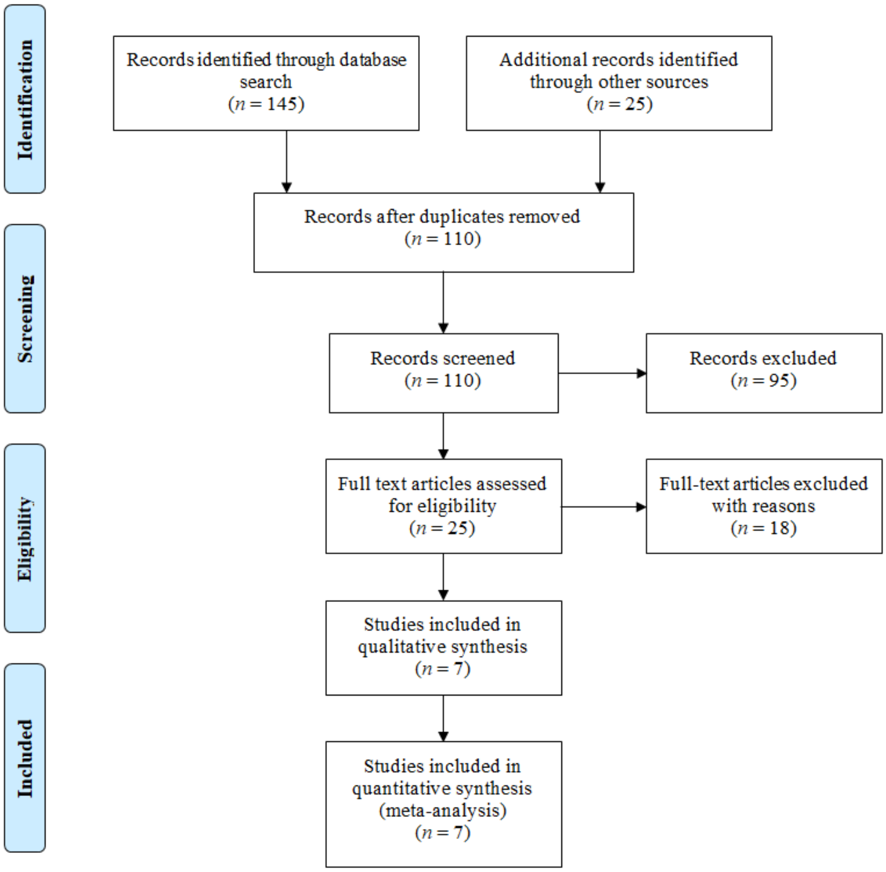

FIGURE 1. Data collection based on PRISMA.

We used the meta-analysis method as a systematic research method to obtain answers to research questions. The meta-analysis method allows the use of strict mechanisms and standards for the selection of literature [28, 29]. The results of several independent studies have been comprehensively studied using web databases Web of Science Core Collection (WoS), Springer, Scopus, ProQuest, ERIC. Key words "STEM education", "3D modeling/printing", "digital education", "teaching physics", "future physics specialists", "virtual reality", "modeling of physical phenomena" and others were taken to search for materials. Articles were included if they covered topics such as "physical phenomena," "3D modeling," and "STEM education," published within the last 5 years (2019-2023), and were available in full text. Articles were excluded if they lacked sufficient data or if the full text was not accessible. The results of several independent studies have been comprehensively studied using web databases Web of Science Core Collection (WoS), Springer, Scopus, ProQuest, ERIC. This helps to identify significant conclusions and solutions to research issues using the results of research in several sources.

Key words "STEM education", "3D modeling/printing", "digital education", "teaching physics", "future physics specialists", "virtual reality", "modeling of physical phenomena" and others were taken to search for materials. During the study, articles from magazines were analyzed using these keywords. The topics and theses of the collected articles were carefully studied, the filtered articles were used in writing the descriptive concepts presented in the discussion section. In the process of searching for articles by keywords and evaluating the content working with websites has been done.

