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The impact of virtual reality on vocabulary learning and cognitive efficiency

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Highlights

- The study demonstrates the effectiveness of VR in enhancing vocabulary acquisition and engaging teacher training students through immersive experiences.
- Quantitative findings reveal significant improvements in motivation, cognitive efficiency, and perceptions of VR's suitability for language learning.
- The research highlights the potential of VR to transform traditional language teaching by offering innovative, context-rich, and interactive learning environments.

Article Info: Research Article

Keywords: *Virtual reality, vocabulary acquisition, immersive learning, computer-assisted language learning, educational technology*

Abstract

Virtual reality (VR) presents an innovative and powerful approach to foreign language teaching, offering immersive and interactive environments that support vocabulary acquisition in engaging and meaningful ways. This study investigates the potential of VR using the self-developed application GermanVR, specifically designed to enhance vocabulary learning in German as a Foreign Language (GFL) lessons. Conducted with student teachers at Uludag University, the research employed a quantitative approach, including pre-tests, immersive learning sessions using GermanVR, and post-tests to evaluate the impact of VR on learners' motivation, vocabulary acquisition. The results reveal that GermanVR significantly increases learner engagement, accelerates vocabulary learning, and provides realistic, context-rich experiences that closely mirror real-life scenarios. These findings emphasize the potential of VR as a transformative tool in modern language education, showcasing how GermanVR can reshape traditional instructional practices and offer students more dynamic and impactful opportunities for language development.

1. Introduction

Virtual Reality (VR) is a computer-generated simulation of a three-dimensional environment that allows interaction using specialized devices such as a headset equipped with a screen and sensors. Bryson (2013) defines VR as the use of computer technology to simulate an interactive three-dimensional world where objects convey a sense of spatial presence. According to Monteiro and Ribeiro (2020), VR is a technology that creates a simulated environment, which can either resemble the real world or be entirely different. It uses computer-generated images and sounds to provide an immersive experience for the user. VR can be applied in various fields, including education, training, and entertainment.

In education, VR can enhance language learning by immersing students in virtual environments where they can practice listening and speaking in a foreign language. For instance, students can interact with virtual characters and practice vocabulary and grammar in a realistic context. VR improves learning outcomes by increasing motivation, enhancing teaching practices, and encouraging students to innovate learning models (Kustandi et al., 2020). Studies have shown that VR-supported language learning can be more effective than traditional methods for retaining vocabulary and achieving fluency. For example, Monteiro and

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Ribeiro (2020) found that VR has the potential to make significant contributions to teaching and learning foreign language vocabulary. They observed that VR usage helped motivate students and immerse them in lifelike scenarios, enabling them to accurately infer the meanings of target words. Monteiro and Ribeiro (2020) also highlight that the novelty and appeal of the VR learning environment contributed to students' motivation to learn and immerse themselves in the setting.

The rapid advancement of technology has brought about transformative changes in education, reshaping traditional teaching methods and introducing innovative tools for learning. Among these advancements, VR has emerged as a promising technology with the potential to revolutionize language education. By offering immersive and interactive experiences, VR enables learners to engage with content in ways that were previously unimaginable, making it particularly appealing for vocabulary acquisition.

Vocabulary learning is a fundamental aspect of language acquisition, as it forms the basis for effective communication and comprehension. However, traditional methods of vocabulary instruction, such as rote memorization and textbook exercises, often fail to fully engage learners or address the diverse needs of language students. These methods can be perceived as monotonous and disconnected from real-world contexts, leading to a lack of motivation and suboptimal learning outcomes.

VR offers a unique opportunity to overcome these challenges by creating realistic and engaging learning environments. Through VR, learners can immerse themselves in simulated contexts where they can interact with objects, scenarios, and dialogues relevant to the target language. This immersive approach not only enhances motivation but also facilitates deeper cognitive processing, making it easier for learners to retain and recall new vocabulary.

