

The effect of using virtual reality on students' memory retention in learning abstract material

Erni Ratna Dewi^{1,*}, Rusmiaty Rusmiaty¹, Andi Aminullah Alam²

¹Universitas Islam Makassar, Indonesia

²STIE AMKOP Makassar, Indonesia

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Abstract: The advancement of Virtual Reality (VR)-based learning technology offers novel opportunities to circumvent the constraints of traditional media, particularly for delivering abstract learning materials. The immersive, interactive, and three-dimensional characteristics of VR have the potential to support students' cognitive processes, including their ability to retain information. This study aims to analyze the effect of VR use on students' memory retention in learning abstract materials. The objective of the present study is to evaluate the impact of VR on students' retention of abstract information. The study employed an explanatory survey method and a quantitative approach. The study population consisted of junior high school students in Makassar City who had employed VR-based instructional materials during the learning process. The study sample comprised 50 respondents selected through purposive sampling from five schools. Simple linear regression was implemented to analyze the data. The results indicated that the use of VR had a significant positive impact on students' memory retention, with a significance level of 0.001. According to the coefficient of determination (R^2) value of 0.814, VR accounted for 81.4% of the variation in students' memory retention in the research model. Research results suggest that VR not only serves as an innovative learning medium but also influences students' cognitive processes in the acquisition, processing, and retention of abstract material.

Keywords: Abstract learning, memory retention, virtual reality

Abstrak: Kemajuan teknologi pembelajaran berbasis *Virtual Reality* (VR) menawarkan peluang baru untuk mengatasi keterbatasan media tradisional, khususnya dalam penyampaian materi pembelajaran yang bersifat abstrak. Karakteristik VR yang imersif, interaktif, dan tiga dimensi memiliki potensi untuk mendukung proses kognitif siswa, termasuk kemampuan mereka dalam mengingat informasi. Penelitian ini bertujuan untuk menganalisis pengaruh penggunaan VR terhadap retensi ingatan siswa dalam mempelajari materi abstrak. Tujuan penelitian ini adalah mengevaluasi dampak VR terhadap retensi informasi abstrak pada siswa. Penelitian ini menggunakan metode survei eksplanatori dan pendekatan kuantitatif. Populasi penelitian terdiri dari siswa sekolah menengah pertama (SMP) di Kota Makassar yang telah menggunakan materi pembelajaran berbasis VR dalam proses belajar. Sampel penelitian mencakup 50 responden yang dipilih melalui teknik *purposive sampling* dari lima sekolah. Analisis data dilakukan menggunakan metode regresi linear sederhana. Hasil penelitian menunjukkan bahwa penggunaan VR memberikan dampak positif yang signifikan terhadap retensi ingatan siswa, dengan tingkat signifikansi sebesar 0,001. Berdasarkan nilai koefisien determinasi (R^2) sebesar 0,814, VR berkontribusi sebesar 81,4% terhadap variasi retensi ingatan siswa dalam model penelitian tersebut. Hasil penelitian mengindikasikan bahwa VR tidak hanya berfungsi sebagai media pembelajaran yang inovatif, tetapi juga memengaruhi proses kognitif siswa dalam perolehan, pengolahan, dan retensi materi abstrak.

Kata kunci: Pembelajaran abstrak, retensi ingatan, virtual reality

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*Corresponding author: erni_ratna_dewi@uim-makassar.ac.id

INTRODUCTION

Learning abstract material remains a challenge in the educational process due to the characteristics of concepts that cannot always be directly observed through students' real-

life experiences. Abstract concepts demand higher cognitive abilities because students need to construct mental representations of objects, processes, or phenomena that are not easily visualized (Torun & Altun, 2022). Difficulty understanding abstract material can impact the ability to retain information in long-term memory, especially when the learning process relies solely on verbal and symbolic delivery (Akdag et al., 2025). Cognitive load theory explains that limited working memory capacity can make information difficult to process if learning material is not presented through appropriate representations (Sweller, 2024). This situation emphasizes the importance of developing learning strategies that provide more concrete learning experiences to help students understand and retain the information they acquire.

