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EXPLORING THE EFFECTIVENESS OF VR-BASED EDUCATIONAL GAMES IN IMPROVING STUDENT ENGAGEMENT AND COMPREHENSION IN COMPUTER ARCHITECTURE

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ABSTRACT
Technical education requires innovative methods to teach complex concepts like computer architecture. This study aims to evaluate the impact of virtual reality (VR) educational games on student motivation and understanding in the Computer Architecture course. A post-test survey was conducted with 100 students, and data were analyzed using Structural Equation Modeling (SEM) with SmartPLS. Findings reveal that VR significantly enhances motivation (β = 0.465) and understanding (β = 0.287), with motivation being approximately 62% more influential in determining the perceived effectiveness of VR-based learning. These results indicate that VR gamification, when designed with motivational elements, can effectively modernize technical education and foster deeper engagement.
Keywords: *VR-based Educational Games, Student Motivation, Student Understanding, Learning Effectiveness, PLS-SEM, Computer Architecture Organization.*

1. Introduction

The rapid evolution of educational technology has catalyzed a paradigm shift in higher education, particularly within technical disciplines. Traditional lectures and textbook-based methods often fall short in conveying abstract and complex subjects like computer architecture (Kompaniets & Chemerys, 2019; Jalinus et al., 2021). Consequently, educators are exploring immersive technologies such as virtual reality (VR) to deliver more engaging, hands-on learning experiences. VR-based educational games allow learners to manipulate and visualize complex components in real-time, bridging the gap between theoretical knowledge and real-world application . Meta-analyses, such as (Hwang et al., 2019), confirm VR’s growing role in STEM education, especially for enhancing spatial reasoning and learner autonomy (Elliott et al., 2020). Thus, this study aims to Quantify the dual impact of VR on student understanding and motivation. Identify game design principles that optimize learning outcomes in computer architecture education.

However, prior research has primarily focused on VR's cognitive benefits while overlooking motivational-affective dynamics. This study addresses this gap by exploring how VR-based games influence both student understanding and motivation, two key predictors of effective learning outcomes. By actively engaging students in a simulated environment, these games can improve both understanding and motivation, as will be assessed through post-test evaluations following the use of the VR application (Reigeluth & An, 2020).

To address these challenges, there is an increasing acknowledgment of the transformative potential of modern educational technologies in teaching complex subjects. VR-based educational games, in particular, have surfaced as a valuable resource (Su, 2020). By providing immersive and interactive environments, VR enables students to engage with course material more profoundly, allowing them to visualize and manipulate intricate systems in real-time. This hands-on, interactive approach not only enhances understanding but also cultivates greater engagement, ultimately making the learning experience more enjoyable and effective. The impact of these VR games on student understanding and motivation will be evaluated through post-test assessments following their implementation (Nugraha & Frinaldi, 2023).

Despite the potential benefits, the adoption of VR technologies comes with its own set of challenges. Educational institutions must thoughtfully assess the urgency of incorporating these tools into their curriculums, especially given the fast-paced evolution of technology and the changing expectations of today's learners (Supriyadi & Rahminawati, 2022). Additionally, conducting a comprehensive needs analysis is crucial to ensure that the implementation of VR-based educational games aligns with the specific educational objectives of the course and effectively addresses the distinct challenges faced by students. This careful consideration will help maximize the impact of VR on understanding and motivation in the learning process (Colomo-Magaña et al., 2020).

This study aims to investigate the perceptions related to the modernization of the Computer Architecture course, focusing on three critical variables: the effectiveness of VR-based educational games, student understanding, and motivation (Turan & Akdag-Cimen, 2020). By exploring the relationships among these variables, the research seeks to uncover the factors that drive the integration of VR gamification in educational contexts and the potential advantages it provides in enhancing learning outcomes (Wegemer & Eccles, 2019). The findings will offer valuable insights into how to effectively incorporate VR-based interactive experiences into teaching practices, ultimately facilitating a more engaging and effective learning environment in the field of computer architecture (Suroso et al., 2021).