This study explores the impact of VR on vocabulary learning and cognitive efficiency, focusing on its ability to enhance motivation, accelerate vocabulary acquisition, and improve information processing. The research uses the self-developed GermanVR application, which was specifically designed to provide an immersive learning experience. By examining both pre-test and post-test data, this research aims to provide insights into the effectiveness of VR as a tool for language education. The findings contribute to the growing body of literature on educational technology and highlight the potential of VR to transform language learning practices.

2. Literature Review

VR is a rapidly evolving technology with broad applications across various fields, from gaming and entertainment to healthcare and education. Hua and Wang (2023) note a significant increase in VR research post-pandemic, with an expansion into diverse domains. Research focuses on enhancing haptic feedback, human-computer interaction (e.g., hand gestures or brain-computer interfaces).

In education, VR fosters emotional engagement, motivation, and improved learning outcomes. Lampropoulos and Keramopoulos (2022) associate VR with increased academic performance, immersive learning experiences, and enhanced problem-solving skills. Banerjee et al. (2023) found that medical students preferred VR training over traditional methods, appreciating its immersive qualities for learning anatomy and pathology. Similarly, Asad et al. (2021) highlight VR's potential for experiential learning, particularly in fields like healthcare and social work. VR enables realistic simulations, such as surgeries or historical events, offering learners safe environments to practice critical skills (Vesisenaho et al., 2019). Virtual field trips and interactive educational games expand accessibility and engagement, especially for rural students or those with limited travel opportunities. For special education, VR creates safe, controlled environments for students with autism or sensory processing disorders. Despite its benefits, challenges remain. High equipment costs and limited education-specific VR content hinder widespread adoption. As research advances, addressing these barriers will unlock VR's full potential for transforming education and other sectors.

VR offers the potential to enhance vocabulary learning through its ability to provide immediate feedback and foster motivation, interaction, and engagement in language lessons. As Asad et al. (2021) noted, VR increases learners' enthusiasm to use it for language acquisition by simulating realistic scenarios, enabling

practical application of vocabulary in context. Chen and Yuan (2023) emphasized that VR creates authentic, multimodal, and learner-friendly environments that facilitate vocabulary acquisition. These immersive settings also promote retention and memory through repeated contextual usage.

VR supports active learning by placing learners in simulated environments where they can directly apply new vocabulary, thus fostering deeper understanding and long-term retention (Held & Durlach, 1992). For instance, Liu (2009) highlighted how VR allows students to interact in virtual contexts, such as ordering food in a simulated restaurant, which helps bridge the gap between language and real-world application. Similarly, Akyıldız (2019) showed that digital learning games contribute to collaborative and individual learning, enhancing motivation and making language acquisition enjoyable. Despite its benefits, VR poses challenges. Akçayır and Akçayır (2016) pointed out issues such as the high cost of VR technology, technical complexity, and the need for teacher training. Additionally, the availability of tailored VR content remains limited (Alyaz & Demiryay, 2023). Physical discomfort, cognitive overload, and the lack of genuine social interaction in VR environments can also hinder its effectiveness. However, Lampropoulos and Keramopoulos (2022) argued that the interactive and dynamic nature of VR can increase learner motivation, making it a valuable supplement to traditional methods.

In summary, VR enhances vocabulary learning by providing immersive, interactive, and contextually rich environments. It enables active engagement, supports memory retention, and caters to diverse learner needs. Nonetheless, its successful implementation requires addressing technical, financial, and pedagogical barriers.

3. Methodology

This study utilized a quantitative research design to evaluate the effectiveness and impact of the GermanVR application for vocabulary acquisition in German as a Foreign Language (GFL). The research focused on assessing the learners' motivation, learning effectiveness, and perceived engagement during the VR-based vocabulary learning experience.

3.1. Research Design

This study employed a quantitative research design without a control group, focusing on assessing the effectiveness and acceptance of the GermanVR application for vocabulary acquisition. Instead of a comparative approach with traditional learning methods, the study aimed to capture in-depth insights into participants' attitudes and experiences exclusively within the VR learning environment. This study employed a quantitative research design without a control group, focusing on assessing the effectiveness and acceptance of the GermanVR application for vocabulary acquisition. Instead of a comparative approach with traditional learning methods, the study aimed to capture in-depth insights into participants' attitudes and experiences exclusively within the VR learning environment.

