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Application of Cognitive Load Theory in VR Development and Its Impact on Learning: A Perspective on Prior Knowledge, Learning Interest, Engagement, and Content Comprehension

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Abstract*—This research examines the utilization of Virtual Reality (VR) and its implications for the learning process, specifically focusing on learning interest, prior knowledge, learning engagement, and content comprehension. The central objective is to establish a comprehensive model that unravels the intricate interplay between these factors within the context of VR-based learning. The study also aims to shed light on the impact of integrating Cognitive Load Theory into VR development and its effects on the learning experience. Adopting an observational design, this study elucidates the intricate relationships among learning interest, prior knowledge, learning engagement, and content comprehension in VR-based education. The VR technology employed in this research has previously undergone rigorous feasibility testing. The VR application was designed following cognitive load theory principles. Its immersive content offers users a lifelike immersion into the natural habitats of diverse animal species across various global regions. By leveraging VR technology, elementary school students engage in a more profound and authentic learning journey. A total of 85 participants, encompassing fourth and fifth-grade elementary school students, were involved in the study. These students were drawn from schools situated in rural areas in particular regions in Indonesia and had moderate to low economic backgrounds. The variables under examination include Prior Knowledge, Learning Interest, Engagement, and Content Comprehension as learning outcomes. Data analysis was conducted utilizing a blend of linear regression and path analysis techniques, with a confidence level of 95%. The Guttman scale questionnaire was used, and total scores were transformed into a ratio scale through a conversion process. The study reveals a positive correlation between learning interest and learning outcomes, highlighting that a strong interest in a subject contributes to improved learning results. Additionally, both learning interest and prior knowledge influence learning engagement. Students with higher learning interests and prior knowledge are more likely to actively engage in the learning process actively, underscoring internal factors' role in motivating participation. Learning engagement moderates the relationships between learning interest, prior knowledge, and learning outcomes. By enhancing the effect of learning interest and prior knowledge on learning outcomes, engagement enables more comprehensive and practical information processing.

***Keywords*— Cognitive load theory; content comprehension; engagement; learning interest; prior knowledge; virtual reality.**

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I. INTRODUCTION

Education has become a battleground for unstoppable technological innovation. Advances in technology have provided promising new opportunities to enrich the learning experience. One intriguing innovation that has captured attention is the development of Virtual Reality (VR). VR is a technology that enables individuals to "immerse" themselves in digitally created worlds, crafting immersive experiences that merge visual, auditory, and often kinesthetic elements [1], [2]. The potential of VR in creating deep and immersive learning experiences is captivating. With VR, students can directly engage with subject matter, observe complex phenomena from various perspectives, and interact within virtual environments [3], [4].

However, while VR technology offers enticing prospects, it is crucial to remember that the effectiveness of education is not solely determined by the tools or technology employed. This is where Cognitive Load Theory becomes pivotal. Cognitive Load Theory helps us comprehend the extent of the mental "load" students encounter during the learning process

[5], [6], [7]. This encompasses the complexity of learning materials (intrinsic load), how materials are presented (extrinsic load), and the mental effort invested in integrating information (germane load) [6].

The development of VR has brought about a paradigm shift in education. VR technology enables users to interact with highly realistic, visually immersive environments, often accompanied by audio elements [8], [9], [10]. Within the educational context, VR creates deep and immersive learning experiences, allowing students to "dive into" abstract concepts, distant locations, or situations challenging to simulate within traditional classrooms [11]. VR in education holds tremendous potential to transform how we learn, teach, and understand the world around us. VR enables students to engage with lessons more profoundly and tangibly. They can explore 3D structures, observe intricate processes in action, or grasp complex concepts more visually [9], [12], [13]. With VR, students can partake in realistic simulations of scientific experiments, aviation scenarios, or historical recreations. This aids students in comprehending concepts more practically and interacting with environments otherwise inaccessible in real life. The immersive and enjoyable learning experiences offered by VR can boost student motivation. They become more likely to actively engage with learning as it introduces elements of gamification and exploration [8], [11]. Through 3D visualizations and interactions, students can gain a better grasp of abstract concepts. VR allows them to "see" concepts from various angles, reinforcing their understanding. It's essential to approach the use of VR in education with caution. Virtual learning should be different from real-world social interaction and hands-on experiences. Hence, VR integration must combine diverse learning strategies to achieve optimal learning outcomes [14], [15]. By combining the potential of VR with established teaching methods, education can leverage this technology to shape more meaningful and compelling learning experiences for students.

In developing VR applications for learning, it is imperative to consider how this technology might influence cognitive load. While immersive learning experiences can enhance content comprehension, processing information within a VR environment may also demand increased mental effort [16], [17]. This can impact student motivation and even cognitively burden them, diminishing the learning process's effectiveness.