From the total collected articles, 7 articles were selected based on the following criteria:

- Articles defined by the phrase "physical phenomena" and "3D modeling", "STEM education";
- Coverage of articles for the last 5 years (2019-2023);
- Articles whose full text is unavailable;
- Articles in which there was not enough data to calculate the dimensions of the effect.

The remaining 7 articles were analyzed in detail and the final wording was given on the analyzed articles. We used the formula (1) below to calculate the effect measurements during the meta-analysis.

$$ES = t\sqrt{\frac{1}{Ne} + \frac{1}{Nc}} \quad (1)$$

ES = Effect size; t = Result of t-test; Ne = Sum of experimental group; Nc = Sum of control group. The effect size quantifies the magnitude of differences between the experimental and control groups.

In addition, the possibilities of improving the content of the discipline "Computer modeling of physics phenomena" in the physics educational program based on 3D modeling technology were analyzed. Students of physical education participated in the study. In general, 350 students' study in the field of physics education at Sakarya University of the Republic of Turkey and Khoja Akhmet Yassawi International Kazakh-Turkish University, Kazakhstan. 64 students voluntarily enrolled in the course "Computer modeling of physics phenomena" in the curriculum of 2 courses (32 students from Sakarya University: 17 students in the control group, 15 students in the experimental group), (32 students from Khoja Akhmet Yassawi International Kazakh-Turkish University: 14 students in the control group, 18 students in the experimental group) and took part in the survey (Table 1). The course participants were randomly divided into control (31 students) and experimental (33 students) groups. However, potential biases could include the self-selection of students into the course and differences in baseline knowledge between institutions. The classes lasted 15 weeks, and at the end of the course 64 students took part in a survey on this subject. The results of the study were analyzed using SPSS software. We employed descriptive statistics (mean, standard deviation) to summarize the data and inferential statistics (ANOVA and t-test) to test hypotheses about differences between groups. Cronbach's alpha was used to assess the reliability of the survey instrument. The purpose of the survey was to determine the vision and academic performance of students in STEM education based on 3D modeling and printing.

In this study, ethical approval was obtained from the relevant ethical review boards at Sakarya University and Khoja Akhmet Yassawi International Kazakh-Turkish University. Informed consent was obtained from all participants prior to their involvement in the study. The reliability test results were verified using the Cronbach's alpha scale to ensure that the scale meets the reliability requirements. The reliability of the survey instrument was verified using Cronbach's alpha, which ensured that the scale met reliability requirements. Validity was ensured through expert reviews and pre-testing of the questionnaire. When analyzing the results of the study in the SPSS program, the reliability and reliability of the scale was checked using descriptive statistics (mean, standard deviation) and final statistics (ANOVA and t-test). Limitations of the study include the small sample size and potential selection biases due to voluntary participation. These factors may impact the generalizability of the findings. Future research could explore the impact of 3D modeling and STEM technologies across different educational contexts and with larger sample sizes. Further studies could also investigate longitudinal effects on student learning and career outcomes.

Table 1. Information about the survey participants

Educational institution of participants	Number	Percentage (%)	Total
Sakarya University, Turkey	32	50	64 (100%)
Khoja Akhmet Yassawi International Kazakh-Turkish University, Kazakhstan	32	50	
Gender	female 40	62.5	
	male	37.5	

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The information from this questionnaire allows us to track the effectiveness in integrating 3D modeling technology into undergraduate physics curricula. In addition to the PRISMA flow diagram, visual aids such as tables and charts summarizing survey responses and effect size calculations should be included to enhance clarity. The results of the survey were analyzed by other teachers of the Department of physics. 64 students completed the simulation questionnaire in full. The survey questions are presented in Table 2.