Conventional learning media such as textbooks, two-dimensional images, and visual presentations are still widely used in delivering abstract material (Damopolii, 2025; Ratna & Adlini, 2024), despite their limitations in providing an immersive learning experience (Dita et al., 2024; Orpa & Sohan, 2026). Static visual representations do not always show spatial relations, process mechanisms, or phenomena that require a direct experience in order to form conceptual images. Learners can experience the phenomenon of a gap between information received by learners and the ability to create conceptual images in their minds (Dwigustini et al., 2024; Roussou & Slater, 2020). Despite the cognitive benefits of multimedia in the learning process, its effectiveness is contingent upon the quality of the design and the level of student engagement in the learning activities (Fiorella & Mayer, 2022). The weaknesses of these media necessitate the development of learning media that facilitate knowledge construction and provide a more contextual and interactive learning experience.

The advancement of digital technology in the sphere of education has brought an innovation in the form of Virtual Reality (VR) that can provide an experience of a learning process in a three-dimensional virtual environment. VR technology enables the emergence of a new type of learning experience by allowing learners to interact directly with learning objects by simulating real experiences, thus stimulating the senses and cognitive processing of the learning process (King et al., 2022; Paramita et al., 2024; Yani et al., 2024). The immersive nature of VR technology also allows learners to experience abstract concepts, such as molecular structures, biology, and the processes of living things, which were previously challenging to imagine and visualize (Radianti et al., 2020). The research conducted by Hamilton et al. (2021) revealed that the use of VR-based learning processes can encourage the emergence of a more active learning experience due to direct interaction with objects in the learning content. The use of VR technology is not only a medium for conveying information but also a learning facilitator that can enrich students' learning experience through engagement.

The development of VR as a learning medium has also been implemented in several educational units in the secondary education level in Indonesia, including Makassar City (Sahabuddin & Makkasau, 2024; Sahnir et al., 2025). One of the examples of the implementation of VR learning media is in SMP Negeri 6 Makassar, which has developed the use of VR as a supporting facility for immersive technology-based learning. Based on these facts, VR as a learning tool may be seamlessly incorporated into the educational process, moving beyond the status of an experimental tool. Compared to other digital technologies, such as computers, projectors, and digital learning platforms, the use of VR as a learning

facility is still relatively new and scarce. In Makassar City, only a few educational units have officially adopted VR as their daily learning facility, so that the implementation of VR in SMP Negeri 6 Makassar is a fascinating opportunity to study.

Besides the implementation in the educational unit level, the introduction of VR technology in secondary schools in Makassar City is also conducted through teacher competency development activities. One of the training programs was conducted through an Informatics Subject Teachers' Conference (MGMP) activity, with the involvement of several public junior high schools, namely Makassar's SMP Negeri 1, 11, 12, and 16. The involvement of these schools indicates the emergence of an ecosystem in the introduction of VR technology in learning, although it is still partial. This fact proves that the development of VR-based learning media has a significant potential for use in educational settings, especially materials that require advanced visual skills and conceptualization skills. In the context of secondary school students' learning experiences, it is imperative to research the efficacy of VR technology on students' memory to determine the full extent of its benefits (Ryan & Poole, 2019).

The immersive and interactive characteristics of virtual reality are associated with the process of storing information in human memories (Namazi et al., 2021). Memory retention in learning refers to the ability of individuals to retain and recall information after the learning process (Alkhabra et al., 2023; Yusmaridi et al., 2022). The cognitive theory perspective of multimedia learning states that the combination of visual and verbal information can contribute to more meaningful knowledge structures via the integration of multiple cognitive channels (Mayer, 2024). Learning with visualization, exploration, and interaction can lead to increased learners' attention which allows easier processing and storage of information into the long-term memory (Makransky & Petersen, 2021). Virtual reality, with its multisensory features, can provide an alternative learning option to facilitate the cognitive processes, especially for the information with high abstraction level.