Therefore, developing education applications is more than just about creating visually impressive environments; it is also concerned with optimizing the learning experience by minimizing excessive cognitive load. Integrating Cognitive Load Theory into the design of VR applications will enable developers to identify points that require simplification or more structured approaches. By attending to these factors, VR technology can yield more effective learning outcomes, prevent cognitive fatigue, and maintain the requisite immersion. Rapid technological changes, especially in computing and graphics, have transformed the education paradigm remarkably. One particularly compelling innovation in this context is the development of VR [8], [16], [18], [19]. VR introduces new possibilities to the learning experience by altering how students interact with information and learning content.

Alongside the promised potential of VR, some challenges need to be addressed to maximize its effectiveness within the educational context. This is where Cognitive Load Theory plays a crucial role. Cognitive Load Theory seeks to comprehend the extent of an individual's mental "load" during the learning and thinking processes. This load can encompass various factors influencing information processing, cognitive resource utilization, and learning outcomes.

Applying cognitive load theory concepts to developing VR for education has significant implications. An effective VR environment should alleviate the excessive cognitive load on students [7], [17]. Cognitive Load Theory is a framework utilized to understand how the mental or cognitive load experienced by an individual can impact information processing, learning, and task performance. This theory delineates how the human mind is limited to processing information within short-term memory (working memory) [6]. In the context of Information and Communication Technology (ICT) utilization, such as software applications, online learning platforms, and immersive technologies like VR, Cognitive Load Theory holds significant implications concerning the efficiency of comprehension and technology utilization [16], [20], [21]. Within the realm of ICT, intrinsic load refers to the complexity of material or information presented through technology [21]. For instance, dense material or intricate concepts can elevate the intrinsic load in online learning. Therefore, interface design and content presentation should consider how information is conveyed for easier digestion. Extrinsic Load pertains to how information is presented through technology. The extraneous load can increase if the interface is non-intuitive, the navigation must be more accessible to grasp, or the layout needs to be more apparent. In ICT utilization, it's crucial to design user-friendly interfaces, reduce extrinsic load, and enable easy access to information [22], [23]. In the context of ICT, germane load involves the mental effort required to comprehend and connect new information with existing knowledge. ICT utilization can be enhanced by providing clear context and linking new concepts to prior content. Technology can be harnessed to create interactions that encourage more profound understanding. By grasping the elements of Cognitive Load Theory, ICT developers and designers can craft solutions that are more adaptive and responsive to user needs and capabilities [14].

By optimizing material complexity, transparently presenting information, and designing interactions that facilitate content comprehension, VR development can create more effective and meaningful learning experiences. The influence of Cognitive Load Theory on student motivation cannot be ignored. When students feel cognitively burdened, their motivation to learn can diminish. Hence, VR development must balance material complexity and students' capacity to cope with this load while maintaining enthusiasm in the learning process.

Numerous studies have delved into the correlation between learning interest and learning outcomes. Motivational theories, such as intrinsic and extrinsic motivation, are often employed to elucidate how learning interest can impact students' engagement levels and learning outcomes [14], [24]. These investigations frequently indicate that students with a heightened interest in a subject tend to achieve better learning outcomes. Literature concerning prior knowledge and learning outcomes often centers on how students' preexisting knowledge can influence their aptitude for comprehending new concepts [25], [26], [27]. Constructivist and transfer learning theories frequently serve as the foundation to explore how prior knowledge shapes the learning process and its eventual outcomes.

Research also frequently considers the role of learning engagement as a factor influencing the relationship between learning interest, prior knowledge, and learning outcomes [28], [29]. Concepts of information and cognitive processing are frequently harnessed to expound on how learning engagement can moderate these relationships. Learning engagement may act as a mediator or enhancer in the interaction among these variables [25], [30], [31]. Studies that involve a combination of variables—learning interest, prior knowledge, learning engagement, and learning outcomes—can shed light on the intricate dynamics of the learning process [32], [33], [34]. Motivation, cognition, and learning theories may be employed to comprehend how the interplay of these variables shapes students' learning experiences.

This research aims to investigate the application of VR and its impact on the learning process, focusing on learning interest, prior knowledge, learning engagement, and content comprehension. Specifically, this research aims to establish a model to elucidate the interrelationships among learning interest, prior knowledge, learning engagement, and content comprehension in VR-based learning. This study is expected to understand better how utilizing cognitive load theory in VR development can influence learning.

II. MATERIALS AND METHODS

A. Research Context

This study employs an observational design to explore a model that can elucidate the interconnections between learning interest, prior knowledge, learning engagement, and content comprehension in VR-based learning. The VR utilized in this research has undergone feasibility testing in previous studies [12], [35]. This VR was developed with the application of cognitive load theory. The VR content immerses users in the lifelike depiction of animals and their natural habitats across various regions worldwide. This application enables elementary school students to explore the authentic habitats of animals realistically through VR technology. Through VR, students undergo a more profound and immersive learning experience. The study participants comprised 85 elementary school students from both fourth and fifth grades. They hail from schools located in economically moderate to low-income rural areas.

