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SUCCESSION IN TEACHING 3D MODELING AND AR/VR TECHNOLOGIES

Abstract

This article is devoted to the continuity in teaching 3D modeling, augmented (AR), and virtual reality (VR) technologies. The authors pay special attention to integrating these technologies into the educational process, their interrelation, and their importance for forming professional skills of future computer science teachers. Topics were considered in two disciplines: “Computer graphics and 3D modeling” and “Augmented and virtual reality”, which have a systematic character and continuity. The project works of students within the framework of studying these disciplines are presented, which were evaluated according to a specially developed assessment scale according to six main criteria. The article presents the results of a pedagogical experiment in teaching 3D modeling and AR/VR. 72 students of the educational programs “6B01506-Computer Science”, “6B01514-Computer Science-Robotics” and the educational program “6B01505-Physics-Computer Science” took part in the experiment. The phased nature of the study helped to reveal these research questions comprehensively. The phased nature of the study helped to reveal these research questions comprehensively.

Keywords: end-to-end digital technologies, continuity**,** 3D modeling, augmented reality, virtual reality, future computer science teachers.

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3D МОДЕЛЬДЕУ ЖӘНЕ AR/VR ТЕХНОЛОГИЯЛАРЫН ОҚЫТУДАҒЫ САБАҚТАСТЫҚ

Аңдатпа

Мақалада 3D модельдеу, толықтырылған (AR) және виртуалды шынайылық (VR) технологияларын оқытудағы сабақтастық қарастырылады. Авторлар бұл технологияларды білім беру үдерісінде интеграциялауға, олардың өзара байланысына және болашақ информатика мұғалімдерінің кәсіби дағдыларын қалыптастырудағы маңыздылығына ерекше назар аударады. Екі пән бойынша тақырыптарға талдау жасалынып алынды: «Компьютерлік графика және 3D модельдеу» және «Толықтырылған және виртуалды шынайылық», бұл 2 пән жүйеленген сипат пен сабақтастыққа ие. Осы пәндерді зерттеу барысында студенттердің жобалық жұмыстары ұсынылды, жобалар арнайы әзірленген алты негізгі критерийға сәйкес бағалау шкаласы бойынша бағаланды. Мақалада 3D модельдеу, толықтырылған және виртуалды шынайылық технологияларын оқытуда жүргізілген педагогикалық эксперименттің нәтижелері көрсетілген. Экспериментте «6В01506-Информатика», «6В01514-Информатика-робототехника» және «6В01505-Физика-Информатика» білім беру бағдарламаларының 72 студенті қатысты. Жүргізілген зерттеудің кезеңмен орындалуы зерттеу сұрақтарын жан-жақты ашуға көмектесті.

Түйін сөздер: цифрлық технологиялар, сабақтастық, 3D модельдеу, толықтырылған шынайылық, виртуалды шынайылық, болашақ информатика мұғалімдері.

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ПРЕЕМСТВЕННОСТЬ В ОБУЧЕНИИ 3D МОДЕЛИРОВАНИЮ И ТЕХНОЛОГИЯМ AR/VR

Аннотация

В статье рассматривается преемственность в обучении 3D моделированию и технологиям дополненной (AR) и виртуальной реальности (VR). Особое внимание авторы уделяют интеграции этих технологий в образовательный процесс, их взаимосвязи и значимости для формирования профессиональных навыков будущих учителей информатики. Сопоставлены темы двух дисциплин: «Компьютерная графика и 3D моделирование» и «Дополненная и виртуальная реальность», которые характеризуются систематизированной структурой и преемственностью. Изложены проектные работы студентов в рамках изучения данных дисциплин, которые были оценены по специально разработанной шкале оценивания по 6 основным критериям. В статье представлены результаты проведенного педагогического эксперимента при обучении 3D моделированию и технологиям дополненной и виртуальной реальности. В эксперименте приняли участие 72 студента образовательных программ «6В01506-Информатика», «6В01514-Информатика-робототехника» и образовательной программы «6В01505-Физика-Информатика». Поэтапность проведенного исследования помогли всесторонне раскрыть исследовательские вопросы.

Ключевые слова: сквозные цифровые технологии, преемственность, 3D моделирование, дополненная реальность, виртуальная реальность, будущие учителя информатики.