Memory retention is a critical indicator of the learning success. Both the capacity to understand the material at hand and the capacity to remember what one has learned over time are indicators of a successful learning process (Arifin et al., 2020; James et al., 2025). The information which is processed through meaningful learning experiences has a higher chance to be stored in the long-term memory than the information which is passively learnt (Baddeley, 2012). The experiential learning approach explains that direct experience can reinforce the process of generating knowledge through individual participation in the learning activities (Kolb & Kolb, 2017). The research demonstrates that the use of virtual environments can have an impact on the understanding and memory retention of information as students can have a more enriched learning experience compared to traditional learning methods (Di Natale et al., 2020; Dwigustini et al., 2024; Parong & Mayer, 2021; Sakr & Abdullah, 2024). The aforementioned research shows that VR has great promise as a learning tool for improving memory retention.

A number of empirical studies have investigated the use of VR in educational settings which showed its positive effect on learning engagement, motivation, conceptual understanding, and learning experiences. The review conducted by Radianti et al. (2020) shows that VR can contribute to the creation of an immersive learning environment and increase student engagement across different fields of education. Students' cognitive processes and learning experiences are correlated with their level of presence in a virtual

world (Dengel & Magdefrau, 2018; Makransky et al., 2019; Slater & Sanchez-Vives, 2016). VR-based learning can enable students to comprehend abstract concepts through more realistic visualizations and interactions (Acevedo et al., 2022; Akgün & Atici, 2022). The mentioned outcomes demonstrate the interest in researching VR in education, though the relations between the use of VR and memory retention still require further empirical investigations.

The present research conceptualizes the influence of VR use on secondary students' memory recall while studying abstract information. While the body of research on the use of VR in education has been expanding rapidly, the majority of studies focus on examining the influence of VR on the affective and behavioral outcomes of learning such as motivation, engagement, learning satisfaction, and students' experiences. The studies which focus on the cognitive processes and outcomes of learning, and more specifically, memory retention are still limited, particularly in the context of abstract material learning which requires high level of conceptual visualization skills. This study seeks to fill this gap by analyzing the extent to which the use of VR contributes to students' memory retention. The research findings are expected to enrich the literature on educational technology, particularly regarding the potential of immersive learning environments to support students' cognitive processes. Based on this, this study aims to analyze the effect of the use of VR on students' memory retention in learning abstract material.

METHOD

This study utilizes a quantitative, explanatory type of research. The purpose of the study is to investigate how VR impacts memory retention of abstract learning materials. The choice of a quantitative study design was justified by the need to establish a cause-and-effect relationship between the studied variables by using statistical analysis. Dependent and independent variables were identified for this study. Specifically, student memory retention was the dependent variable, while VR use was the independent variable. Junior high school students in Makassar City who had participated in the development or utilization of VR-based teaching materials as part of MGMP Informatics training activities comprised the population of this study. The study population consisted of students from five SMP Negeri in Makassar. These schools have all incorporated VR into their educational activities. The population selection was based on the fact that students from these institutions have acquired educational experiences associated with immersive technology-based learning media. Purposive sampling was used to select 50 respondents, each representing 10 students from their respective schools.

The research instrument used a questionnaire with a Likert scale to measure the variables of VR usage and student memory retention. The VR usage variable was measured through several indicators covering aspects of immersive experience, interactivity, ease of use, visualization quality, and student engagement during learning. The memory retention variable was measured through indicators of information recall ability, conceptual understanding after learning, ability to retain information for a certain period, and ability to apply acquired knowledge. Before being used in the study, the instrument was tested through validity and reliability tests to ensure its feasibility (Table 1). Data analysis was carried out through several stages, namely descriptive statistical analysis, instrument quality testing, assumption testing, and simple linear regression analysis.