B. Variables

The variables measured in this study encompass several aspects, namely:

- Prior Knowledge (PRK): Assessing how students possess prior knowledge concerning animal life and their habitats.
- Learning Interest (INT): Gauging the level of students' motivation in learning before utilizing VR.
- Engagement (ACT): Measuring the degree of students' engagement during learning through VR.
- Content Comprehension as learning outcomes (LEP): Evaluating the extent to which students comprehend the learning content related to animal life and their habitats after using VR.

Before the learning session commences, participants' learning interests and prior knowledge are measured. Following this, they engage in learning using the VR application. Throughout the learning process, observation is conducted, and the student's engagement levels are quantified. After the learning session, students are measured again to gauge their understanding of the material acquired during the VR-based learning.

C. Instruments

Data for this study was collected through a Guttman scale questionnaire for learning interest and engagement. Additionally, prior knowledge and content comprehension were measured using multiple-choice tests. In developing the instruments, the previous knowledge (PRK) assessment consisted of 15 multiple-choice questions covering comparisons (item number 1-5), categorizations (item number 6-10), and life pattern analysis (item number 11-15).

TABLE I
THE ITEM VALIDITY AND RELIABILITY FOR EACH VARIABLE

Variable/ Item	Mean	STD	Correlation (r)	Alpha Cronbach
Prior Knowledge (PRK)				
PRK1	.8235	.38348	.441	
PRK2	.7765	.41908	.316	
PRK8	.6824	.46832	.226	
PRK9	.7294	.44690	.425	.683
PRK10	.7294	.44690	.440	
PRK11	.7176	.45282	.521	
PRK12	.4824	.50265	.385	
PRK14	.5412	.50126	.393	
Learning Interest (INT)				
INT1	.5882	.49507	.284	
INT5	.7412	.44059	.426	.686
INT6	.8118	.39322	.430	
INT8	.6588	.47692	.526	
Learning Engagement (ACT)				
ACT1	.8235	.38348	.236	
ACT2	.9412	.23669	.302	
ACT4	.5059	.50293	.513	.610
ACT5	.6353	.48420	.383	
ACT6	.4588	.50126	.352	
Learning Outcome (LEP)				
LEP4	.8824	.32410	.285	
LEP7	.8588	.35027	.287	
LEP8	.8588	.35027	.314	
LEP9	.8235	.38348	.402	.207
LEP11	.8706	.33765	.215	
LEP12	.9059	.29373	.230	
LEP14	.8941	.30951	.318	
LEP15	.8000	.40237	.308	

Investigation revealed that only eight items were usable (PRK1, PRK2, PRK8, PRK9, PRK10, PRK11, PRK12, and PRK14). For learning interest (INT), there were eight perceptual statement items encompassing enjoyment (item number 1,2), interest (item number 3,4), attention (item number 5,6), and involvement (item number 7,8). Analysis results indicated that only four items (INT1, INT5, INT6, and INT8) were usable.

Six observational items for learning engagement (ACT) were included: task completion, asking questions, participating in discussions, recording activity outcomes, seeking information, and self-assessment. However, analysis showed that only five items (ACT1, ACT2, ACT4, ACT5, and ACT6) were usable. For learning outcomes (LEP), data from a 15-item multiple-choice test covering comparisons (item number 1-5), categorizations (item number 6-10), and life pattern analysis (item number 11-15) were used. Analysis results found that only eight items were usable (LEP4, LEP7, LEP8, LEP9, LEP11, LEP12, LEP14, and LEP15). See Table 1 for the statistical result.

D. Analysis Technique

A combination of linear regression and path analysis techniques was employed to analyze the obtained data. The level of confidence was 95%. For the Guttman scale questionnaire, total scores were derived by converting the scores into a ratio scale. The conversion involved summing the scores of each item and dividing by the total possible score, then multiplying by 100 percent. The path analysis model tested can be observed in Figure 1. SPSS software was applied for this analysis.