A purely quantitative design was chosen to ensure internal consistency and focus on measuring the within-group changes over time. By utilizing pre-tests and post-tests, the study could assess the impact of GermanVR on learners' motivation and vocabulary acquisition. The absence of a control group does not undermine the study's validity, as the primary aim was to evaluate the direct effect of the VR intervention on the participants. Future research could consider incorporating control groups and comparative studies to enhance the generalizability and robustness of the findings.

3.2. Data Collecting Tools

Data for this study were collected using three main instruments: a profiling survey, a VR attitude scale, and a digital education environment evaluation scale. Likert scale surveys (pre-test and post-test) measured participants' attitudes and experiences with VR-based vocabulary learning. The scale ranged from 1 (Strongly Disagree) to 5 (Strongly Agree) and covered constructs such as the perceived usefulness of VR for vocabulary acquisition, engagement levels, and overall satisfaction.

The Profiling Survey captured demographic data and prior knowledge about VR technology, enabling segmentation and analysis of different participant groups based on their background and prior exposure to VR.

The Educational Virtual Reality Attitude Scale, developed by Akçelik and Baran (2022), was used to measure students' attitudes toward educational virtual reality applications. Exploratory Factor Analysis (EFA) revealed a single-factor structure consisting of 18 items, explaining 54.96% of the variance. The Cronbach's Alpha coefficient was calculated as 0.95, and after Confirmatory Factor Analysis (CFA), it was found to be 0.94. Descriptive statistical methods were used in data analysis, and the scale demonstrated a high level of reliability with a Cronbach's Alpha value of 0.90 in this study. These results indicate that the 18-item attitude scale has strong psychometric properties, making it a valid and reliable tool for assessing students' attitudes toward educational virtual reality applications.

The University Digital Education Environment Evaluation Scale was adapted into Turkish by Serbest, Aydın, and Kuş (2023) from the original "Scale for Assessing University Digital Educational Environment" developed by Sorokova, Odintsova, and Radchikova (2021). This adaptation study was conducted in two phases, involving 223 university students selected through appropriate sampling methods. EFA determined the structure of the scale, which consists of 21 items grouped into four sub-dimensions, explaining 56% of the total variance. CFA confirmed this four-factor structure. Reliability analyses indicated that the scale has high psychometric quality, with internal consistency coefficients of 0.91, 0.86, 0.87, 0.79, and 0.73 for different sub-dimensions.

The reliability analysis of the VR Attitude Scale demonstrated good to very good internal consistency, with Cronbach's Alpha values of 0.87 for the pre-test and 0.90 for the post-test, confirming the robustness of the instrument. This suggests that the six statements reliably measure a single underlying construct, namely participants' attitudes toward the use of VR in vocabulary acquisition. The use of individual data for both tests allowed for a more precise calculation, reinforcing the robustness of the instrument.

Furthermore, the observed increase in mean values from pre-test to post-test is an interesting finding that may indicate the effectiveness of the VR intervention. The high reliability of the scale ensures that it is a valid tool for assessing changes in attitudes before and after the intervention, thereby strengthening the conclusions drawn from the study. Future research could further strengthen criterion validity by comparing these survey results with behavioral data or external performance measures.

3.3. Development of the GermanVR Application

A central element of this study is the self-developed GermanVR application, designed to enhance vocabulary acquisition in GFL lessons. GermanVR combines immersive virtual reality environments with interactive learning activities designed to create realistic and contextually rich scenarios. GermanVR exemplifies how modern technology can complement traditional learning methods, creating efficient and innovative solutions for the digital generation. The GermanVR application creates an immersive learning environment where learners can explore a virtual home and interact with everyday objects to enhance their vocabulary acquisition. The application features four distinct rooms - living room, kitchen, bathroom and bedroom - allowing users to navigate freely and select commonly used household items. When an object is selected, its name appears with the correct spelling, reinforcing word recognition and spelling accuracy. By simulating real-life spaces through VR technology, GermanVR enhances the sense of presence, making learners feel as if they are inside an actual home. The vocabulary selection is based on frequently used household items and is aligned with CEFR (Common European Framework of Reference for Languages) guidelines to ensure practical language learning.