Table 2. The content of the survey questions

No.	List of survey questions	Rating			
1	How much has 3D modeling and printing expanded your understanding of physical phenomena?	1	2	3	4
2	How interesting was the virtual reality simulation based on STEM technology?	1	2	3	4
3	To what extent has virtual reality 3D modeling increased your interest in performing physical experimental work?	1	2	3	4
4	Do you think STEM-based modeling needs to be interactive?	1	2	3	4
5	Do you think that other 3D simulations will be useful for deepening your understanding of complex physical phenomena and laws?	1	2	3	4
6	Want to use more virtual reality simulations?	1	2	3	4
7	Do you want to master 3D modeling of physical phenomena yourself?	1	2	3	4
8	How much do you think 3D modeling and 3D printing will contribute to the economic development of the country, the development of Science and technology in the country?	1	2	3	4

Students answered questions on a scale from 1 to 4:
1 – "not at all"; 2 – "at some point"; 3 – "at a good level"; 4 – "very high".

Having made conclusions on the research methods, based on the research methods used by us, the results were analyzed and final works were made. All the answers of the study participants were checked on the questionnaire sheets and the average indicators were calculated. Standard Deviation is determined by the formula (2):

$$\delta = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(xi-\mu)^2} \qquad (2)$$

Where, $\boldsymbol{xi}$ - is an individual value; $\boldsymbol{\mu}$ - is the mean/expected value; $\boldsymbol{n}$ - is the total number of values.

IV. RESULTS

1. FEATURES DERIVED FROM THE RESULTS OF META-ANALYSIS OF SCIENTIFIC RESEARCH

This study conducts a meta-analysis of literature on the effectiveness of STEM technology-based 3D modeling/printing in physics teaching, focusing on the type of publication, year of publication, research approach and level of knowledge. Based on the data obtained, it can be concluded that the articles selected for meta-analysis are 100% taken from international journals [30,31]. In this study, STEM technology-based 3D modeling/printing efficiency in physics teaching is divided by author, article title, and Article results. The results of the effect of 3D modeling/printing integration on the results of teaching physics based on STEM technology are presented in Table 3. Data were extracted from selected articles, and effect sizes were calculated using the formula (1). The results of this meta-analysis, including effect sizes and standard errors, are presented in Table 3. Effect sizes in this study range from 2.15 to 3.7, indicating a high effectiveness of STEM technology-based 3D modeling/printing in enhancing physics teaching. High effect sizes suggest significant positive impacts on learning outcomes.

Table 3. All information about the latest selected studies according to the topic

No.	Authors	Description of the result obtained	Effect Size	Standard error	Category
1	Elfakki et al. [32]	A virtual 3D physical laboratory was developed and its effectiveness was evaluated.	2,19	0.095	High
2	Guan et al. [33]	The main perspectives of STEM education of physics teachers are identified.	2,15	1.201	High
3	Sulaeman et al. [34]	Opportunities for professional development in STEM education were identified.	2,48	0,078	High
4	Haryadi and Pujiastuti [35]	The effectiveness of using the STEM-PJBL model was evaluated.	3,7	0,025	High
5	Sulaiman et al. [36]	The effectiveness of the STEM - PBL integrated physical module was evaluated.	2,57	0,095	High
6	Aulyana and Fauzi [37]	The electronic module "the effectiveness of teaching STEM-based physics" has been developed.	2,35	1.105	High
7	Dosymov et al. [38]	Developed a methodology for using computer modeling and evaluated its effectiveness.	2,45	1.905	High

By analyzing the scientific literature, we were convinced of programs that occupy an important place in teaching physics: Algodoo [39] and Phet interactive simulation projects [40].

Algodoo is a digital program language for 2D physics simulations. It allows students and teachers to easily create simulations and explore physics through a user-friendly and visually appealing interface. The interactivity and flexibility of Algodoo allows you to conduct research on new physics topics [41], including those where there are few opportunities for real experiments. Algodoo's user-friendly graphical interface (Figure 2) allows the user to create visualizations to improve understanding of the phenomenon and serve as observation displays to provide vivid images to students.