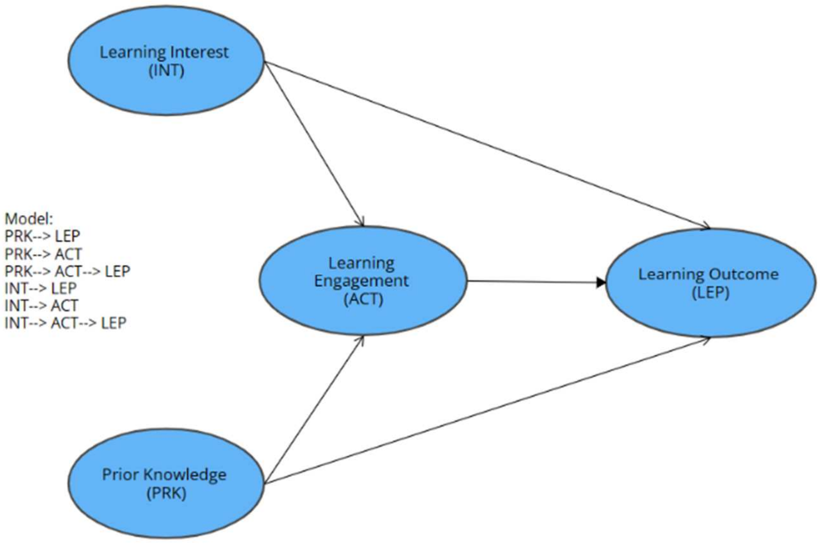

Fig. 1 The conceptual model

III. Results and Discussion

A. Results

1) Learning Implementation: To ensure students fully leverage the VR-based curriculum, introductory sessions are conducted to acquaint them with VR technology. In these sessions, educators lead students through the operation of the Meta Quest 2 VR headset, including proper fitting, adjustments, and menu navigation. Subsequently, teachers elucidate the utilization of provided student worksheets, which aid students in reflecting on their learning encounters and applying acquired knowledge to real-world scenarios. Teachers direct students to complete worksheets progressively alongside the VR-based curriculum. Through these orientation sessions and guidance on using student worksheets, instructors ensure that students are well-prepared to participate in VR-based learning activities and make the most of the experience.

Students are organized into groups during learning sessions based on their assigned worksheets. Each student accessed the Meta Quest 2 VR headset to explore and interact with virtual animal habitats. The VR-based curriculum encompasses a variety of animal-related subjects, such as habitat, locomotion, physical attributes, sounds, and corresponding textual explanations. Figure 2 shows the VR environment. VR technology permits students to freely navigate between distinct animal habitats and observe them at their own pace. Following the group activities, observations made by students during their VR-based exploration are utilized to complete worksheet exercises.

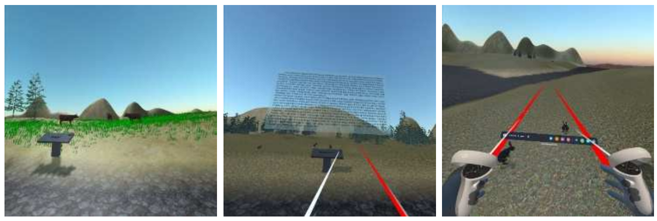

Fig. 2 The screenshot of the VR environment

See Figure 3 for the learning activity illustration. These activities prompt students to ponder their observations, enhance their comprehension of animal habitats, and employ their acquired knowledge in practical scenarios. Students experience more immersive and interactive learning by working collaboratively and engaging with VR-based curricula. VR technology offers a distinctive and captivating learning journey, enabling students to explore and study animal habitats in ways that are unattainable through traditional classroom methods. Overall, integrating VR technology in the educational setting gives students a more dynamic and hands-on learning experience.

Fig. 3 The learning activity using VR

Students articulate their understanding of animal characteristics after engaging in VR-based observations. VR technology immerses students in virtual animal habitats, facilitating observation and comprehension of animals' physical and behavioral traits. This description is written post-VR exposure. Throughout this learning encounter, students encounter new vocabulary relating to animal attributes and habitats that may be unfamiliar to them. This enhances their comprehension of animals and surroundings. Moreover, students are motivated to identify various wildlife conservation issues and devise alternate solutions from their perspective. This encourages them to critically assess the impact of human activities on the sense of responsibility toward safeguarding and preserving wildlife. The synergy between VR technology and the learning activities furnishes a distinctive learning experience that advances students' knowledge of animals and their habitats while nurturing critical thinking and problem-solving skills. By empowering students to play an active role in environmental conservation, this learning journey holds the potential to ignite future generations to become conscientious and environmentally aware global citizens.

2) Linear Regression: Table 2 shows the analysis results with partial linear regression in various models 2.

TABLE II
THE PARTIAL LINEAR REGRESSION RESULTS

Path	Variables		Model Summary				Coefficient		
	Dependent	Predictor	R	R Square	Adjusted R Square	Std. Error of the Estimate	Standardized Coefficients Beta	t	Sig.
PRK→LEP	LEP	PRK	.371	.138	.127	12.61458	.371	3.643	.000
PRK→ACT	ACT	PRK	.348	.121	.110	18.60219	.348	3.381	.001
INT→LEP	LEP	INT	.592	.350	.342	10.95315	.592	6.685	.000
INT→ACT	ACT	INT	.600	.360	.353	15.86910	.600	6.838	.000
ACT→LEP	LEP	ACT	.506	.256	.247	11.71861	.506	5.344	.000

The analysis results with partial linear regression show that all models have an R Square value from 0.127 to .353, a moderate category. In all models, predictors can be used to estimate the dependent variable significantly.

The analysis results with multiple linear regression in various models are shown in Table 3.