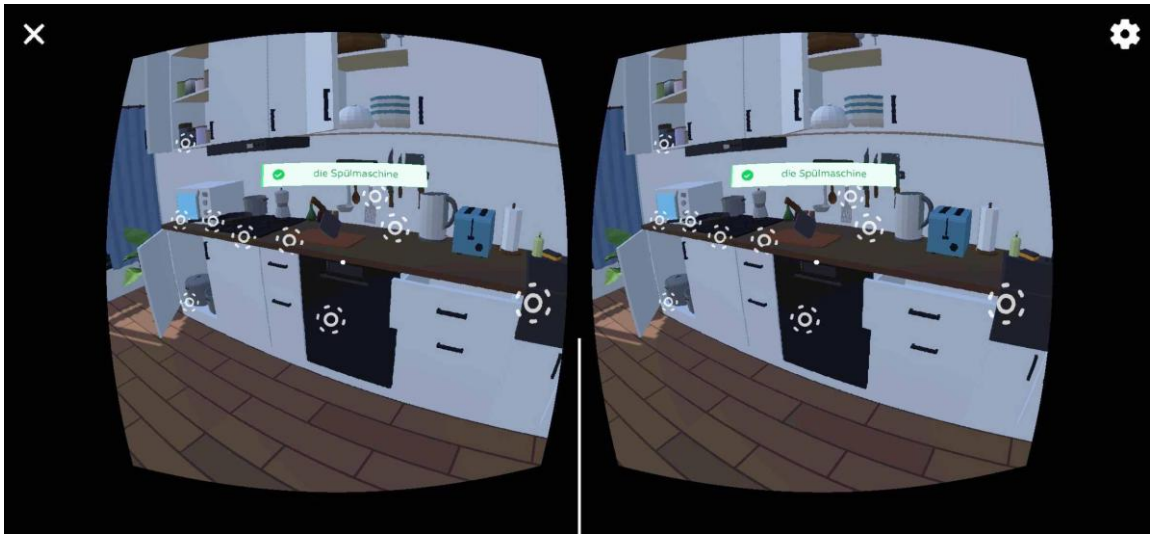

Figure 1. Screenshot from the VR application "GermanVR"

The development of the GermanVR application followed a structured process aimed at enhancing German vocabulary acquisition through an immersive and interactive virtual reality experience. Designed using the Unity Game Engine and optimized for Google Cardboard headsets, the application allows learners to explore a virtual house, interact with objects, and associate vocabulary with real-world items in context.

The idea for GermanVR stemmed from the need to create a more interactive and engaging method for vocabulary acquisition. Traditional learning tools, such as flashcards and textbooks, often lack contextual depth, making it difficult for learners to retain new words effectively. Virtual reality offers an opportunity to present vocabulary in a meaningful, real-world setting where learners can actively engage with their environment, reinforcing memory retention and comprehension. Developed for learners at beginner to intermediate levels, the application focuses on vocabulary related to everyday household items and activities. The virtual environment is structured as a typical house, consisting of a living room, kitchen, bedroom, and bathroom. Each room contains realistic 3D models of common objects, designed to create an immersive learning experience. By selecting objects within the environment, users can see their corresponding German names, strengthening word recognition and contextual learning.