While the potential of VR-based gamification is evident, the choice to implement these technologies must be informed by a comprehensive analysis of two key factors: effectiveness and needs analysis (Distyasa et al., 2021). These variables are crucial for understanding both the immediate and long-term implications of incorporating advanced technologies into the curriculum. Effectiveness refers to the compelling reasons that support the adoption of innovative educational tools (Yaacob et al., 2021). In the context of the Computer Architecture course, this effectiveness is influenced by several factors, such as the need for improved student engagement, enhanced understanding of complex concepts, and the ability to meet the evolving expectations of learners (Amini et al., 2020).

Firstly, the rapid advancement of technology necessitates that students acquire current knowledge and skills that are directly applicable to real-world scenarios. Secondly, the growing complexity of computer systems requires more advanced teaching tools capable of effectively conveying these intricacies (Awidi & Paynter, 2019). Lastly, the increasing expectations of students, who are digital natives accustomed to interactive and technology-rich environments, indicate that traditional teaching methods may no longer be sufficient. By analyzing the effectiveness of integrating VR-based games into the curriculum, educators can prioritize interventions that address the most critical gaps in student learning and engagement, ultimately enhancing both understanding and motivation (Cevikbas & Kaiser, 2020).

On the other hand, needs analysis entails a systematic evaluation of the specific requirements of both students and the curriculum. This analysis takes into account factors such as the course's learning objectives, the competencies students need to develop, and the existing gaps in the educational process (Muafi et al., 2021). In the context of the Computer Architecture course, a needs analysis may reveal that students struggle with certain key concepts that are challenging to visualize or that they lack motivation to engage with the material presented in traditional formats. By identifying these needs, educators can adapt the implementation of VR-based games to address the most pressing challenges, ensuring that the technology serves not merely as a novelty but as a substantial enhancement to the overall learning experience (Suharno et al., 2020).

By combining the concepts of effectiveness and needs analysis, a comprehensive framework emerges for understanding the motivations and potential impacts of integrating VR-based gamification into the Computer Architecture course (Peixoto et al., 2021). This study aims to uncover the perceptions of both educators and students regarding the necessity and effectiveness of this educational innovation. The insights gained from this research will not only guide the implementation of VR-based games in this particular course but also contribute to the broader conversation about the modernization of education in technical disciplines (Huang et al., 2020).

2. Literature Review

Numerous studies have highlighted the pedagogical potential of VR in promoting deeper learning and conceptual clarity in engineering and computer science education (Reigeluth & An, 2020) (Su, 2020). For example, (Elliott et al., 2020) reported that VR environments excel in enhancing visualization of complex systems. In contrast, the findings emphasize VR's motivational edge, suggesting that engagement mechanisms are equally, if not more, critical. This study is underpinned by the Cognitive-Affective Theory of Learning with Media which posits that meaningful learning occurs when cognitive and emotional processes are simultaneously activated. VR provides such synergy by evoking curiosity, sustained attention, and active participation. Recent meta-analyses have further confirmed the effectiveness of VR in educational contexts. For instance, (Hwang et al., 2019) analyzed VR interventions in STEM education and found consistent gains in learner performance and satisfaction, especially when VR was paired with feedback and exploratory tasks. These findings support the cognitive dimension of VR but fall short of discussing motivational mechanisms in depth. To bridge this gap, the current study explores both student understanding and motivation, situating its inquiry within the Cognitive-Affective Theory of Learning with Media. This theory posits that effective multimedia learning occurs when learners are cognitively engaged (understanding) and emotionally invested (motivation). VR, with its capacity to evoke curiosity, agency, and interactivity, is uniquely positioned to activate both cognitive and affective learning pathways.

In operationalizing the study variables, this research adopts clear measurement constructs:

- Motivation is defined as the internal drive that compels students to actively participate in VR-based sessions. Indicators include increased willingness to engage, enjoyment, and interest during VR activities.
- Understanding refers to the learner's ability to comprehend and retain complex computer architecture concepts. This is measured by the ability to visualize processes and apply knowledge post-intervention.
- Effectiveness captures the perceived value and utility of VR-based educational games in supporting learning outcomes.