TABLE III
THE MULTIPLE LINEAR REGRESSION RESULTS

Path	Variables		Model Summary				Coefficient		
	Dependent	Predictor	R	R Square	Adjusted R Square	Std. Error of the Estimate	Standardized Coefficients Beta	t	Sig.
PRK→ACT	LEP	PRK	.547	.299	.282	11.44095	.222	2.253	.027
→LEP		ACT					.429	4.348	.000
INT→ACT	LEP	INT	.621	.386	.371	10.71409	.450	4.159	.000
→LEP		ACT					.236	2.178	.032

From Table 3, it can be seen that learning engagement acts as a moderator. This variable moderates between prior knowledge and learning outcomes and, At the same time, between learning engagement and learning outcomes. The Standardized Coefficients Beta values all have a significance level of less than 0.05.

3) Model Structure: Table 2 and Table 3 describe the relationship of all variables that explain the phenomenon of learning using VR developed with cognitive load theory. Figure 4 shows this connection.

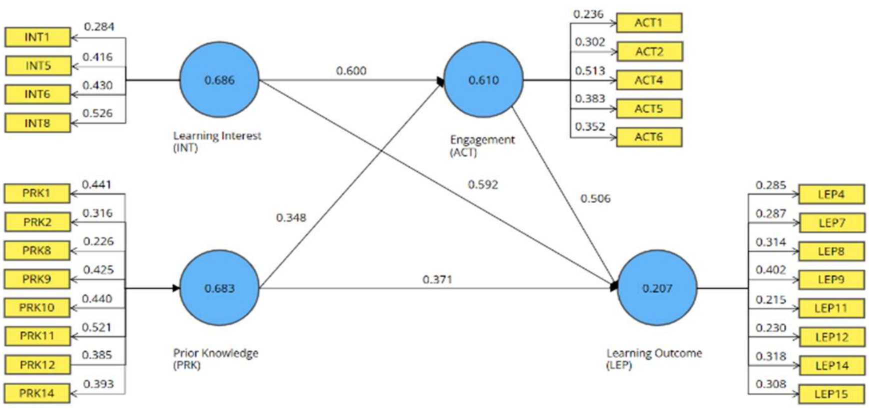

Fig. 4 The final model explaining the relationship of the variables

B. Discussion

1) Prior Knowledge, Learning Engagement, and Learning Outcome: This path analysis focuses on the relationships among three variables: prior knowledge (PRK), learning engagement (ACT), and learning outcomes (LEP). Prior knowledge (PRK) maximizes learning outcomes (LEP), implying that an individual's prior knowledge about a subject or topic impacts their learning outcomes. Those with better prior knowledge about a specific topic are an individual's mental "load." This was attributed to the solid foundational understanding of basic concepts that help individuals build further knowledge more quickly and deeply [26], [28]. A relevant theory here is constructivism. Constructivism emphasizes that individuals develop based on existing experiences and knowledge. In this context, individuals with prior solid knowledge framework comprehend new concepts. This allows them to build more profound and structured knowledge about the subject matter, ultimately impacting better learning outcomes.

Prior knowledge (PRK) affects learning engagement (ACT). This finding indicates that prior knowledge also impacts an individual's level of engagement in learning. Individuals with a solid initial understanding of the subject material tend to participate actively in learning [28]. They might feel more confident and inclined to understand further and deepen their comprehension. Learning engagement drove information processing [30], [33]. When active in learning, involving critical thinking, concept connection, and seeking solutions, they process information more deeply and critically [36]. Hence, it profoundly impacts learning outcomes when an individual actively engages in learning, as they better associate and apply concepts effectively.

Learning engagement (ACT) influences learning outcomes (LEP). This demonstrates that the level of learning engagement also affects learning outcomes. Individuals who are more actively engaged in learning, such as participating actively in class, engaging in discussions, and involving themselves in learning activities, tend to achieve better learning outcomes [30], [33], [36]. Active involvement in learning allows individuals to deepen their understanding and regularly practice concepts, ultimately influencing better learning outcomes. Cognitive and information processing theories may be relevant here. These theories suggest that students actively engage in learning, participating in discussions, critically thinking, and applying knowledge in practical contexts tend to have deeper understanding and stronger connections between concepts [28], [37]Therefore, learning engagement reinforced the effect of learning interest on learning outcomes, as it enables students to be more cognitively engaged and process information more effectively.

2) Learning Interest, Learning Engagement, and Learning Outcome: Path analysis is a statistical method used to understand the cause-and-effect relationships among variables within a model. In the context you've provided, three variables are under discussion: learning interest (INT), learning engagement (ACT), and learning outcomes (LEP). An individual's level of interest in a subject or topic impacts their learning outcomes [35], [38]. In this context, the greater someone's learning interest in an issue, the better their learning outcomes tend to be in that subject [34]. This was attributed to a higher motivation to comprehend and master the material they're interested in, leading them to invest more time and effort in studying, subsequently aiding them in achieving better learning outcomes.