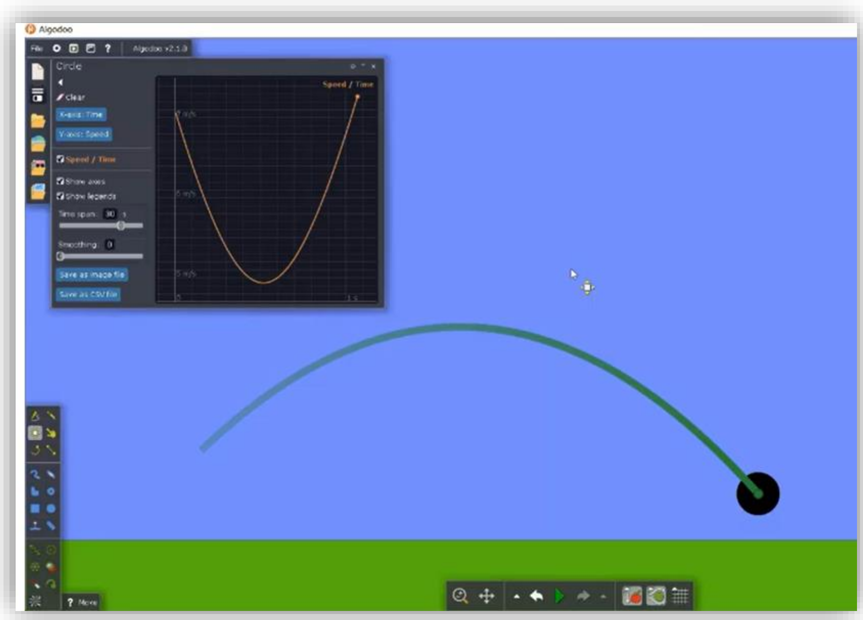

FIGURE 2. Physics simulations of Algodoo-2D on the movement of the projectile

Fast and simple modeling of the horizontal movement of the projectile, accompanied by visualization of the path traveled (tracking tool), characteristics of the velocity vector (horizontal and vertical components of the vectors, also displayed in real time) and drawing kinetic energy values. Consequently, the Algodoo program language provides an increase in students' physical activity through a combination of modern hardware touch screen interfaces, such as an interactive whiteboard.

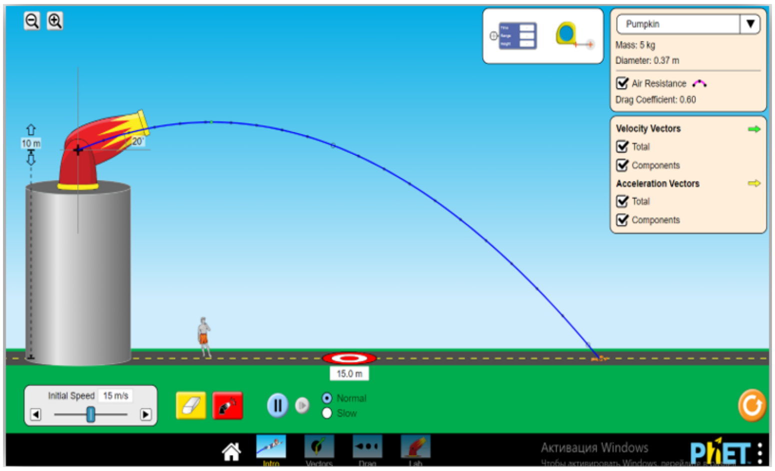

FIGURE 3. Phet-2D physics simulations on projectile motion.

The animations of the PhET program are based on a wide range of educational physics studies (Figure 3). PhET simulations offer animated, interactive, and game-like environments. This allows for a comprehensive study of the subject of physics. They emphasize the connections between real-life phenomena and basic science, make invisible things visible (e.g. atoms, molecules, electrons, photons) and use visual models for their study and search. The simulations are written in Java, Flash or HTML5 and can be run online or downloaded to your computer. PhET simulations are available for all students, students and teachers.

