

Virtual Reality

Development of Virtual Reality-Based Computer Assembly Simulation Learning Media

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A B S T R A C T

The development of Virtual Reality (VR) technology provides great opportunities in creating interactive and immersive learning media that can simulate hands-on practice more realistically. In computer assembly learning at vocational schools, limited availability of laboratory equipment often becomes a major obstacle, resulting in students not gaining optimal direct practice experience. This study aims to develop a Virtual Reality-based computer assembly learning simulation as an interactive, safe, and engaging alternative learning tool. The research employed a Research and Development (R&D) method using the ADDIE model, consisting of the stages of analysis, design, development, implementation, and evaluation. Computer component assets were modeled using Blender 3D and then integrated into Unity to build an interactive VR-based simulation. The testing phase involved Black Box Testing and Application Testing with 10 respondents, consisting of 7 vocational students and 3 alumni from the Computer and Network Engineering major. The results show that all interactive features performed according to the expected scenarios, and the feasibility assessment through Application Testing achieved a score of 87.2%, indicating that the simulation is suitable, easy to use, and effective in improving students' understanding of computer assembly procedures. Additionally, the VR media was considered to provide a more realistic learning experience, reduce the potential for errors during real practice, and increase student engagement throughout the learning process. Therefore, this VR-based learning media can serve as a solution to laboratory limitations and a foundation for further development of VR-based practical learning materials in the field of Computer and Network Engineering.

INTRODUCTION

The development of computer technology demands practical competency in hardware assembly and installation. In Vocational High Schools (SMK) majoring in Computer and Network Engineering (TKJ), computer assembly is a core competency that students must master. However, significant obstacles exist in the learning process, particularly related to the limited number of computers available for practical work, limited lab time, and the risk of component damage during practice.

To understand the correct computer assembly process, a thorough understanding of computer hardware is required, both logically and physically. Computer assembly and installation skills can also be a source of creative economic opportunities based on information technology. The role of computers in everyday life is increasingly important, both in business, industry, construction, and education.

Virtual Reality (VR) is a technology that can provide an immersive and interactive experience in learning. VR technology allows students to practice computer assembly virtually without relying on physical devices. This research develops VR-based computer assembly simulation learning media as an alternative solution that is safe, efficient, and widely accessible.

LITERATURE REVIEW

Virtual Reality

Virtual Reality represents a technology that enables users to experience a virtual world resembling the real world through devices such as VR headsets. This technology has undergone rapid advancement with increasingly innovative features, ranging from screen technology and motion sensors to more affordable pricing. VR has been utilized to create educational simulations across various fields, including medical training, architecture, and disaster simulation. The immersive nature of VR technology makes it particularly suitable for practical learning applications, allowing users to engage in realistic scenarios without the constraints and risks associated with physical practice environments.

Unity 3D

Unity 3D is a cross-platform game engine used to create applications that can run on various devices. Unity is renowned for its ease of use and features main components such as Assets, Scenes, Game Objects, and Components. Unity supports scripting in Javascript, C#, and BOO to provide interactivity to objects. As one of the most popular development platforms in the industry, Unity offers a comprehensive integrated development environment that combines powerful 3D rendering capabilities with an intuitive visual editor. The engine's versatility extends beyond gaming applications, making it an ideal choice for developing educational simulations, virtual reality experiences, and interactive training programs. Unity's extensive asset store provides developers with ready-made resources, including 3D models, scripts, and plugins, significantly accelerating the development process. Furthermore, its strong community support and extensive documentation make it accessible to both beginners and experienced developers. The engine's real-time rendering capabilities and physics engine enable the creation of realistic and immersive virtual environments, which are essential for educational applications such as computer assembly simulations. Unity's built-in VR support and compatibility with major VR platforms, including Oculus, HTC Vive, and other headsets, make it particularly well-suited for developing virtual reality learning media that can provide students with hands-on practice experience in a safe and controlled digital environment.