The technical implementation of the application relied on Unity's capabilities for interactive 3D content and VR development. The 3D models were sourced from the Unity Asset Store, a comprehensive library of assets that developers can use in their projects. The interactive features, such as object selection and movement within the house, were programmed using C# programming language. Users can explore the house by teleporting between predefined points, ensuring smooth navigation while maintaining immersion. The application was designed to function efficiently on a variety of smartphones by incorporating low-poly 3D models and optimized textures to reduce rendering demands. Compatibility with Google Cardboard specifications was a priority to ensure accessibility across different devices. By integrating these pedagogical and technical elements, GermanVR provides an innovative approach to vocabulary learning, demonstrating the potential of immersive technology in language acquisition. The application offers learners a dynamic and context-rich environment that facilitates deeper engagement with new vocabulary, making the learning process both effective and enjoyable.

Figure 2 illustrates the virtual kitchen within the GermanVR application, designed to help learners acquire and reinforce vocabulary related to kitchen items and household objects in an engaging and practical manner. The kitchen features a realistic and detailed environment, offering learners a familiar setting that mirrors everyday life, making vocabulary learning both intuitive and immersive.

Figure 2. Kitchen in the “GermanVR”

Figure 3 shows the virtual bedroom in the "GermanVR" application. This interactive learning environment allows users to learn vocabulary and expressions related to furniture and everyday items in the bedroom. By interacting with objects like the bed, wardrobe, nightstand, and lamp, learners can practice and apply the corresponding vocabulary. The realistic design of the bedroom enhances contextual understanding and targeted vocabulary acquisition.

Figure 3. Bedroom in the “GermanVR”

The main function of the application is to provide users with an immersive and interactive learning experience in virtual reality. In this VR environment, learners can navigate through rooms designed to offer a variety of learning content. Each room focuses on specific everyday topics, such as a kitchen, living room, or bedroom, and is filled with objects related to the vocabulary being taught. Navigation between rooms is

facilitated by visual markers, which guide users intuitively to the next area. These markers, in the form of symbols, help users move from one room to another. This visual guidance ensures easy, user-friendly interaction, supporting the learning process without overwhelming the learner.

3.4. Study Group

The participants in this study were 48 teacher trainees enrolled in the German as a Foreign Language program at Uludag University. The sample consisted of 32 female and 16 male participants, aged between 20 and 45 years. All participants had some prior experience with language learning but were new to the use of VR in education.

3.5. Data Analysis

Quantitative data were analyzed using both SPSS software and Excel to ensure comprehensive analysis. Descriptive statistics, including mean (Ẋ) values, standard deviations (Sd), and percentages (%), were calculated for each survey item to summarize the data and identify trends. The analysis focused on examining differences in motivation, engagement, and the perceived effectiveness of the VR application based on these statistical measures. These tests allowed for a deeper understanding of the impact of the VR application on the learners. All analyses were conducted with the aim of providing a clear assessment of how the VR tool influenced vocabulary acquisition and learning outcomes.

4. Findings

The findings from the study on the use of the GermanVR application for vocabulary acquisition in GFL revealed significant improvements in learners' motivation, engagement, and effectiveness of vocabulary learning. The data, collected through pre-tests and post-tests, demonstrated the positive impact of VR technology on students' language learning experiences. Below are the key findings:

Table 1 presents the level of interest in vocabulary learning through VR before and after the intervention, measured using a pre-test and post-test. The table indicates that 72.91% of participants showed interest in the pre-test, with a mean score (Ẋ) of 3.92 and a standard deviation (Sd) of 0.73. After the intervention, the post-test results reveal a significant increase, with 93.75% of participants expressing interest, a higher mean score of 4.38, and the same standard deviation of 0.73. The shift from neutral responses in the pre-test 25% to a significantly lower number of neutral answers in the post-test 2.08% indicates a strong boost in learners' engagement with the method.

Table 1.
Interest in vocabulary learning through VR

	N	**%**	**Ẋ**	**Sd**
Pre-Test	48	72,91	3,92	0,73
Post-Test	48	93,75	4,38	0,73

Table 2 illustrates the suitability of VR applications for vocabulary acquisition, as assessed through pre-test and post-test results. In the pre-test, 64.58% of participants found VR applications suitable, with a mean score (Ẋ) of 3.71 and a standard deviation (Sd) of 0.87. The post-test results show a notable improvement, with 89.58% of participants perceiving VR applications as suitable, a higher mean score of 4.21, and a lower standard deviation of 0.68.