After analyzing scientific works related to the creation of virtual laboratory work by modeling physical phenomena and its application in the educational process, we identified the following features:

- conducting virtual experiments on a computer is much cheaper than on real hardware;
- allows the modeling of physical phenomena and patterns that are invisible to the naked eye. For example, in the study of electromagnetic field theory, the distribution of lines of force and the interaction of fields can only be clearly demonstrated by a virtual experiment with good dynamic graphics and sound;
- virtual laboratory work is interactive. They can respond to user actions in different ways;
- virtual laboratories provide independence, that is, virtual laboratory activities can only be carried out in classrooms equipped with computers. This approach allows you to perform the creation of laboratory equipment without additional costs.
- virtual laboratories provide security. Students can easily and safely participate in a virtual experiment. It can be checked and deleted at any time without losing data.

2. *AN EXAMPLE OF A PROGRAM CREATED BY THE AUTHORS AND ITS APPLICATION IN THE EDUCATIONAL PROCESS*

The program we have developed has prepared a 3D model of the equipment necessary for the physical experience to determine the acceleration of free fall, and shows a way to organize the experience in a real environment (Figure 4).

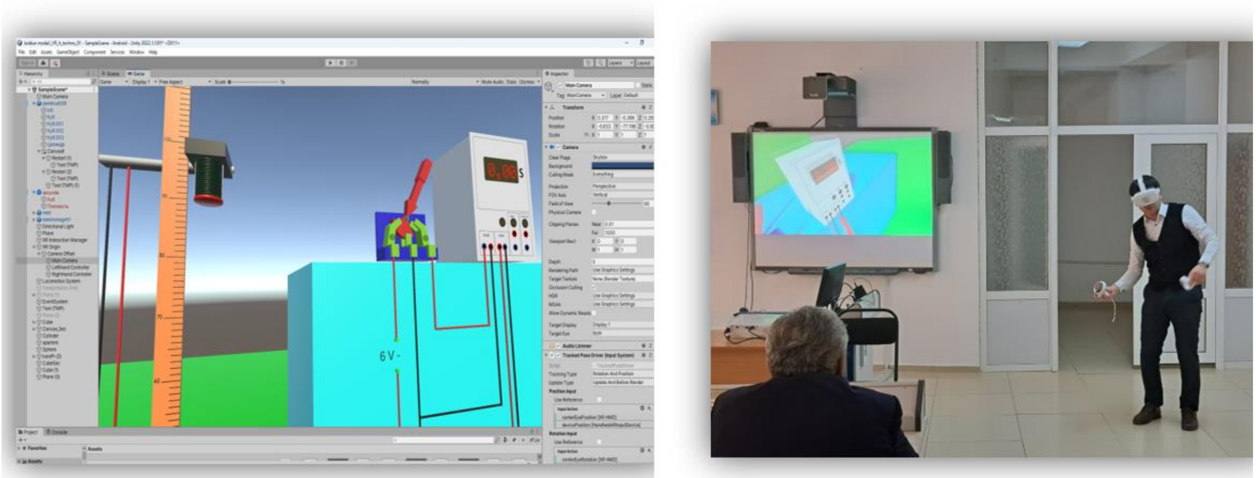

FIGURE 4. Virtual reality 3D model for determining free fall acceleration

The 3D models of the stopwatch, key, solenoid, measuring ruler, metal ball and conductive wires necessary for the experiment are prepared in a similar detail to real-life ones. To organize the experiment, it is necessary to magnetize the electromagnet so that it connects to the current and holds the metal ball. When the solenoid is de-energized, the metal ball begins to collapse. At the time of the start of this movement and when the solenoid is disconnected from the mains, the key automatically turns on the stopwatch. At the end of the ball movement, the stopwatch hits the contact made to the stop button. As a result, the stopwatch allows you to calculate the acceleration of free fall, measuring the time of movement of the ball with a small error. This program shows the principle of operation of each equipment and the scheme of connection of electrical conductors.