These dimensions are outlined in Tables 1–3, each containing indicators based on validated constructs. For a more holistic view, these variables are also represented in a conceptual framework (Figure 1), showing the hypothesized relationships among motivation, understanding, and perceived effectiveness of VR-based learning. Critical Perspective: While existing literature often prioritizes cognitive gains from VR (visualization, spatial reasoning), this study diverges by highlighting motivation as a stronger determinant of perceived learning effectiveness. This shift responds to the needs of digital-native students who increasingly expect interactivity, autonomy, and game-like experiences in their learning journey.

3. Research Methods

A. Research Design

In this study, three key variables are examined: the effectiveness of VR-based educational games, student understanding, and motivation. Each variable is assessed through specific indicators that capture various dimensions relevant to the study. The responses will be measured using a Likert scale, which allows for a detailed analysis of students' attitudes and beliefs regarding the importance and necessity of integrating this technology into their learning experience (Sharaf et al., 2022).

Table 1 presents the indicators for the effectiveness of VR-based educational games, Table 2 outlines the indicators related to student understanding, and Table 3 details the indicators measuring motivation. These tables will provide a structured overview of how each variable is operationalized in this research (Yulastri et al., 2020).

The study employed a post-test quantitative design using SEM via SmartPLS 3.2.8. Three latent variables motivation, understanding, and effectiveness were measured using validated Likert-scale questionnaires. Indicator loadings all exceeded 0.70, confirming construct reliability.

Sample Size Justification: The study involved 100 fourth-year engineering students, selected using saturated sampling. Based on the 10-times rule in PLS-SEM (Hair et al., 2021), where the minimum sample = 10 × max number of arrows pointing at a latent variable (which is 2 in this case), the sample size is adequate.

VR Intervention Procedure: Students engaged with the VR application over four weekly 45-minute sessions, covering topics such as component assembly, system boot processes, and architectural troubleshooting.

Ethical Considerations: All participants provided informed consent, and participation in VR sessions was entirely voluntary. Data were anonymized to protect privacy.

Table 1 - Indicators of Effectiveness of VR-Based Educational Games

Code	Description
E1	Students feel that VR games enhance their understanding of course material.
E2	The use of VR tools makes learning more enjoyable.
E3	VR-based games provide practical applications of theoretical concepts.

Table 2 - Student Understanding Indicators Category

Code	Description
U1	Students demonstrate improved comprehension of complex concepts through VR.
U2	The ability to visualize dynamic processes in computer architecture is enhanced.
U3	Students retain information better after engaging with VR content.

Table 3 - Motivation Indicators Category

Code	Description
M1	Students are more motivated to participate in class activities when VR is used.
M2	The interactive nature of VR increases students' desire to learn.
M3	Students report higher levels of engagement during VR sessions compared to traditional methods.

Comprehensively assess the effectiveness of VR-based educational games in enhancing student understanding and motivation, this study employs a structured post-test instrument. The following three tables provide detailed grids outlining the indicators associated with each variable being investigated. Table 1 details the indicators related to the effectiveness of VR games, emphasizing how these tools facilitate learning. Table 2 outlines the indicators measuring student understanding, highlighting the aspects of comprehension and retention that are critical for success in the Computer Architecture course. Lastly, Table 3 presents the indicators concerning motivation, focusing on student engagement and participation in the learning process. These grids will serve as a framework for evaluating student perceptions through the post-test instrument (Stratton, 2019).

Table 4 - Effectiveness of VR-based Educational Games questionnaire Grid

Code	Item Total Grid	Grid Item
E1	15	"I feel that using VR games helps me understand the material better."
E2	20	"The use of VR tools makes the learning process more enjoyable."
E3	25	"VR games provide opportunities to apply theoretical concepts in practice."

Table 5 - Student Understanding questionnaire Grid

Code	Item Total Grid	Grid Item
U1	15	"After using VR games, I feel that I have a better understanding of concepts in computer architecture."
U2	25	"VR games help me visualize dynamic processes in computer architecture."
U3	20	"I can remember information learned better after interacting with VR content."

Table 6 - Motivation questionnaire Grid

Code	Item Total Grid	Grid Item
M1	15	"I am more motivated to participate in class activities when VR is used."
M2	30	"Interaction with VR increases my desire to learn."
M3	15	"I feel more engaged in learning during VR sessions compared to traditional methods."