This path analysis focuses on the relationships among three variables: prior knowledge (PRK), learning engagement (ACT), and learning outcomes (LEP). Prior knowledge (PRK) maximizes learning outcomes (LEP), implying that an individual's prior knowledge about a subject or topic impacts their learning outcomes. Those with better prior knowledge about a specific topic are an individual's mental "load." Learning interest (INT) influences learning engagement (ACT). This indicates that learning interest also impacts an individual's level of engagement in learning. Those interested in a subject are more likely to actively seek information, participate in discussions, ask questions, and involve themselves in other learning activities. This can be explained by their genuine fascination with the subject, motivating them to engage more actively in learning. This concept aligns with intrinsic motivation theory, where internal interest and desire drive individuals to learn and attain better learning outcomes [24], [30]. The theory explains that when someone has an extrinsically strong interest in a topic, they're more motivated to understand, explore, and delve into it.

Learning engagement (ACT) affects learning outcomes (LEP). This reveals that the level of learning engagement also impacts learning outcomes. Individuals who engage in learning, such as participating actively in class, practicing more, and interacting with the subject material, tend to achieve better learning outcomes [14], [30], [33]This was attributed to active involvement in the learning process, which allowed individuals to understand and practice concepts more extensively, ultimately aiding them in higher learning outcomes.

This path analysis highlights the intricate relationships among learning interest, engagement, and outcomes. Learning interest influences learning engagement and learning outcomes, while learning engagement also impacts learning outcomes. In an educational context, these findings underscore the importance of cultivating strong learning interest and encouraging active student engagement in the learning process, as both factors contribute to achieving better learning outcomes.

3) Learning Engagement as a Moderator: The concept of "moderation" refers to a relationship where the effect of an independent variable on a dependent variable change depending on the level of a moderator variable. In the context you mentioned, if learning engagement (ACT) is considered a moderator variable between learning interest (INT) and learning outcomes (LEP), it means that the level of learning engagement influenced the effect of learning interest on learning outcomes. Two scenarios should be considered if learning engagement moderates the relationship between learning interest and learning outcomes. At low levels of learning engagement, the effect of learning interest on learning outcomes might be less intense or significant. This could occur because even though someone has a high interest in a subject, more active involvement in learning could help their ability to achieve better learning outcomes. Conversely, at high levels of learning engagement, the effect of learning interest might be more pronounced and impactful on learning outcomes. Individuals with high interest who are also actively engaged in learning tend to achieve better learning outcomes as they possess both motivation and active involvement to delve into the subject matter. In this finding, learning engagement is a factor that moderates or influences the strength of the relationship between learning interest and learning outcomes. This underscores the importance of having a high learning interest and fostering active engagement in the learning process to achieve optimal learning outcomes.

The concept of moderation also applied to the relationship between prior knowledge (PRK) and learning outcomes (LEP), with learning engagement (ACT) as a moderator variable. This means that the level of learning engagement influenced the prior knowledge of learning outcomes. At low levels of learning engagement, the effect of prior knowledge on learning outcomes might be insignificant [32], [33]. Even though someone possesses substantial prior knowledge, a lack of active involvement in learning could hinder their ability to apply that knowledge and achieve better learning outcomes effectively. Similarly, at high levels of learning engagement, the effect of prior knowledge on learning outcomes might be more pronounced and robust. Individuals with strong prior knowledge who are also actively engaged in learning tend to leverage their knowledge more effectively, form deeper understandings, and ultimately achieve better learning outcomes [28], [30], [39]. Learning engagement is a variable that moderates or influences the strength of the relationship between prior knowledge and learning outcomes. In essence, while prior knowledge is essential, the level of active engagement in the learning process also plays a role in determining the extent to which that knowledge will impact the resulting learning outcomes.

IV. Conclusion

There is a positive relationship between learning interest and learning outcomes. Individuals interested in a subject tend to achieve better learning outcomes. This highlights the significance of cultivating a solid learning interest to enhance learning outcomes. Both learning interest and prior knowledge influence learning engagement. Individuals with high learning interests and prior knowledge are more likely to engage in learning actively. This underscores that internal factors such as interest and ability motivate active participation in the learning process. Learning engagement is a moderating factor in the relationships between learning interest and learning outcomes and between prior knowledge and learning outcomes. Learning engagement enhances the positive influence of learning interest and prior knowledge on learning outcomes by enabling more profound and practical information processing.

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Conflicts of Interest

The authors declare no conflict of interest.

References

[1] J. Bacca-Acosta, J. Tejada, R. Fabregat, and J. Guevara, “Scaffolding in immersive virtual reality environments for learning English: an eye tracking study,” *Educational technology research and development*, vol. 70, no. 1, pp. 339–362, 2022.

[2] E. A. O’Connor and T. Worman, “Designing for interactivity, while scaffolding student entry, within immersive virtual reality environments,” *Journal of Educational Technology Systems*, vol. 47, no. 3, pp. 292–317, 2019.