Table 1. Validity and reliability test

Research Instruments	Validity	Reliability
	r	Cronbach's Alpha
X11	0.68	0.601
X12	0.791	0.612
X13	0.74	0.631
X14	0.733	0.659
X15	0.699	0.633
Y11	0.78	0.631
Y12	0.565	0.732
Y13	0.562	0.657
Y14	0.533	0.719

Based on the validity and reliability test results for the research instrument shown in Table 1, it is evident that all statement items met the criteria for validity ($r > 0.170$) and reliability (0.601 to 0.732).

RESULTS AND DISCUSSION

To evaluate the impact of VR use on students' memory retention during abstract learning, data analysis was conducted. The validity and feasibility of the model were initially verified through a series of assumption tests prior to interpreting the results of the simple linear regression.

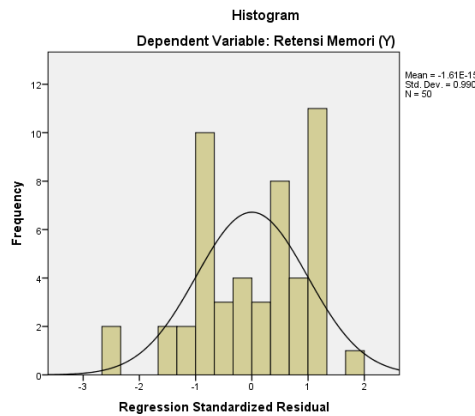


Fig. 1. Normality of residuals

The residual values' distribution appears to adhere to a normal distribution pattern, as indicated by Figure 1. This suggests that the residuals in the regression model have a distribution that is nearly normal. This condition suggests that the residual data does not exhibit any substantial deviations; consequently, the regression model satisfies the normality assumption. It is essential to satisfy the normality assumption in regression analysis, as residuals that are normally distributed suggest that the model parameter estimates are suitable for hypothesis testing.

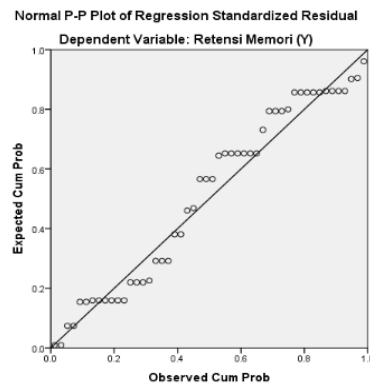


Fig. 2. Normal P-P plot

Figure 2 shows the results of the Normal Probability Plot (Normal P-P Plot) test. The observation points appear to follow and approach the diagonal line. This distribution pattern indicates that the residual data in this study are normally distributed. There are no deviations far from the diagonal line, thus concluding that the regression model does not encounter problems with the normality assumption. These results confirm that the VR usage and memory retention data can be analyzed using simple linear regression. Furthermore, heteroscedasticity is determined from the scatter diagram between the dependent variable and the residual variable, as shown in Figure 3.

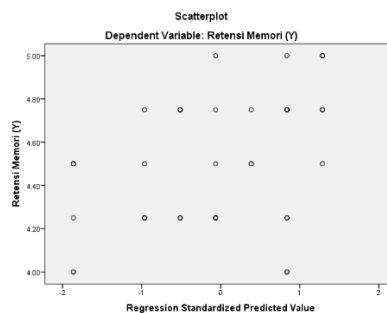


Fig. 3. Residual Heteroscedasticity

Based on Figure 3, the heteroscedasticity test indicate that the residual points on the scatterplot graph are randomly distributed around the horizontal line and do not form a specific pattern, such as a wavy, widening, or narrowing pattern. This condition suggests that the residual variance is constant (homoscedasticity), which means that the regression model does not exhibit symptoms of heteroscedasticity.