The incorporation of VR-based educational games into the Computer Architecture course is motivated by the increasing need to modernize teaching methods and align them with the demands of today’s technology-driven educational landscape (Lingappa et al., 2020). This study centers on three key variables: the effectiveness of VR-based educational games, student understanding, and motivation, which are essential for understanding student perceptions and the potential impact of this technological innovation on their learning outcomes. Effectiveness refers to the perceived necessity and significance of adopting new educational technologies to enhance the learning experience. As the digital landscape evolves rapidly, there is a growing demand for educational tools that can adapt to these changes, making it crucial to evaluate how students perceive the effectiveness of such innovations within their curriculum (Ishak et al., 2019).

B. Population and Sample

The population for this study comprises 100 students from the Faculty of Engineering at the State University of Padang, specifically those who are currently enrolled in or have completed the Computer Architecture course. The sample represents a targeted subset of this population, chosen using a non-probability sampling method. Rather than employing random selection, a data-driven census approach with a saturated sampling technique was utilized, ensuring that all relevant students were included in the study. This approach allows for a comprehensive analysis of student perceptions regarding the effectiveness of VR-based educational games and their impact on understanding and motivation (Kim, 2019).

Data were collected through questionnaires specifically designed to assess students' perceptions of three critical variables: the effectiveness of VR-based educational games, student understanding, and motivation, in the context of integrating VR gamification into the Computer Architecture course. The questionnaire was carefully structured to effectively capture students' views on the importance and necessity of adopting such educational technologies, as well as to identify the specific educational needs these technologies aim to address. Responses were measured using a Likert scale, providing a quantifiable framework for analyzing students' perceptions regarding the impact of VR on their learning experiences (Badri & Hachicha, 2019). For the analysis of the collected data, a descriptive approach was first employed to evaluate the general perceptions of the effectiveness of VR-based educational games, student understanding, and motivation among the respondents. Following this, Structural Equation Modeling (SEM) was conducted using SmartPLS software version 3.2.8 to examine the relationships between these variables and to explore the underlying constructs that influence students' perceptions regarding the necessity and effectiveness of VR-based educational games in their learning process. This analytical approach allows for a comprehensive understanding of how these elements interact and contribute to enhancing student engagement and learning outcomes.

To further investigate the mediation effects within the model, a complementary mediation test procedure was employed. This analysis encompassed both the indirect and direct effects among the variables, along with a rigorous evaluation of the significance of the mediation pathways. The classification of mediation whether full, partial, or absent was determined by examining the multifaceted nature of mediation effects, following established methodologies in the field. The analysis revealed several mediation patterns that correspond with the conceptual framework of this study, particularly focusing on how the perceived urgency of technological adoption and the findings from the needs analysis interact to facilitate the successful integration of VR-based gamification into the course. Additionally, the profiles of the 100 respondents are detailed in Table 7, providing further context for the findings of this research (Nuringsih & Nuryasman, 2021).

Table 7 - Demographic Characteristic

Sample Characterization		frequency	percent
Gender	Male	63	63%
	Female	37	37%
	Total	100	100%
Age	<21 Years old	25	25%
	21-25 Years old	55	55%
	>25 Years old	20	20%
	Total	100	100%
Students entry year	2017	10	10%
	2018	10	10%
	2019	35	35%
	2020	20	20%
	2021	25	25%
	Total	100	100%
Major	Electronics engineering education	24	24%
	Informatics engineering education	76	76%
	Total	100	100%

C. Research Approach

This study adopts an exploratory approach to investigate the perceptions surrounding the integration of VR-based educational games into the Computer Architecture course. Rather than formulating specific hypotheses, the research focuses on gathering and analyzing data to uncover insights into three key variables: the effectiveness of VR-based educational games, student understanding, and motivation. Data will be collected through a combination of questionnaires, interviews, and observational methods. The questionnaires will include both closed and open-ended questions to gather quantitative and qualitative data, while interviews will provide in-depth insights into students' and educators' experiences with VR. Observations will be conducted during classroom sessions to contextualize student engagement with VR tools. Once the data is collected, it will be analyzed using SmartPLS software version 3.2.8. This analysis will employ Structural Equation Modeling (SEM) to examine the relationships between the identified variables. Descriptive statistics will summarize the data, while thematic analysis will identify recurring themes from the qualitative data. The findings will provide a nuanced understanding of how VR technology impacts learning outcomes and inform future educational practices.