[3] L. F. Dreimane, “Understanding the educational rationale behind learning in virtual reality: a historical development vignette,” *Innovations, Technologies and Research in Education*, p. 23, 2019.

[4] N. Pellas, A. Dengel, and A. Christopoulos, “A scoping review of immersive virtual reality in STEM education,” *IEEE Transactions on Learning Technologies*, vol. 13, no. 4, pp. 748–761, 2020.

[5] S. A. W. Andersen, P. T. Mikkelsen, L. Konge, P. Cayé-Thomasen, and M. S. Sørensen, “Cognitive load in distributed and massed practice in virtual reality mastoidectomy simulation,” *Laryngoscope*, vol. 126, no. 2, pp. E74–E79, 2016.

[6] P. Ayres, “Something old, something new from cognitive load theory,” *Computers in Human Behavior*, vol. 113. Elsevier, p. 106503, 2020.

[7] J. J. G. Van Merrienboer and J. Sweller, “Cognitive load theory and complex learning: Recent developments and future directions,” *Educ Psychol Rev*, vol. 17, pp. 147–177, 2005.

[8] X. Xu and F. Ke, “Designing a Virtual-Reality-Based, Gamelike Math Learning Environment,” American Journal of Distance Education, vol. 30, no. 1, pp. 27–38, Jan. 2016, doi: 10.1080/08923647.2016.1119621.

[9] D. Bogusevschi, C. Muntean, and ..., “Teaching and learning physics using 3D virtual learning environment: A case study of combined virtual reality and virtual laboratory in secondary school,” *... and Science Teaching*, 2020, [Online]. Available: https://www.learntechlib.org/p/210965/

[10] J. Martín-Gutiérrez, C. E. Mora, B. Añorbe-Díaz, and ..., “Virtual technologies trends in education,” *... Technology Education*, 2017, [Online]. Available: https://www.ejmste.com/article/virtual-technologies-trends-in-education-4674

[11] D. M. Shafer, C. P. Carbonara, and M. F. Korpi, “Factors Affecting Enjoyment of Virtual Reality Games: A Comparison Involving Consumer-Grade Virtual Reality Technology,” Games for Health Journal, vol. 8, no. 1, pp. 15–23, Feb. 2019, doi:10.1089/g4h.2017.0190.

[12] D. Sulisworo, V. Y. Erviana, and B. Robiin, “Enhancing Elementary School Students’environment Awareness through Virtual Reality Based Immersive Learning Experiences,” in *EDULEARN23 Proceedings*, IATED, 2023, pp. 8384–8390.

[13] M. T. Y. Lin, J. S. Wang, H. M. Kuo, and Y. Luo, “A study on the effect of virtual reality 3D exploratory education on students’ creativity and leadership,” *... and Technology Education*, 2017, [Online]. Available: https://www.ejmste.com/article/a-study-on-the-effect-of-virtual-reality-3d-exploratory-education-on-students-creativity-and-4820

[14] K. Cheng and C. Tsai, “Students’ motivational beliefs and strategies, perceived immersion and attitudes towards science learning with immersive virtual reality: A partial least squares analysis,” British Journal of Educational Technology, vol. 51, no. 6, pp. 2140–2159, May 2020, doi: 10.1111/bjet.12956.

[15] S. Chang, T. Hsu, W. Kuo, and M. S. Jong, “Effects of applying a VR-based two-tier test strategy to promote elementary students’ learning performance in a Geology class,” British Journal of Educational Technology, vol. 51, no. 1, pp. 148–165, Apr. 2019, doi:10.1111/bjet.12790.

[16] A. Armougum, E. Orriols, A. Gaston-Bellegarde, C. Joie-La Marle, and P. Piolino, “Virtual reality: A new method to investigate cognitive load during navigation,” *J Environ Psychol*, vol. 65, p. 101338, 2019.

[17] H. K. Tabbers, R. L. Martens, and J. J. G. Van Merriënboer, “Multimedia instructions and cognitive load theory: Effects of modality and cueing,” *British journal of educational psychology*, vol. 74, no. 1, pp. 71–81, 2004.

[18] R. Liu, L. Wang, J. Lei, Q. Wang, and Y. Ren, “Effects of an immersive virtual reality-based classroom on students’ learning performance in science lessons,” British Journal of Educational

Technology, vol. 51, no. 6, pp. 2034–2049, Sep. 2020, doi: 10.1111/bjet.13028.

[19] J. Parong and R. E. Mayer, "Learning science in immersive virtual reality.," *J Educ Psychol*, 2018, [Online]. Available: https://psycnet.apa.org/record/2018-03101-001

[20] P. Albus, A. Vogt, and T. Seufert, "Signaling in virtual reality influences learning outcome and cognitive load," *Comput Educ*, vol. 166, p. 104154, 2021.

[21] J. C. Castro-Alonso and B. B. de Koning, "Latest trends to optimize computer-based learning: Guidelines from cognitive load theory," *Computers in Human Behavior*, vol. 112. Elsevier, p. 106458, 2020.