Table 2. Multiple linear regression analysis

	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.177	0.389		8.167	0.000
	Effectiveness of VR Usage (X)	0.306	0.087	0.450	3.495	0.001

Based on Table 2 data, the regression equation is $Y = 3.177 + 0.306X$. Table 2 shows a constant 3.177 using basic linear regression. When VR usage is consistent, student memory retention scores are anticipated to be 3.177. The regression coefficient for VR usage is 0.306, demonstrating a favorable link with memory retention. This shows that memory retention increases by 0.306 units for every unit increase in VR use. Students' memory recall increases with VR usage in abstract content, according to a positive regression coefficient. This suggests that VR technology helps students comprehend and store knowledge. The VR use variable had a t-value of 3.495 with a significance level of $0.001 < 0.05$). Thus, VR improves student abstract memory recall. The standardized beta coefficient of 0.450 shows that VR usage increases student memory retention.

Table 3. F Test

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.904	1	0.904	12.217	0.001
	Residual	3.551	48	0.074		
	Total	4.455	49			

Based on the test results in Table 3, the calculated F-value was 12.217 with a significance level of $0.001 < 0.05$. These results indicate that the regression model used in the study is appropriate and meets the statistical criteria for explaining the relationship between VR use and student memory retention. Thus, the variable VR use has a significant influence on student memory retention in learning abstract material.

The Sum of Squares Regression value of 0.904 indicates a significant amount of variation in memory retention that can be explained by the variable VR use in the regression model. Meanwhile, the residual value of 3.551 indicates that there is still variation in memory retention influenced by factors other than the research model. This finding indicates that VR use is a contributing factor in explaining variation in student memory retention in learning abstract material.

The coefficient of determination (R^2) measures a regression model's ability to explain variance in the dependent variable. Higher coefficients of determination mean more variance in the dependent variable may be explained by the research model's independent variables. The coefficient of determination test results are in Table 4.

Table 4. Determinant coefficient

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.902 ^a	0.814	0.728	0.20642

Based on the coefficient of determination analysis in Table 4, the R value was 0.902. This value indicates a very strong relationship between the variable "use of VR" and student memory retention. This finding indicates a positive relationship between the use of VR in abstract learning and student memory retention, where higher levels of VR use tend to be followed by higher levels of memory retention.

The R Square (R^2) value of 0.814 indicates that the variable "use of VR" has explained 81.4% of the variation in student memory retention. Therefore, the majority of variation in

memory retention in this study can be explained by the use of VR, whereas the remaining 18.6% is explained by factors outside the research model. Factors that potentially explain the variation in memory retention outside the research model include students' initial abilities, learning strategies used, learning environment, learning motivation, and individual cognitive characteristics. Furthermore, the Adjusted R Square value of 0.728 indicates that the model characteristics adjustment did not significantly reduce the effect of VR use on the variation in students' memory retention. This result reinforces the finding that the use of VR is a factor that significantly contributes to students' memory retention in learning abstract material.

The research found that VR improves abstract memory retention in student. A simple linear regression analysis showed a positive regression coefficient of 0.306 with a significance level of 0.001. VR explains 81.4% of students' memory retention variance in the study model, according to the coefficient of determination (R^2) of 0.814. This finding indicates that the integration of VR technology in learning not only serves as a medium for presenting material but also is related to the cognitive processes of students in receiving, processing, and retaining learning information. The significant amount of variation explained by the model indicates that the use of VR is a factor that has a strong relationship with memory retention in the context of learning abstract material.

The impact of VR on memory retention can be explained by the characteristics of the technology that enable it to provide immersive, interactive, and three-dimensional visualization-based learning. Abstract learning materials are often challenging to grasp as students need to develop mental representations of concepts that cannot be directly observed. The use of VR helps to overcome these limitations by presenting objects and phenomena in a virtual environment, enabling students to explore them in greater detail. The integration of various types of information through VR technology allows students to obtain a richer learning experience, thus increasing the likelihood of retaining the information learned in long-term memory (Akdag et al., 2025; Ryan & Poole, 2019).