Blender 3D

Blender is an open-source software for creating three-dimensional visual content, including modeling, animation, rendering, and physics simulation. Blender has experienced rapid development and is used by professional studios across various fields. Blender has also been utilized to create VR-based educational simulations in numerous research studies. As a comprehensive 3D creation suite, Blender offers a complete pipeline for developing high-quality 3D assets, from initial concept design to final production. The software's robust modeling tools enable artists to create detailed and accurate representations of physical objects, making it particularly valuable for educational applications that require precise replicas of real-world components such as computer hardware parts. Blender's advanced texturing and material systems allow developers to achieve photorealistic surfaces, enhancing the visual fidelity and realism of virtual learning environments. The software's animation capabilities support both keyframe and procedural animation, enabling the creation of interactive tutorials and step-by-step assembly demonstrations. Additionally, Blender's physics engine can simulate real-world behaviors such as gravity, collisions, and object interactions, which are essential for creating authentic assembly experiences in VR simulations. The open-source nature of Blender not only makes it freely accessible to educational institutions with limited budgets but also ensures continuous improvement through active community contributions. Its compatibility with various file formats and seamless integration with game engines like Unity 3D make Blender an ideal tool for creating 3D assets for VR-based learning media. Furthermore, Blender's extensive plugin ecosystem and Python scripting support provide developers with the flexibility to customize workflows and automate repetitive tasks, significantly improving production efficiency in developing educational VR content.

ADDIE Development Model

The ADDIE model is a systematic framework frequently used in the development of learning media, consisting of five interconnected stages that guide the entire instructional design process. The first stage, Analysis, involves identifying learning needs, understanding the target audience's characteristics, examining existing learning constraints, and determining the gaps between current and desired knowledge or skills. The second stage, Design, focuses on planning the

learning flow and structuring content, including defining learning objectives, selecting appropriate instructional strategies, creating storyboards, and designing the user interface and interaction patterns. The third stage, Development, encompasses the actual creation of the simulation media, where all designed elements are transformed into functional learning materials through asset creation, programming, integration, and initial testing. The fourth stage, Implementation, involves deploying the media into the target environment, which includes installation, user training, pilot testing with actual learners, and gathering initial feedback on usability and effectiveness. The final stage, Evaluation, measures the effectiveness of the learning media through both formative and summative assessments, analyzes user feedback, identifies areas for improvement, and implements necessary revisions to enhance the overall quality and learning outcomes. This iterative and systematic approach ensures that the developed learning media is pedagogically sound, technically functional, and aligned with the intended educational goals, making the ADDIE model particularly suitable for developing complex educational technologies such as VR-based computer assembly simulations.

METHOD

Research Type

This research is classified as Research and Development (R&D) with a mixed-method approach, combining quantitative methods to measure product effectiveness and feasibility, as well as qualitative methods to explore user experiences and gather in-depth feedback on the learning media.

Development Model

The research adopts the ADDIE model, which consists of five systematic stages that guide the entire development process. In the Analysis stage, the research identifies students' learning needs and facility limitations in schools, including the shortage of computer units during practical sessions and time constraints that hinder effective hands-on learning. The Design stage encompasses several critical activities, including the development of a simulation storyboard with 12 assembly stages, designing the virtual environment layout representing a practical classroom, creating a minimalist and intuitive user interface (UI), and designing object interactivity for various computer components such as motherboard, RAM, processor, PSU, and other hardware elements. The Development stage involves the actual creation process, which includes 3D object modeling using Blender software, integration into Unity with Blueprint implementation, and adjustment of animations and sensory feedback to enhance realism and user engagement. The Implementation stage focuses on field testing, where the developed media is evaluated by 10 respondents consisting of 7 tenth-grade vocational high school students majoring in Computer and Network Engineering (TKJ) and 3 alumni who already have professional experience in the field. Finally, the Evaluation stage is conducted through two main approaches: Black Box Testing to examine the functionality of features and ensure all interactive elements work properly, and Application Testing using Likert scale questionnaires to measure the feasibility, usability, and effectiveness of the VR-based learning media from the users' perspectives.