Main provisions

Currently, there is an increased demand for skilled professionals in 3D modeling and AR/VR in the labor market. 3D modeling is a multidisciplinary field and requires knowledge and skills to solve a variety of tasks through analysis, abstractions, modeling, and programming. It requires a revision and systematization of university education in terms of the principle of continuity of skills and knowledge in 3D modeling, and the development of AR/VR applications to eliminate knowledge gaps of university graduates.

Also, it is necessary to observe the principle of continuity in the presentation of educational material and the integration of two disciplines for a more holistic perception of the surrounding world.

Introduction

The contemporary advancement of digital technologies profoundly has influenced educational processes. Particular emphasis is placed on 3D modeling, as well as augmented and virtual reality (AR/VR) technologies, as their demand is increasing across numerous industries. In this regard, there is a need to develop effective continuity principle-based educational programs. The article aims to explore the continuity in teaching 3D modeling and AR/VR technologies, identify key methodological approaches, and offer recommendations for improving the educational process. 3D modeling and AR/VR expand possibilities in the design, visualization, and interaction with digital content. Educational programs and courses focused on these technologies must ensure continuity, consistency, and logical development of students' knowledge and skills. This includes both the fundamental principles of manipulating 3D models and the complex aspects of integrating these models into AR/VR environments.

International research also confirms that the ability to model is an increasingly necessary skill for future computer science teachers. Cross-curricular technology use in the classroom appears to be effective at the educational level, according to international research. Research in physics, astronomy, anatomy, chemistry, etc. are a few examples [1-3].

By utilizing cross-cutting technologies, students became highly motivated to learn and could easily discover new knowledge about complex and unavailable real-life processes, mastering their practical skills. Studies have revealed, for example, that students using the traditional method misunderstood some astronomy concepts and carried the misconception for years. Through AR technology, students were able to achieve an accurate understanding of astronomy concepts [3, 4].

This skill is relevant in the development of interactive learning tools using AR/VR technology in the educational environment. AR tools are known to be promising and effective because they activate students' learning and cognitive activities.

For example, in the field of building design and architecture [5], a preliminary visual representation is significant and is successfully implemented with Building Information Modeling (BIM) [6]. The dynamic facade of the building, responding to climatic conditions, filling with various textures, animation of the movement of vehicles, and the functioning of the electrical and heating systems are tangibly conveyed through augmented and virtual reality [7, 8]. Restoring damaged parts of stone sculptures and artifacts found in archaeological excavations through virtual 3D reconstruction is also the result of the integrated work of modeling and augmented reality [9].

A notable achievement in this area is the development of the NeRF (Neural Radiance Field) algorithm, which is capable of constructing highly realistic models even with weak geometric image configurations. Another algorithm, SIFT (Scale Invariant Feature Transformation), is effective under various radiometric and geometric conditions. In addition, based on the assigned tasks, algorithms such as the SURF (Speeded Up Robust Features), ORB (Oriented FAST and Rotated BRIEF), SfM (Structure from Motion), and MVS (Multi-View Stereo) can be used as well [10]. All these studies are aimed at automating the modeling process, making it more accurate and detailed.

All studies mentioned above highlight the necessity of developing 3D models without diminishing the significance of professional 3D content creators' work. Particularly, this requires paying special attention to their artistic and aesthetic training, boosting design and construction skills, and evoking spatial thinking through mathematical and/or physical modeling. In this context, teaching students 3D modeling is not only practical but also has a theoretical meaning that includes a deep understanding of the modeling process as a whole.

Despite their benefits, 3D-modeled objects require integration with other technologies to fully utilize their potential. This is possible in symbiosis with immersive technologies such as augmented and virtual reality.

Research methodology

The continuity study was organized into several stages in teaching 3D modeling and augmented and virtual reality technologies. The study's phased nature helped to reveal comprehensively these research questions.

The first stage involved identifying a targeted academic group of undergraduate students. Particularly, they were studying similar educational programs, which are "6B01506-Informatics", "6B01514-Informatics-Robotics" and "6B01505-Physics-Informatics" where they also studied the development of AR/VR applications during the "Augmented and Virtual Reality" course in their fourth academic year. 72 students who developed AR/VR applications in a project-based learning format, participated in the study. A discipline with a volume of 5 credits (ECTS) made it possible to conduct a pedagogical experiment in consensus with the curriculum. Note that completing "Computer Graphics and 3D Modeling" a course in the third academic year, is the primary requirement to enroll in this course.

We compared the topics in these two disciplines. The topics discussed in these two disciplines are systematic and consistent (Table 1).