Table 2.
Suitability of VR applications for vocabulary acquisition

	N	**%**	**Ẋ**	**Sd**
Pre-Test	48	64,58	3,71	0,87
Post-Test	48	89,58	4,21	0,68

Table 3 highlights participants' motivation to learn vocabulary through VR, based on pre-test and post-test results. In both the pre-test and post-test, 87.50% of participants expressed motivation. However, the mean score (Ẋ) increased slightly from 4.10 in the pre-test to 4.31 in the post-test, while the standard deviation (Sd) shifted from 0.71 to 0.79. These results suggest that while the percentage of motivated participants remained constant, their level of motivation showed a modest increase following the intervention.

Table 3.
Motivation to learn vocabulary through VR

	N	%	Ẋ	Sd
Pre-Test	48	87,50	4,10	0,71
Post-Test	48	87,50	4,31	0,79

Table 4 demonstrates participants' perception of VR as a realistic and immersive learning experience, based on pre-test and post-test results. In the pre-test, 72.92% of participants perceived VR as realistic and immersive, with a mean score (Ẋ) of 3.92 and a standard deviation (Sd) of 0.73. The post-test results show an increase to 87.50% of participants, with a higher mean score of 4.25 and a slightly larger standard deviation of 0.92. These findings indicate a positive shift in participants' perceptions after the intervention.

Table 4.
Perception of VR as a realistic and immersive learning experience

	N	%	Ẋ	Sd
Pre-Test	48	72,92	3,92	0,73
Post-Test	48	87,50	4,25	0,92

Table 5 presents participants' perceptions of their ability to acquire vocabulary faster using VR, as measured through pre-test and post-test results. In the pre-test, 62.50% of participants believed VR enhanced their speed in vocabulary acquisition, with a mean score (Ẋ) of 3.71 and a standard deviation (Sd) of 0.79. The post-test results reveal a significant improvement, with 89.58% of participants expressing this belief, a higher mean score of 4.21, and a lower standard deviation of 0.68. These results suggest that VR was perceived as more effective for accelerating vocabulary acquisition after the intervention.

Table 5.
Ability to acquire vocabulary faster using VR

	N	%	Ẋ	Sd
Pre-Test	48	62,50	3,71	0,79
Post-Test	48	89,58	4,21	0,68

Table 6 examines participants' assessment of VR's impact on quick and efficient information processing, as reflected in pre-test and post-test results. In the pre-test, 60.42% of participants believed VR contributed to efficient information processing, with a mean score (Ẋ) of 3.75 and a standard deviation (Sd) of 0.75. The post-test results show an improvement, with 79.17% of participants holding this belief, a higher mean score of 4.08, and a slightly lower standard deviation of 0.70. These findings suggest an increased perception of VR's effectiveness in facilitating quick and efficient information processing following the intervention.

Table 6.
Assessment of VR's impact on quick and efficient information processing

	N	%	Ẋ	Sd
Pre-Test	48	60,42	3,75	0,75
Post-Test	48	79,17	4,08	0,70

The comparison of pre-test and post-test results reveals a significant shift in learners' attitudes and perceptions regarding the use of VR applications for vocabulary learning.