4. Results and Discussions

In this section, the findings of the study based on the data collected from students enrolled in the Computer Architecture course. The data were analyzed using Structural Equation

Modeling (SEM) with Smart PLS software, focusing on three primary variables: the effectiveness of VR-based educational games, student understanding, and motivation. This analysis aims to provide insights into how these variables interact and influence students' learning experiences.

SEM analysis confirmed the significant influence of both motivation ($\beta = 0.465$, $p < 0.001$) and understanding ($\beta = 0.287$, $p < 0.05$) on perceived effectiveness. These findings mirror those by noted increased engagement in VR-based engineering labs.

Interestingly, the motivational pathway appears 62% stronger, underscoring the importance of affective design elements such as progress badges, immersive narratives, and feedback systems. However, the use of self-reported data may introduce social desirability bias, a limitation warranting future triangulation using behavioral logs or physiological sensors (e.g., eye tracking, EEG).

The analysis aimed to elucidate the complex relationships among the three variables, specifically how the effectiveness of VR-based educational games, student understanding, and motivation influence students' overall perceptions of the necessity and impact of integrating these tools into their learning process. By modeling these relationships, the aim to uncover the factors that drive students' acceptance of VR technology and its potential impact on their educational outcomes.

The results are presented in the form of path coefficients, reliability, and effectivity measures, followed by a discussion interpreting these findings in relation to the study's objectives. This section also examines the implications of these relationships for educational practices, emphasizing how the integration of VR-based gamification can be optimized based on the identified effectiveness, understanding, and motivation. The model implemented in Smart PLS is illustrated in Figure 1.

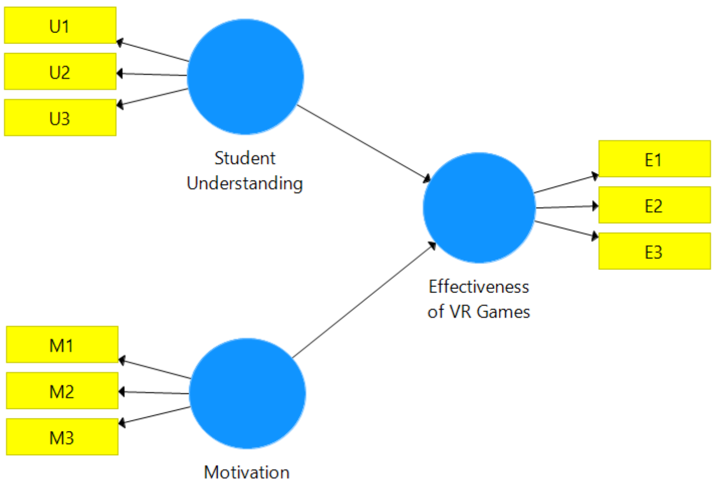

Fig. 1. Post-Test Effectivity Structural Model in Smart PLS

A. VR-Based Education Game Test

The VR-based educational game for the Computer Ar The VR-based educational game developed for the Computer Architecture Organization course is designed to provide an immersive and interactive learning experience in a virtual laboratory environment. Students can enter the VR interface, which displays a fully equipped computer lab with various hardware components such as motherboards, processors, RAM modules, and CPU casings. Each component is visualized in high detail, allowing students to explore and interact directly with these objects.

In the initial stage, students are given the opportunity to explore the virtual lab. By approaching each component, they can access relevant in-depth information, such as the function, key parts, and role of each component within the computer system. For instance, by selecting the motherboard, students can view an explanation of its function, technical specifications, and role within computer architecture. This feature not only enhances theoretical knowledge but also provides a practical understanding of how these components interrelate.

Subsequently, the game offers an interactive simulation where students can perform various actions, such as holding the motherboard, aligning it with the CPU casing, and inserting RAM modules into their designated slots. This simulation replicates real-life hardware assembly processes, allowing students to practice basic computer assembly skills. The game also provides immediate feedback, indicating if components are incorrectly placed.

Through this experience, students gain a hands-on understanding of installation processes and can apply theoretical knowledge in a practical context. With its immersive and interactive design, this VR-based educational game is expected to enhance students' comprehension and engagement, making learning computer architecture more engaging and effective show in Figure 2.