Table 1. Interrelated topics across the two courses

№	«Computer Graphics and 3D Modeling» course	«Augmented and Virtual Reality» course
1.	Modeling objects based on primitives	Introduction to Augmented Reality and Virtual Reality Technologies. Hardware and Software of AR/VR
2.	Fundamentals of Mesh Modeling	AR/VR development in Unity. Introduction to Unity: User Interface, Scene, Navigation and Primitives
3.	Fundamentals of spline	3D Models for AR/VR Applications. The Asset Store
4.	Creating models using the lofting method	Vuforia Engine Package for Unity
5.	Deformation of models built using the lofting method	Graphics: Rendering, AR Camera, Lighting, Meshes, Textures, Shaders, Materials
6.	Modeling using Boolean operations	Interaction with virtual objects: buttons, virtual buttons, voice recognition, Lean Touch, Gaze interaction
7.	Working with materials. Non-standard materials	Physical properties of virtual objects: Rigidbody, Collision, Joints
8.	Applying texture maps	Animation of virtual objects: Rotation, Clips, Animator Controllers
9.	Material Projection Basics	Scripting for interactions: Scripting concepts, Important Classes, Unity architecture, Plug-ins
10.	Cameras in the scene. Dynamics in the scene. Stage Lighting Basics	Targets: Image Targets, Cylinder Targets, Ground plane and MultiTarget
11.	Introduction to Animation. Character animation using Character Studio	Multimedia in VR scene: Audio Mixer and Video Clips

By examining topics covered by the two disciplines, we could determine how closely related and intersecting 3D modeling and AR/VR are. Knowledge and skills from one field are directly applied to another, which makes the preliminary study of 3D modeling necessary for the effective development of augmented and virtual reality technologies. At the next stage, a selection of educational projects was carried out, in which students developed various projects using Unity or Unreal Engine with integration of the Vuforia SDK and Easy AR. Consider a project that aims to create a virtual reality that allows for internal teleportation (Figure 1).

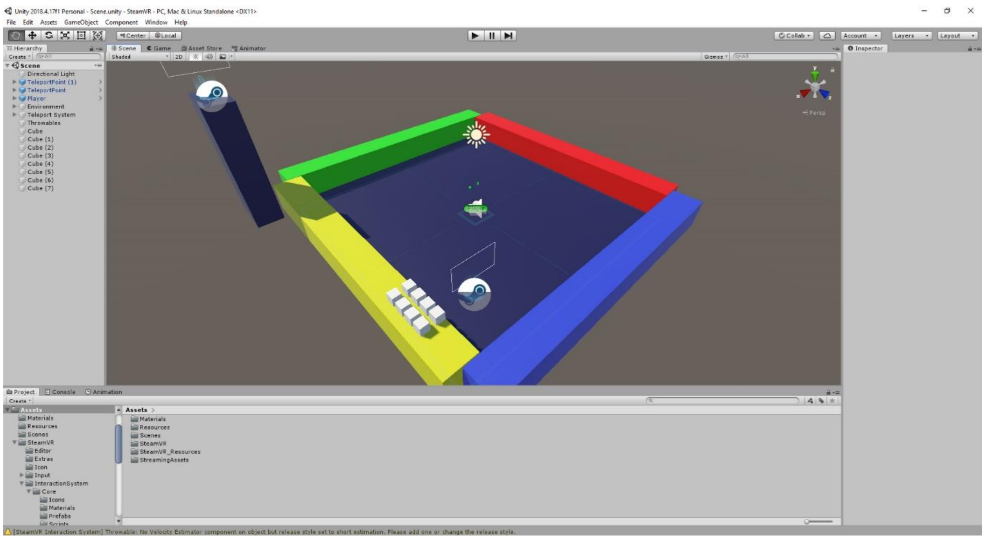

Figure 1. Teleportation in VR

Teleportation is instant movement from one location to another. By calculating the distance based on the Collider's position and opting for a focus mode, students were able to implement it and add interaction with virtual objects.

As it is already known, virtual 3D objects can be split into two main types, low poly and high poly, based on the number of polygons used, which affects their detail. Low poly is a simplified model with fewer polygons, requiring less computing power, and all flat details that do not affect the silhouette are drawn through textures or on the normal. High poly is more detailed due to no polygon restrictions. Students used the produced 3D models with few polygons for minor objects when completing projects, but these models were better and more detailed for the primary elements. Consider, for example, a project to manage virtual models using Lean Touch (Figure 2).