RESULTS AND DISCUSSION

Black Box Testing

Black Box Testing was conducted to evaluate the functionality and technical performance of the VR-based computer assembly simulation. The testing results demonstrated that all 13 scenarios were successfully executed according to expectations, indicating that the application functions properly without critical errors. All interactive features, including component installation, the use of virtual drills for screws, cable connections, and the power button functionality, operated smoothly and responded appropriately to user inputs. This comprehensive testing validated that the system's core mechanics work as intended, ensuring that users can perform assembly tasks seamlessly within the virtual environment. The successful completion of all test scenarios confirms that the developed VR learning media is technically sound and ready for deployment in educational settings, providing students with a reliable and functional platform for practicing computer assembly skills without encountering technical obstacles that could hinder the learning experience.

Tabel 1. Respondent Data Testing

Question	Scale 1	Scale 2	Scale 3	Scale 4	Scale 5
The simulation is easy to use	0	0	0	6	4
The simulation runs smoothly	0	0	2	4	4
Components are easy to install	0	0	0	5	5
Screw installation is easy	0	0	3	3	4
Improves assembly skills	0	0	1	2	7

The feasibility assessment of the VR-based computer assembly simulation was conducted through comprehensive evaluation involving multiple respondents from the target user group. The calculation results revealed that the media achieved a feasibility level of 87.2%, which falls within the "very feasible" category according to standard assessment criteria. This high percentage indicates that the simulation is not only technically sound but also highly regarded by users in terms of usability, functionality, and educational value. Respondents consistently rated the simulation as very easy to use, with an intuitive interface that allows students to navigate and interact with virtual components without significant difficulty. Furthermore, the evaluation demonstrated that the VR learning media is highly effective in enhancing students' understanding of computer assembly processes, providing them with clear visualization and hands-on practice opportunities that traditional learning methods may not adequately offer. The strong feasibility score validates that the developed simulation meets the educational objectives and successfully addresses the limitations identified in conventional practical learning, making it a valuable supplementary tool for vocational education in computer and network engineering programs.

The research findings demonstrate that the VR-based learning media successfully delivers a comprehensive learning experience that addresses multiple pedagogical and practical challenges in computer assembly education. The interactive nature of the simulation allows users to engage directly with virtual components, manipulating and assembling parts through intuitive hand controllers, which closely mimics the physical experience of handling actual hardware while providing a safe learning environment. The immersive quality of the media, achieved through carefully designed visual and audio elements, creates a strong sense of presence within the virtual environment, enabling students to feel as though they are genuinely working in a computer assembly workshop, thereby enhancing engagement and knowledge retention. One of the most significant advantages of this VR-based approach is the elimination of safety concerns, as there is no risk of damaging expensive physical components during practice, allowing students to experiment freely and learn from mistakes without financial consequences or fear of breaking equipment. The effectiveness of the media is evidenced by the high feasibility rating of 87.2%, indicating that it substantially improves students' understanding of assembly procedures through repeated practice and clear step-by-step guidance. Additionally, the flexibility of the VR simulation represents a major pedagogical advancement, as students can access the learning material at any time without being constrained by laboratory availability, equipment scheduling, or the presence of instructors, thereby supporting self-paced and independent learning. The media also incorporates real-time visual and audio feedback mechanisms that inform students whether assembly steps have been completed correctly, providing immediate validation or correction that reinforces proper techniques and reduces the likelihood of errors when students eventually transition to working with physical hardware in real-world scenarios.

CONCLUSION

Based on the research findings, it can be concluded that the Virtual Reality-based computer assembly simulation learning media has been successfully developed using the ADDIE model with the integration of Blender and Unity, demonstrating full functionality as confirmed by Black Box Testing where all features operated according to scenarios. The media achieved a feasibility level of 87.2% based on Application Testing, indicating that it is highly suitable for educational use and effectively enhances students' understanding of computer assembly procedures while serving as a viable alternative solution to address laboratory facility limitations in vocational high schools. For future development, it is recommended

to add troubleshooting features to handle assembly errors, optimize the application to run on lower-specification devices for wider accessibility, expand the research subject pool for more representative results, integrate an automatic evaluation system with real-time feedback to enhance the learning process, and develop additional VR simulations for other Computer and Network Engineering topics such as network installation and server configuration, thereby creating a comprehensive suite of virtual learning tools that can transform practical education in vocational technical programs.

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