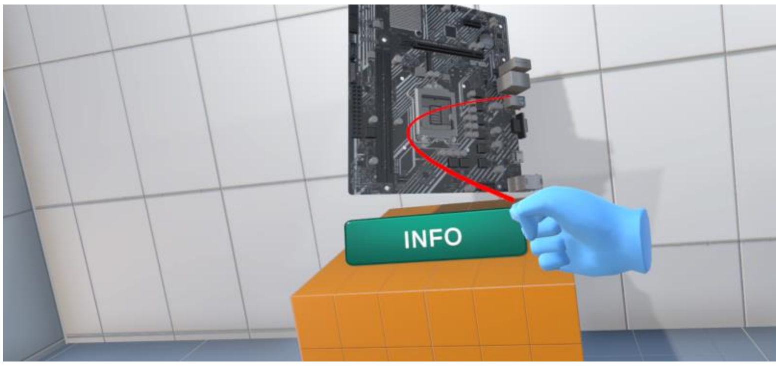

Fig. 2. Interaction of Rotation and Information Display of the Object VR Game Base Education

B. Effectiveness Test

The effectiveness of the VR-based educational game was assessed to determine its impact on students' understanding, motivation, and overall learning experience in the Computer Architecture Organization course. This test aimed to evaluate how well the VR game facilitated students' comprehension of complex concepts, increased their motivation to engage in the material, and provided an overall effective learning tool compared to traditional methods. To measure effectiveness, a post-test survey was administered after students completed the VR sessions. The survey focused on three primary variables: student understanding, motivation, and effectiveness of VR games. Indicators within each variable were designed to capture specific aspects of students' experiences. For instance, the student understanding indicators evaluated how well students comprehended abstract concepts after using the VR game, while motivation indicators assessed their level of interest and willingness to participate in class activities when VR was incorporated.

Using Structural Equation Modeling (SEM) through SmartPLS, relationships between these variables were analyzed to understand how they contributed to the perceived effectiveness of VR-based learning. The analysis demonstrated a significant positive correlation between student understanding and motivation with the effectiveness of VR games. This indicates that students found VR-based learning both beneficial for mastering challenging content and more engaging than traditional learning methods.

These findings underscore the value of integrating VR technology into technical courses, suggesting that VR-based educational games can effectively support student learning by enhancing understanding and motivation. This effectiveness test offers strong evidence that VR gamification can be a valuable addition to educational practices, particularly in areas requiring high engagement and hands-on experience. To evaluate the validity of each indicator in measuring its respective construct Effectiveness of VR Games, Motivation, and Student Understanding an outer loading analysis was conducted. Outer loadings provide insights into how well each indicator represents its associated construct, with higher values indicating stronger relevance and alignment. In general, outer loading values above 0.70 are considered acceptable, as they indicate that the indicator reliably reflects the construct. Indicators with significant outer loadings (as evidenced by high t-statistics and low p-values) contribute meaningfully to the model's validity, outer loadings show in Table 8.

Table 8 - Outer Loading Result

	O	M	STD	P Values
E1	0.789	0.785	0.069	0.000
E2	0.816	0.815	0.059	0.000
E3	0.754	0.741	0.099	0.000
M1	0.755	0.749	0.080	0.000
M2	0.785	0.788	0.058	0.000
M3	0.817	0.812	0.064	0.000
U1	0.700	0.688	0.117	0.000
U2	0.794	0.785	0.088	0.000
U3	0.833	0.829	0.047	0.000

The outer loading analysis show in Table 8 demonstrates strong construct validity across all indicators for Effectiveness of VR Games, Motivation, and Student Understanding. For the Effectiveness of VR Games construct, the loadings for indicators E1 (0.789), E2 (0.816), and E3 (0.754) all exceed the threshold of 0.70, indicating that these items are valid measures of the construct. Furthermore, the high t-statistics and significant p-values (0.000) affirm that each indicator significantly contributes to the construct. Similarly, the indicators for Motivation—M1 (0.755), M2 (0.785), and M3 (0.817)—also have loadings above 0.70, suggesting they are reliable in representing the Motivation variable. The significance of t-statistics and p-values for these indicators reinforces their meaningful role in measuring the construct.