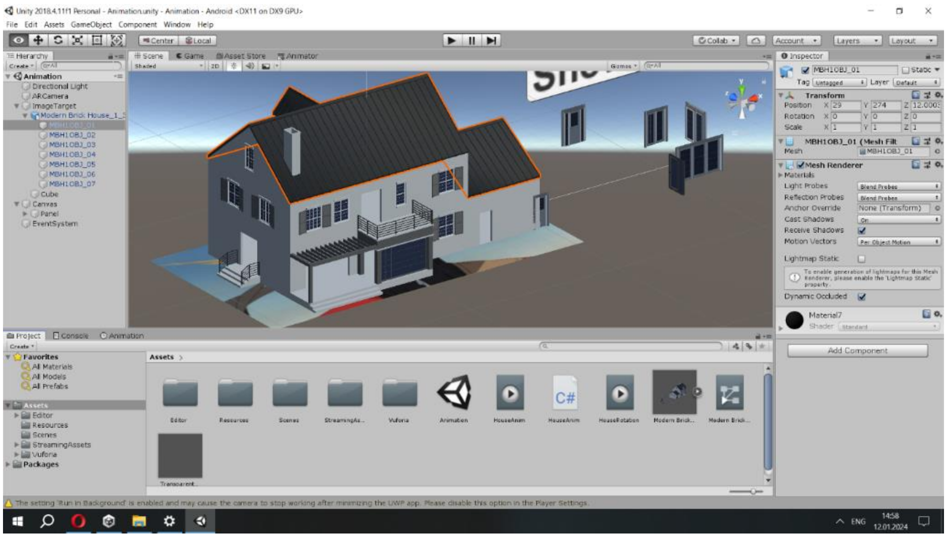

Figure 2. Managing a 3D model using Lean Touch

Lean Touch is an asset that activates Touch operation in smartphones. It allows you to move, connect, grab, etc. virtual models controlled through sensors. The project contains minor low poly and main high poly models in the form of furniture and various structures in the house, which can be manipulated to build an entire house.

Students’ work was assessed according to the developed project evaluation scale, according to six main criteria (Table 2).

Table 2. Project work assessment scale

Criteria	*Explanation of the criterion*	*Assessment scale*
Purpose	*Indicate the projects’ purpose and relevance; analyze the problem's relevance and emphasize its uniqueness*	*Excellent 90-100%*
	Outline the problem that the project intends to address	*Good 70-89%*
	Understanding of the purpose of the project is not clearly expressed	*Satisfactory 50-69%*
	Expressing the project’s objective is unclear, and it	*Unsatisfactory 0-49%*
Analysis of existing solutions and methods	*An analysis of existing solutions and a search are conducted. The project’s original within its field and proposed solution are both promising and relevant*	*Excellent 90-100%*
	Some indicators are considered during the project’s subsequent analysis, including a literature review, comparison with similar studies, etc.	*Good 70-89%*

	Some indicators are considered during the project's subsequent analysis, including a literature review and comparison with similar studies. However, there is an insufficient comparison with similar studies	*Satisfactory 50-69%*
	Existing solutions and similar projects are presented	*Unsatisfactory 0-49%*
Methods	*The selected methods are justified and align with the identified issue. Appropriate tools and methods were chosen for the project implementation*	*Excellent 90-100%*
	Methods are not as effective as widely accepted alternatives and contribute to addressing the issues in the project	*Good 70-89%*
	Methods are not as effective as widely accepted alternatives and do not fully contribute to addressing the issues in the project	*Satisfactory 50-69%*
	The results do not coincide with the stated objectives. The selected tools and methods for project implementation are irrelevant and failed to facilitate getting the desired outcome	*Unsatisfactory 0-49%*
The result quality	*The project's goal and objectives are fully realized. The project demonstrates the fundamental principles of project execution*	*Excellent 90-100%*
	The project's goal and objectives are not fully realized. The project demonstrates the fundamental principles of project execution. The fundamental principles of the project are not fully articulated	*Good 70-89%*
	The project's goal and objectives are partially realized. The fundamental principles of the project are presented in fragments	*Satisfactory 50-69%*
	The project's goal and objectives are not achieved. There is no understanding of the fundamental principles of working on the project	*Unsatisfactory 0-49%*
Independence, individual contribution to the project	*The participant is confident in his/her contribution to the project, detailing the specific role he undertakes. The participant's contribution to the project is significant and meets the established goals and objectives; the participant shows a strong understanding of the subject area*	*Excellent 90-100%*
	The participant possesses a general understanding of the project's content but lacks clarity regarding their specific contributions. The participants' work aligns with the project's goal and objectives; the participant shows a general understanding of the project	*Good 70-89%*
	The participant understands the project's content but is unable to specify their contribution to it. The participant's work aligns partially with the project's goal and objectives	*Satisfactory 50-69%*
	The participant is unable to articulate their contribution to the project. The participant's work does not align with the project's goals and objectives	*Unsatisfactory 0-49%*
Specific Criteria	*All project requirements are met*	*Excellent 90-100%*
	The largest number of requirements for the project are fulfilled	*Good 70-89%*
	Half of the project requirements are fulfilled	*Satisfactory 50-69%*
	Project requirements are met or not fully met	*Unsatisfactory 0-49%*