The VR environments provide visual and spatial representations that help learners to better understand concepts more concretely, allowing working memory capacity to be more focused on processing relevant information. In this regard, the use of VR has the potential to help learners develop more organized knowledge structures and support their ability to retain information in memory (Sweller, 2024). Acquiring knowledge via VR allows learners to actively engage with the virtual world, rather than only absorbing information. Such encounters may augment student involvement in the educational process and fortify the relationship between the acquired knowledge and the learning experience gained. Kolb and Kolb (2017) explain that concrete experiences are a crucial stage in the learning cycle as they allow individuals to reflect and develop deeper conceptual understanding. In the context of this research, VR acts as a medium that provides a more concrete learning experience for abstract material, potentially supporting the process of storing information in memory.

Merchant et al. (2014) assert that a heightened sense of presence inside a virtual reality setting may enhance student involvement in the educational experience. This research shows that not only is the application of VR related to the educational process, but it is also found to have a significant correlation to students' memory retention. These findings are relevant to current studies examining the relationship between the immersive

nature of VR and students' cognitive ability. Elevated degrees of immersion in virtual reality settings may enhance the educational process and knowledge retention, since learners have a more profound experience than with two-dimensional media (Peney & Skarratt, 2024). These results align with the study's findings, indicating a favorable and substantial correlation between the use of VR and the retention of memory in students. The visual, spatial, and interactive experiences acquired throughout education allow learners to forge more robust links between new material and their prior knowledge frameworks. Consequently, virtual reality may be regarded as a pioneering educational technology capable of enhancing students' cognitive functions, especially regarding the retention of abstract concepts.

The findings of this study indicate that VR use contributes substantially to the variations in students' memory retention, particularly in material with abstract characteristics. Abstract material often requires representational thinking skills as learning objects cannot always be directly observed in a real environment. The use of VR provides an alternative way for presenting learning through simulations of objects, spaces, and processes that are challenging to visualize using conventional media. The research on VR-based laboratory learning shows that the use of virtual environments can enhance students' visual attention and support longer-term knowledge retention compared to traditional media-based learning approaches (Wen et al., 2024). These findings indicate that the relationship between VR use and memory retention is not only technological but also influenced by the appropriateness of the learning media characteristics and students' cognitive needs to understand abstract material.

The use of VR in junior high schools in Makassar City provides an empirical contribution to the development of learning technology studies at the secondary education level. The implementation of VR in schools that have used technology-based teaching materials demonstrates that the use of immersive technology is starting to gain ground in formal learning practices. This situation can enable the emergence of an idea about using VR not only as a means of technological innovation but also as a phenomenon connected with students' cognitive functions. This paper provides the results of the research in junior high schools that can represent unique values and peculiarities of students' learning processes. Thus, this study makes a valuable contribution by illustrating how VR is applied as an innovative tool that positively correlates with students' cognitive functions related to the retention of the gained knowledge. Consequently, these results enhance our comprehension of the use of VR technology in formal education at the secondary level.

CONCLUSION

Based on the result of research, it can be concluded that the use of VR has a positive and significant influence on students' memory retention. The results of the regression analysis show that VR usage has a positive relationship with memory retention, which means that the higher the use of VR in learning, the higher the tendency of students' memory retention. VR has a high contribution in explaining the variation in students' memory retention in the research model. These results bolster the notion that immersive learning technology has the potential to support the learning process, especially in materials that have a high level of abstraction and need more concrete conceptual visualization. Based on the results of the research, school and educators are suggested to consider using VR as an

alternative learning medium, especially for materials that are challenging to understand by conventional representation. The development of VR content must be appropriate to students' characteristics, learning objectives, and material characteristics so that its use can optimally support the learning process. Further research is suggested to employ a larger number of respondents and more diverse educational contexts. Future research can also use experimental or quasi-experimental design to obtain a deeper understanding of the relationship between the use of VR technology and various learning outcomes.

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