[22] M. R. A. Haryana, S. Warsono, D. Achjari, and E. Nahartyo, "Virtual reality learning media with innovative learning materials to enhance individual learning outcomes based on cognitive load theory," *The International Journal of Management Education*, vol. 20, no. 3, p. 100657, 2022.

[23] J. G. Frederiksen *et al.*, "Cognitive load and performance in immersive virtual reality versus conventional virtual reality simulation training of laparoscopic surgery: a randomized trial," *Surg Endosc*, vol. 34, pp. 1244–1252, 2020.

[24] C. Carbonell-Carrera and J. L. Saorín, "Geospatial Google Street View with virtual reality: A motivational approach for spatial training education," *... International Journal of Geo-Information*, 2017, [Online]. Available: https://www.mdpi.com/218798

[25] T. Trust, N. Woodruff, M. Checrallah, and J. Whalen, "Educators' interests, prior knowledge and questions regarding augmented reality, virtual reality and 3D printing and modeling," *TechTrends*, vol. 65, pp. 548–561, 2021.

[26] G. Makransky, P. Wismer, and R. E. Mayer, "A gender matching effect in learning with pedagogical agents in an immersive virtual reality science simulation," Journal of Computer Assisted Learning, vol. 35, no. 3, pp. 349–358, Nov. 2018, doi: 10.1111/jcal.12335.

[27] H.-L. Chen and Y.-C. Liao, "Effects of panoramic image virtual reality on the workplace English learning performance of vocational high school students," *Journal of Educational Computing Research*, vol. 59, no. 8, pp. 1601–1622, 2022.

[28] Z. Taçgın, "The perceived effectiveness regarding Immersive Virtual Reality learning environments changes by the prior knowledge of learners," *Educ Inf Technol (Dordr)*, vol. 25, no. 4, pp. 2791–2809, 2020.

[29] J. M. Pilgrim and J. Pilgrim, "The use of virtual reality tools in the reading-language arts classroom.," *Texas Journal of Literacy Education*, vol. 4, no. 2, pp. 90–97, 2016.

[30] W. Huang, R. D. Roscoe, M. C. Johnson-Glenberg, and S. D. Craig, "Motivation, engagement, and performance across multiple virtual reality sessions and levels of immersion," *J Comput Assist Learn*, vol. 37, no. 3, pp. 745–758, 2021.

[31] J. A. Bennett and C. P. Saunders, "A virtual tour of the cell: Impact of virtual reality on student learning and engagement in the STEM classroom," *J Microbiol Biol Educ*, vol. 20, no. 2, pp. 10–1128, 2019.

[32] C. Flavián, S. Ibáñez-Sánchez, and C. Orús, "Impacts of technological embodiment through virtual reality on potential guests' emotions and engagement," *Journal of Hospitality Marketing & Management*, vol. 30, no. 1, pp. 1–20, 2021.

[33] B. Mouatt, A. E. Smith, M. L. Mellow, G. Parfitt, R. T. Smith, and T. R. Stanton, "The use of virtual reality to influence motivation, affect, enjoyment, and engagement during exercise: A scoping review," *Front Virtual Real*, vol. 1, p. 564664, 2020.

[34] L. Annetta, J. Mangrum, S. Holmes, K. Collazo, and M. Cheng, "Bridging reality to virtual reality: Investigating gender effect and student engagement on learning through video game play in an elementary school classroom," *Int J Sci Educ*, vol. 31, no. 8, pp. 1091–1113, 2009.

[35] D. Venkat Sulisworo, V. Y. Erviana, B. Robiin, Y. Sepriansyah, and A. Soleh, "The Feasibility of Enhancing Environmental Awareness using Virtual Reality 3D in the Primary Education," *Educ Res Int*, vol. 2022, 2022.

[36] G. Yang, Y. Chen, X. Zheng, and G. Hwang, "From experiencing to expressing: A virtual reality approach to facilitating pupils' descriptive paper writing performance and learning behavior engagement," British Journal of Educational Technology, vol. 52, no. 2, pp. 807–823, Dec. 2020, doi: 10.1111/bjet.13056.

[37] T. Hachaj and D. Baraniewicz, "Knowledge Bricks—Educational immersive reality environment," International Journal of Information Management, vol. 35, no. 3, pp. 396–406, Jun. 2015, doi:10.1016/j.ijinfomgt.2015.01.006.

[38] V. Caro, B. Carter, S. Dagli, M. Schissler, and J. Millunchick, "Can virtual reality enhance learning: A case study in materials science," in *2018 IEEE Frontiers in education conference (FIE)*, IEEE, 2018, pp. 1–4.

[39] M. G. Violante, E. Vezzetti, and P. Piazzolla, "How to design a virtual reality experience that impacts the consumer engagement: the case of the virtual supermarket," *International Journal on Interactive Design and Manufacturing (IJIDeM)*, vol. 13, pp. 243–262, 2019.