The evaluation results demonstrated both strengths and areas for further improvement. These results will be used to analyze further and improve the learning process, and to provide constructive feedback to students to improve their professional skills and the quality of their projects. The results of the reflexive survey of students also showed the research's positive orientation.

Results of the study

The findings from a reflective survey of students indicated the positive direction of the study. A total number of 72 respondents were surveyed, comprising 35 (48%) from the educational program

"6B01506-Informatics", 25 (35%) from "6B01514-Informatics-Robotics", and 12 (17%) from the educational program "6B01505-Physics-Informatics" (Figure 3).

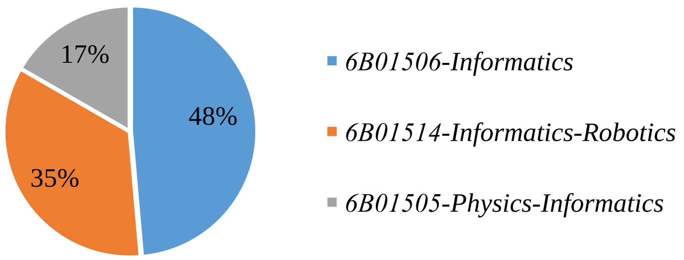

Figure 3. Number of respondents by educational program

To the question, "How do you assess your knowledge and skills in 3D modeling? (choose one of the proposed ones)", 42 students answered that they had an average level ("I have sufficient knowledge and skills in creating models and working with various materials, but more experience is required"), 18 students answered that they had a high level of knowledge ("My knowledge and skills allow me to develop complex and more detailed models in various programs"), and 12 students had a beginner level ("I have only basic knowledge and can create simple models, and a lot of practice and study is required") (Figure 4).

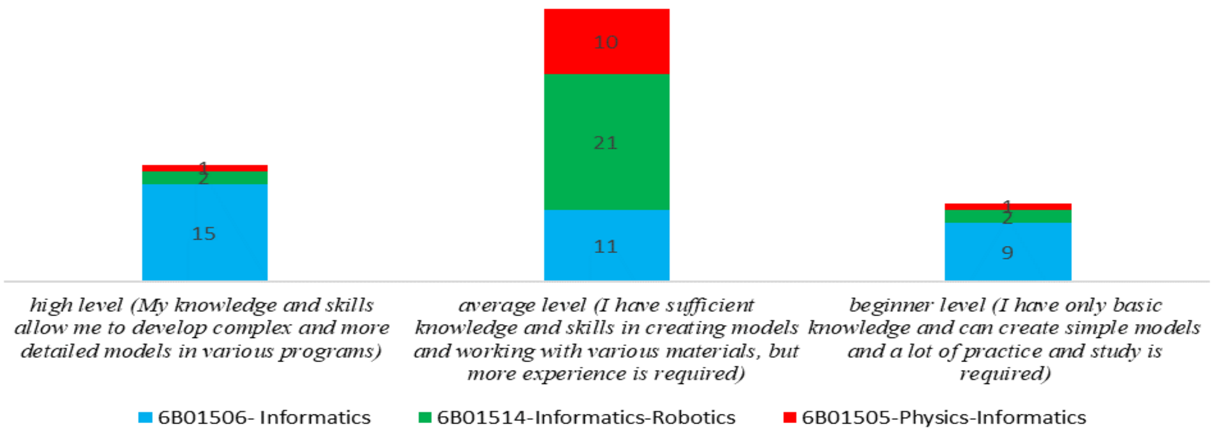

Figure 4. How would you rate your knowledge and skills in 3D modeling?

Students were also asked "Choose 3D modeling programs that you have studied and use most frequently (multiple choice)" and more students chose Blender, that is, 49 times (Figure 5).