The content of the survey (Table 4) was aimed at finding out from future physics teachers how much virtual reality modeling has expanded their physical knowledge. According to question 1, 65% of the survey participants in in the experimental group replied that 3D modeling had an effect on expanding their understanding of physical phenomena at a "very high" level, while the remaining 35% showed that the student was "at a good level". In the experimental group while 92% of the students surveyed said that virtual reality modeling was interesting at a "very high" level, only 2 students expressed interest "in some cases". It was shown that more use of virtual reality modeling and self-mastery of 3D modeling of physical phenomena were considered necessary by 72% of students at a "very high" level.

Table 4. The results of the survey after completing the course

No.	List of survey questions	Average value	Standard deviation	Average value	Standard deviation
		Control group		Experiment group	
1	How much has 3D modeling and printing expanded your understanding of physical phenomena?	3.0	0.6	3.6	0.5
2	How interesting was the virtual reality simulation based on STEM technology?	2.8	0.6	3.3	0.7
3	To what extent has virtual reality 3D modeling increased your interest in performing physical experimental work?	2.82	0.9	3.2	1.1
4	Do you think STEM-based	3.0	0.6	3.6	0.7

	modeling needs to be interactive?				
5	Do you think that other 3D simulations will be useful for deepening your understanding of complex physical phenomena and laws?	3,1	0.0	4.0	0.0
6	Want to use more virtual reality simulations?	3.1	0.7	3.7	0.6
7	Do you want to master 3D modeling of physical phenomena yourself?	2.5	0.4	3.1	0.4
8	How much do you think 3D modeling and 3D printing will contribute to the economic development of the country, the development of science and technology in the country?	2.5	0.4	3.2	0.4

ANOVA analysis (p< 0.05) was performed to identify differences in STEM-based student approaches and academic performance in the control and experimental groups (Table 5).

Table 5. Comparative table of data in groups

Group	**Survey results before studying the course (mean ± SD)**	**Survey results after studying the course (mean ± SD)**	**t**	**p**
Control group	2.74 ± 1.1	2.85 ± 0.6	0.132	0.589
Experimental group	2.72 ± 0.9	3.46 ± 0.6	0.005	0.002

The results presented in Table 5 show that students scored significantly higher scores for student attitudes and academic performance towards STEM-based learning in the control and experimental groups. Although the students in the control group did not have significant differences in results before and after studying the course (p 0.589 > 0.05), the participants in the experimental group had significantly higher scores (p 0.002 > 0.05). The result of statistical analysis confirms that the use of 3D modeling and printing in the STEM curriculum can improve student academic performance.

ANOVA analysis was performed to assess differences in STEM-based student approaches and academic performance between the control and experimental groups (Table 5). The results indicate that students in the experimental group showed significant improvements in attitudes and academic performance related to STEM-based learning, with a p-value of 0.002, which is below the significance level of 0.05. In contrast, students in the control group did not exhibit significant differences in scores before and after the course, with a p-value of 0.589, indicating no significant change.

These findings confirm that the integration of 3D modeling and printing in STEM curricula positively impacts student performance and attitudes. The statistical analysis supports the conclusion that using these technologies enhances learning outcomes more effectively than traditional methods.

Thus, most future physics teachers agree that virtual reality modeling has expanded their understanding of physical phenomena and regularity, which they believe is very useful for mastering a complex physical phenomenon. For the same reason, they want to use more modeling.

V. FURTHER RECOMMENDATIONS AND GAPS

Several recommendations must be considered to enhance the effectiveness and use of STEM technologies and 3D modeling in educational environments. A more extensive comprehension of the effectiveness of these technologies in various educational settings will be achieved when future research is carried out with a bigger sample size and a more diversified spectrum of participants. Conducting longitudinal study is crucial for examining the long-term impact of 3D modeling on students' learning and their eventual career decisions. The incorporation of 3D modeling with other emerging technologies, such as virtual reality and augmented reality, has the capacity to provide enhanced and immersive learning experiences. In addition, the creation of comprehensive curriculum modules and teacher training programs will help effectively integrate these technologies into educational practices. Additionally, gathering extensive feedback from students may aid in refining teaching methods and fostering greater student engagement.