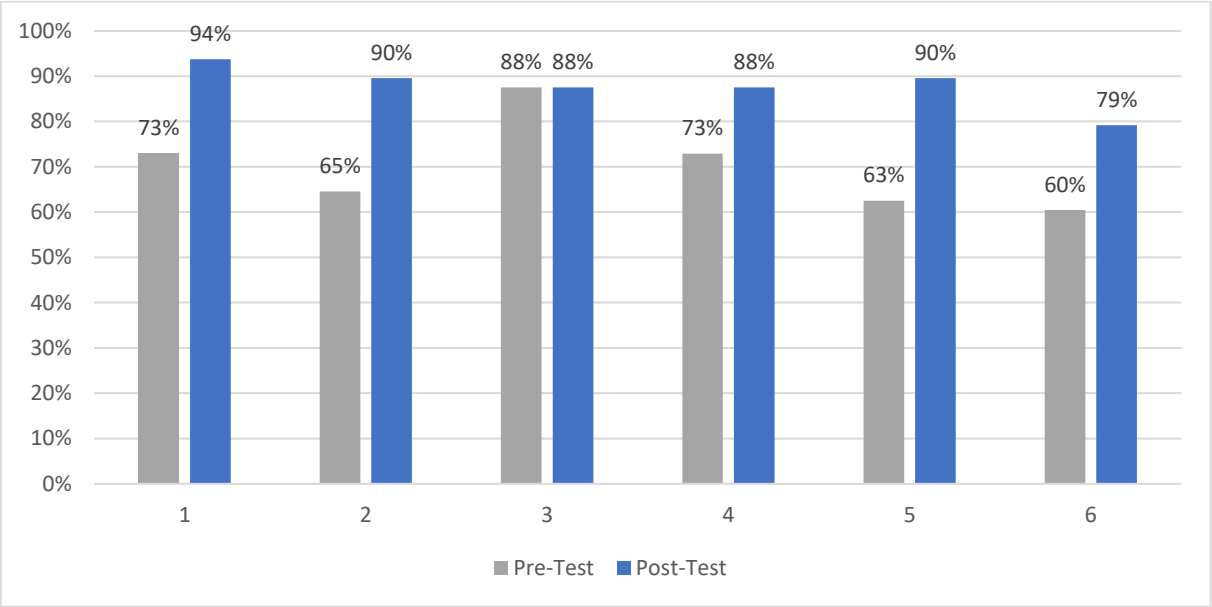

Figure 4. Comparison of pre-test and post-test results

Figure 4 illustrates the results of the pre-test and post-test, measuring participants' perceptions and experiences using GermanVR to expand their vocabulary. Overall, the post-test results show significant improvements in most categories, highlighting the positive impact of the application. Interest (1) in learning vocabulary through VR increased significantly from 73% in the pre-test to 94% in the post-test, demonstrating the application's enhanced appeal. Similarly, the perceived suitability (2) of VR for vocabulary learning rose from 65% to 90%. Motivation (3) to learn vocabulary through VR remained consistently high at 88%, with stronger agreement observed in the post-test. Perception of VR as a realistic and immersive learning experience (4) improved from 73% to 88%. Participants also reported faster vocabulary acquisition (5) after using GermanVR, with scores rising from 63% to 90%. Additionally, the ability to process information quickly and effectively (6) was rated higher, increasing from 60% in the pre-test to 79% in the post-test. These results underline the benefits of VR applications like GermanVR, particularly for motivation, learning speed, and immersive learning scenarios.

5. Conclusion and Suggestions

The analysis of the data collected through pre-test and post-test evaluations reveals significant insights into the effectiveness of VR in enhancing vocabulary learning. Participants demonstrated a clear increase in their interest in learning vocabulary through VR after the intervention. This finding underscores the motivational potential of VR environments, suggesting that their engaging and interactive nature can foster a deeper enthusiasm for language learning. Vesisenaho et al. (2019) confirm that VR establishes an emotionally engaging and immersive learning environment, promoting learner engagement and increasing motivation. Similarly, Banerjee et al. (2023) highlight the unique immersive qualities of VR, noting that these not only facilitate more effective learning but also amplify learners' preference for VR over traditional teaching methods. Furthermore, Chen and Yuan (2023) emphasize that VR offers an authentic and repeatable learning context, characterized by enhanced interactivity and a multimodal framework, which significantly fosters sustained interest in vocabulary acquisition. The findings of this study emphasize the significant potential of VR as a tool for vocabulary acquisition and its broader implications for language education. The results reveal that VR fosters increased interest, motivation, and engagement in learners, aligning with prior research that underscores the immersive and interactive nature of VR as a driver of educational engagement. Participants' heightened interest and sustained motivation, even in the post-test phase, highlight the capacity of VR to maintain learner enthusiasm over time.