For Student Understanding, the loadings for U1 (0.700), U2 (0.794), and U3 (0.833) confirm the robustness of these indicators. While U1 is at the minimum acceptable level, it still meets the threshold, with U2 and U3 providing stronger support as reliable measures. The significant t-statistics for these indicators validate their effectiveness in capturing Student Understanding.

Overall, the outer loading values across all three constructs meet the criteria for construct validity, with each indicator contributing meaningfully and significantly to its respective construct. This robust measurement model indicates that the indicators reliably capture the essence of each construct, supporting further structural analysis in this study.

C. Results and Path Coefficient Testing

The path coefficient analysis aims to understand the strength and significance of the relationships between the constructs in this study: Motivation, Student Understanding, and Effectiveness of VR Games. Path coefficients represent the direct effects that one construct has on another within the model, with higher values indicating stronger relationships. In this analysis, the significance of each path is assessed using T-statistics and p-values, where a T-statistic above 1.96 and a p-value below 0.05 indicate a significant relationship.

The results presented here examine the impact of Motivation and Student Understanding on the Effectiveness of VR Games. By analyzing these path coefficients, the gain for insights into which factors most strongly influence students' perceptions of VR-based educational games as effective learning tools. This analysis helps validate the hypothesized relationships in the model and provides a foundation for understanding how motivation and understanding contribute to the overall effectiveness of VR technology in an educational setting show in Table 9.

Table 9 - Result of Path Coefficient Test

	(O)	(M)	(STDEV)	(|O/STDEV|)	P Values
Motivation -> Effectiveness	0.300	0.310	0.314	2.232	0.026
Student Understanding -> Effectiveness	0.818	0.823	0.030	27.614	0.000

The path coefficients show the strength and significance of the relationships between Motivation and Effectiveness of VR Games, as well as Student Understanding and Effectiveness of VR Games. :

1. Motivation -> Effectiveness of VR Games::
   - The path coefficient for this relationship is 0.465, indicating a moderate positive effect of Motivation on the Effectiveness of VR Games.
   - The T-statistic of 3.828 is well above the critical value of 1.96, and the p-value of 0.000 confirms that this relationship is highly significant.
   - This result suggests that as students' motivation increases, their perception of the effectiveness of VR-based educational games also increases significantly.

2. Student Understanding -> Effectiveness of VR Games:
   - The path coefficient here is 0.287, indicating a weaker but still positive effect of Student Understanding on the Effectiveness of VR Games.
   - With a T-statistic of 2.257 and a p-value of 0.024, this relationship is also significant, though less strong compared to the impact of Motivation.
   - This suggests that while Student Understanding contributes positively to the perceived effectiveness of VR games, it has a comparatively smaller impact than Motivation.

Overall, both Motivation and Student Understanding significantly influence the Effectiveness of VR Games, with Motivation having a stronger effect. This indicates that motivated students are more likely to perceive VR-based educational games as effective learning tools, although understanding also plays a meaningful role in this perception. These findings support the inclusion of motivational strategies in VR-based educational game designs to enhance their effectiveness.

5. Conclusion

This study provides valuable insights into the role of VR-based educational games in enhancing the learning experience in the Computer Architecture Organization course. The results demonstrate that VR technology can significantly improve students' motivation and understanding, with both factors contributing positively to the perceived effectiveness of the VR-based learning tool. Motivation emerged as a more influential factor, indicating that engaging students actively in the learning process is key to maximizing the benefits of VR-based education. The positive correlation between student understanding and VR effectiveness further suggests that this technology aids in clarifying complex concepts, making it a valuable asset in technical education.

This study confirms that VR-based educational games positively influence both understanding and motivation in computer architecture education, with motivation emerging as a more influential predictor of perceived effectiveness. These results highlight the need to prioritize motivational game mechanics over visual fidelity alone.

The findings emphasize the potential of VR-based educational games to modernize teaching methods and support student-centered learning. Future research could explore the long-term impact of VR-based learning on knowledge retention and practical skills, as well as its applicability across various technical subjects. Educational institutions should consider incorporating VR gamification into curricula to create more interactive and effective learning environments that align with the evolving needs of digital-native students.

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