Ongoing research reveals some gaps that need addressing. In addition to the immediate learning outcomes, there is a restricted chance to assess the broader ramifications that 3D modeling has on other aspects of student growth beyond the immediate learning goals. The existence of divergent implementation tactics highlights the need for standardized approaches and best practices. To ensure that advanced technologies are available in all educational settings, it is crucial to address issues of fairness and inclusivity. Moreover, it is essential for study to explore the suitability of three-dimensional modeling in disciplines outside physics, and assess the ways in which these technologies facilitate diverse learning preferences. Addressing these gaps would facilitate the creation of a more comprehensive and equitable approach for integrating 3D modeling and STEM technology into educational settings.

VI. DISCUSSION

There are several works on the influence of the use of computer modeling in teaching physics on improving the level of education [42, 43].

Hattori et al. [44] provide an effective two-way teaching method based on software virtual simulations and real experiments in physics using the "Blender" 3D modeling software for early STEM learning in high schools and a 3D printer that produces objects developed by Blender. We believe that Blender is useful not only as a virtual simulator and visualization tool, but also as an object modeling tool that is needed in real experiments. In addition, it is possible to distinguish its effectiveness from the results of surveys and literary analyzes related to the creation of virtual laboratory work by modeling physical phenomena and its use in the educational process.

In the current "conditions of the Fourth Industrial Revolution", there are works that show that improving the practical training of future physics teachers through 3D modeling and VR technologies is an urgent problem [45-47]. Boice et al. [48] believe that there is a need to increase enthusiasm for STEM education in preparing students for a complex world, but implementing STEM in the classroom can be difficult, as this is achieved by increasing collaboration, workload in subjects. The results of surveys of scientists prove that, despite certain difficulties, aspects of the training program supported the introduction of STEM technology. The results of some studies show that STEM effectively implements knowledge-based digital tools in physics teaching, which positively contributes to the empowerment of teachers and students and the activation of their activities [49-51].

We consider it an urgent problem to train future physics teachers who have mastered 3D modeling and can effectively use VR technology in organizing physical experiments in the process of teaching physics using a specially oriented pedagogical methodology.

VII. CONCLUSION

Based on the analysis of the existing system of teaching on the basis of three-dimensional graphics, we, Future physics teachers, showed the features of teaching 3D modeling and visualization of physical phenomena and patterns. As can be seen from the analysis of the scientific literature in the course of the study, from the results of the survey, the popularity of 3D-based virtual laboratories in the educational process is developing more and more. This area is increasingly focused around the world, especially in the training of future physics specialists at the university level. The effectiveness of the education system, which uses 3D-based virtual laboratories to help better understand physically complex phenomena and patterns, will be improved by future physics teachers ' perception of the theoretical and practical aspects of the subject being studied.

Consequently, since objects created using computer programs can be implemented on a 3D printer, future physics teachers will have the opportunity to touch these objects with their hands and control them. As a result, we find it useful for future physics teachers to use them in modeling physical phenomena when learning any programming language.

The results of the study allow us to develop a methodology for teaching physics using 3D modeling technology. In addition, it will help future teachers to develop the ability to repair or fake out-of-order equipment in the physics room.

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Author contribution

Indira Usembayeva (Conceptualization, Methodology, Writing - Original Draft), Bakitzhan Kurbanbekov (Formal analysis, Visualization, Resources, Investigation), Sherzod Ramankulov (Project administration, Writing - Review & Editing, Funding acquisition), Aknur Batyrbekova (Methodology, Investigation), Kazhymukan Kelesbayev (Visualization, Resources), Asem Akhanova (Methodology, Writing - Review & Editing).

Conflict of Interest

The authors have no potential conflicts of interest, or such divergences linked with this research study.

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