The marked improvement in perceptions of VR's suitability for vocabulary learning further suggests that immersive environments provide learners with opportunities to interact with language in authentic and meaningful contexts. Kim and Im (2022) confirm that VR enhances learners' motivation and performance, positively influencing their readiness and ability to learn, thereby reinforcing the suitability of VR applications for vocabulary learning. Furthermore, Banerjee et al. (2023) emphasize that learners particularly value the immersive nature of VR, which fosters its acceptance as a valuable tool for innovative learning approaches, including vocabulary acquisition. Similarly, Asad et al. (2021) highlight that VR increases learner engagement and inspires a desire to use VR for language learning, further supporting the positive attitude toward its use in vocabulary development. These findings underscore the growing recognition of VR as an effective tool for learning and understanding vocabulary. Such interactions appear to bridge the gap between theoretical knowledge and practical application, fostering deeper cognitive processing and retention. Another key finding is the participants' improved perception of their ability to acquire vocabulary faster and process information more efficiently. Chen and Yuan (2023) emphasize that VR enhances and accelerates vocabulary learning through increased interaction and a multimodal, learner-friendly environment. Koçbuğ (2018) observes that while acquiring new vocabulary in virtual environments is comparable to traditional settings, retention of the learned words is significantly improved. Liu (2009) highlights that integrating VR into language learning environments fosters immersion, providing a richer learning experience that enhances the efficiency of the learning process. Similarly, Huang et al. (2010) found that immersive technologies increase engagement and participation, leading to faster and more sustainable learning outcomes. This aligns with cognitive theories suggesting that immersive environments reduce cognitive load by presenting information in an organized and visually engaging manner. The combination of interactivity and contextual relevance likely enhances memory retention and facilitates quicker recall. Interestingly, while the overall motivation levels were consistently high, the slight increase post-intervention suggests that VR not only sustains intrinsic motivation but may also reinforce it through novel and stimulating experiences. This is particularly relevant in language education, where maintaining learner motivation is often a challenge. However, despite these advantages, there are also some limitations to consider: VR-based learning requires access to appropriate technological infrastructure, which may not always be available in all educational contexts, and some learners may experience cognitive overload or distraction due to the high level of sensory input in virtual environments. Moreover, Alyaz and Akyıldız (2018) note that digital tools, such as games, remain underutilized in foreign language learning, suggesting an untapped potential for integrating VR into educational contexts to foster more engaging and effective learning experiences.

Despite these promising findings, several limitations should be noted. First, the study group was limited to 48 teacher trainees from a single university, which restricts the generalizability of the findings to broader and more diverse learner populations. Although prior research has emphasized VR's potential in language learning, this study uniquely focuses on teacher trainees, offering insights into how future educators perceive and may integrate VR into their teaching practice - an angle less explored in current research. Additionally, the reliance on self-reported survey data introduces potential biases and limits the study's ability to objectively measure vocabulary acquisition. Importantly, the definition of "effectiveness" in this study was based on participants' attitudes and perceptions rather than on direct assessments of vocabulary learning outcomes. The absence of a control group also restricts the ability to establish causal relationships between the VR intervention and the observed effects.

Future research should address these limitations by incorporating more diverse and larger samples to increase external validity, employing objective measures of vocabulary acquisition, and including control or comparison groups to better assess VR's relative effectiveness.

Overall, despite its limitations, this study contributes to the growing body of evidence supporting VR's role in transforming language education. By offering immersive, context-rich, and engaging learning experiences, VR has the potential to overcome many challenges associated with traditional teaching methods. These findings underline the importance of integrating innovative technologies into education to

enhance learning outcomes and meet the evolving needs of learners, while also calling for more rigorous research to substantiate VR's educational benefits.

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