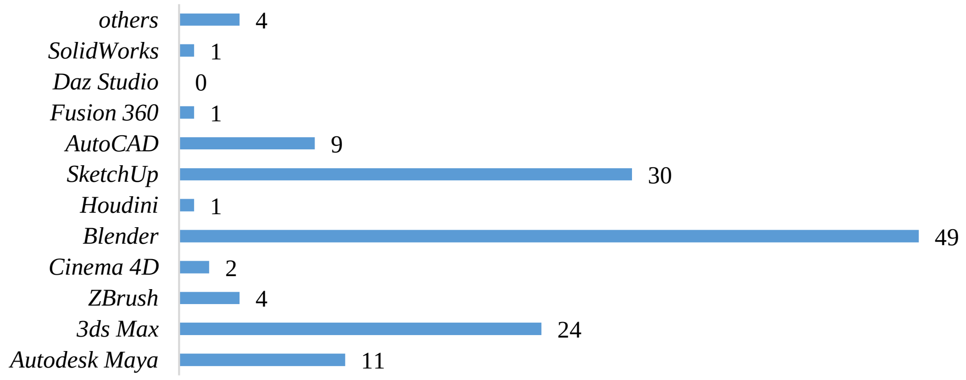

Figure 5. Choose a 3D modeling program that you have studied and use most frequently (multiple selection)

Regarding the question "Choose the most important feature of AR/VR applications" 22% of respondents indicated the functionality and interactivity of the 3D models employed, while 17% opted for the "physical features of the 3D models used" (Figure 6).

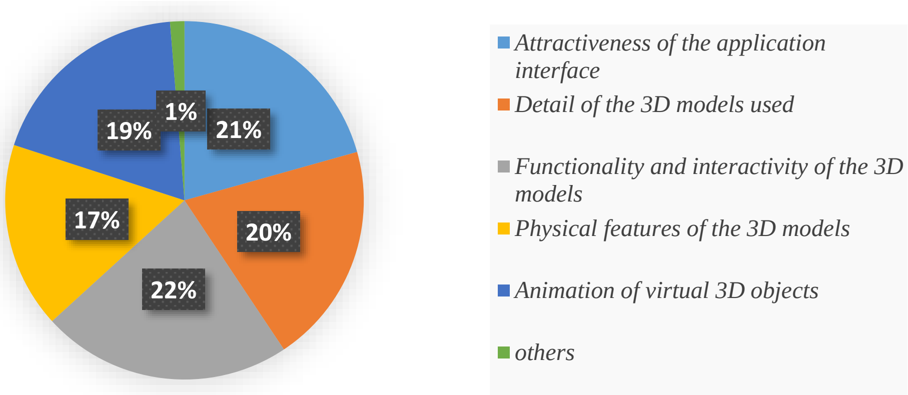

Figure 6. Choose the most important feature of AR/VR applications

Analyzing all the results obtained, it is evident that the phased nature of the study facilitated a thorough exploration of its essence. The continuity in teaching 3D modeling and AR/VR enhanced the learning process by optimizing 3D models' building and improving their physical attributes in a virtual setting, thereby facilitating the attainment of the study's objectives.

Discussion

The study of continuity in teaching 3D modeling as well as augmented (AR) and virtual reality (VR) technologies has shown a positive trend. The continuity of methods and approaches in these disciplines allowed students to learn new skills faster and apply them more effectively in practice. In addition, integrating AR/VR technologies into the process of creating 3D models improved the quality of visualization and increased the accuracy of their physical characteristics, which contributed to an in-depth understanding of complex concepts and accelerated achievement of learning objectives.

Additionally, the closely related topics of the disciplines "Computer Graphics and 3D Modeling" and "Augmented and Virtual Reality" contributed to the enhancement of students' skills in developing AR/VR applications. Students' completed project work validates this, as they underwent evaluation using a specially designed assessment scale that involved six criteria. Each criterion has 4 evaluation levels.

Conclusion

Maintaining continuity in teaching 3D modeling as well as augmented and virtual reality technologies is essential for effectively advancing these rapidly evolving and complex fields. A systematic approach to learning, including basic skills and advanced techniques, provides students with the solid knowledge and practical skills needed to succeed in these fields. Educational programs must consider the peculiarities of technology development, and the educational product is developed logically and consistently. The research perspective is aimed at identifying and optimizing effective approaches to teaching 3D modeling, which will further improve the process of training specialists to create applications in augmented and virtual reality (AR/VR).

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