



Evaluating the Implementation of Virtual Reality-Based Learning in Higher Education: Evidence from Mathematics Education Students

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ABSTRACT: The advancement of science and technology has brought significant changes to various aspects of life, including the delivery of education. Digital transformation has encouraged educational institutions to develop learning processes that are more adaptive, interactive, flexible, and responsive to learners' needs. This study employed a quantitative descriptive-exploratory design to evaluate the implementation of Virtual Reality (VR) as a learning medium among Mathematics Education students at the Faculty of Teacher Training and Education, Universitas Kristen Indonesia. Data were collected through a questionnaire assessing students' responses to the implementation of VR during the learning process and were analyzed using descriptive statistics, including the mean, median, and standard deviation. The findings showed a mean score of 3,14, a median of 3.00, and a standard deviation of 0.71, indicating a relatively consistent pattern of student responses to the implementation of VR. The findings provide empirical evidence regarding the actual implementation of VR as a learning medium in higher education, particularly in mathematics education. The results suggest that VR has been implemented as an interactive and immersive learning medium, although its implementation needs to be continuously supported by appropriate technological infrastructure, relevant learning content, and adequate integration into instructional activities. This study highlights the importance of evaluating the implementation of emerging technologies not only from their technological potential but also from their actual use within the learning process.

KEYWORDS: Virtual Reality, implementation evaluation, learning media, higher education, mathematics education

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1. INTRODUCTION

The advancement of science and technology has brought significant changes to various aspects of life, including the delivery of education. Digital transformation has encouraged educational institutions to develop learning processes that are more adaptive, interactive, flexible, and responsive to learners' needs (Yadav, 2024). These changes involve not only the use of technological devices in learning but also a shift in learning experiences from conventional models toward learning environments that enable students to interact more actively with learning resources and contexts (Hasynets et al., 2024). In this context, digital technology has become an important component in supporting the development of more contextual and meaningful learning experiences.

One form of technology-based learning transformation is the development of e-learning and various multimedia-based learning environments. The use of such technologies enables learning to take place more flexibly while expanding students' access to learning resources beyond the constraints of time and space. Along with these developments, learning technologies have continued to evolve from systems that primarily present information toward environments that allow students to experience and interact directly with learning objects. This development has created opportunities for the use of more immersive technologies in education (Kinshuk et al., 2016; Papanastasiou et al., 2019).

One technology characterized by these capabilities is Virtual Reality (VR). VR is a technology that creates three-dimensional virtual environments in which users can experience a sense of presence within a particular setting and interact with objects available in that environment. Through devices such as head-mounted displays, motion sensors, and digital interaction systems, VR enables learning objects and situations to be presented in a more immersive environment (Freina & Ott, 2015; Mulders, Buchner & Kerres, 2020). These characteristics make VR a potentially valuable learning medium for providing experiences that

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may be difficult to achieve through conventional instructional media. In education, VR can provide an alternative approach to presenting learning materials that require the visualization of spatial relationships, objects, processes, or abstract situations.

This potential is particularly relevant in higher education, especially in fields that require advanced conceptual understanding, visualization, and representation. Mathematics learning, for example, requires not only procedural and computational skills but also the ability to understand relationships among concepts, representations, patterns, shapes, spatial structures, and mathematical structures (Richland, Stigler & Holyoak, 2012; Goldin, 2020). The use of virtual environments may therefore provide an alternative means of creating more visual and interactive learning experiences. However, the availability of technology does not in itself guarantee that VR-based learning will be implemented optimally. The effectiveness of technology use is closely related to how the technology is prepared, utilized, accessed, operated, and integrated into learning activities.

The implementation of VR in education continues to face various challenges that may affect the sustainability and optimization of its use (Llanos-Ruiz et al., 2025; Geriş et al., 2025). Limitations in facilities and supporting devices, technological readiness, educators' competence in integrating VR into learning, and the costs associated with procuring and maintaining equipment are among the factors that need to be considered. Beyond technical aspects, the availability of VR content that is relevant to learning objectives and curriculum requirements is also an important consideration. These conditions indicate that the use of VR in education is determined not only by the sophistication of the technology but also by the readiness of the learning environment to implement it effectively (Rashid et al., 2021; AlGerafi et al., 2023). These implementation challenges are particularly relevant to mathematics learning, which encompasses diverse content areas, including abstract concepts that require strong visualization and representation skills. Students may experience difficulties when mathematical objects, relationships, or processes cannot be readily represented through conventional instructional media. In this context, the three-dimensional virtual environments provided by VR offer an alternative means of presenting learning objects and situations in a more visual and interactive manner. Nevertheless, this potential needs to be supported by appropriate implementation practices to ensure that the available technology can be effectively utilized in actual learning activities.

The use of VR in mathematics learning should therefore be understood not only in terms of its technological potential but also in terms of how the technology is implemented within the learning process. Evaluating the implementation of VR can provide empirical evidence regarding the extent to which the medium is actually utilized by students within a planned learning context (Chen, 2006; Yang & Fan, 2025). Information on the level of implementation is important for identifying the actual conditions of VR use and for determining aspects that may need to be strengthened to support its implementation in higher education.

In the Mathematics Education Study Program, Faculty of Teacher Training and Education, Universitas Kristen Indonesia, the use of VR as a learning medium represents an effort to provide learning experiences that are aligned with developments in educational technology. However, the implementation of any instructional medium needs to be supported by empirical evidence regarding its actual use in a real learning environment. Therefore, this study is directed toward evaluating the implementation of Virtual Reality as a learning medium among students in the Mathematics Education Study Program, Faculty of Teacher Training and Education, Universitas Kristen Indonesia. The use of VR in education needs to be considered not only in terms of its technological potential but also in terms of the extent to which it can be implemented within the actual learning process.

Evaluating implementation is important for obtaining empirical evidence regarding the extent to which VR can be used in accordance with the intended learning objectives and instructional design, as well as how students respond to its use during the learning process. Such information is needed to understand the actual conditions of VR implementation and to identify aspects that support its use as well as those that still require further improvement in higher education. Accordingly, this study focuses on evaluating the implementation of Virtual Reality-based learning among students in the Mathematics Education Study Program, Faculty of Teacher Training and Education, Universitas Kristen Indonesia. The evaluation is intended to describe the level of VR implementation based on students' responses, analyzed using the mean, standard deviation, median, and frequency distribution. The findings are expected to provide empirical evidence regarding the implementation of VR as a learning medium in higher education, particularly within the context of mathematics education.

2. THEORETICAL REVIEW

2.1 Virtual Reality as a Learning Medium

One technology with distinctive characteristics for providing interactive learning experiences is Virtual Reality (VR). VR enables users to enter virtual environments designed to resemble particular conditions or objects through three-dimensional visualization, sound, and responses to user movements (Delaney & Biocca, 1995). VR therefore functions not only as a means of presenting information but also as a learning environment that allows learners to observe, explore, and interact with objects more directly (Korkut & Surer, 2023). In education, VR can be used to provide learning experiences that are difficult to achieve through conventional media, particularly when learning objects or situations are complex, abstract, excessively large or small, or difficult to bring directly into the classroom (Christou, 2010). Virtual environments enable learners to obtain visual representations of and

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interact with the subject matter being studied. The use of VR can therefore serve as an alternative learning medium that supports the exploration and understanding of learning materials through more immersive experiences (Marougkas et al., 2023).

The integration of VR into mathematics learning can also be developed through learning approaches that connect mathematics with other fields of science and technology. One such approach is Science, Technology, Engineering, Arts, and Mathematics (STEAM), which integrates multiple disciplines into contextual learning experiences oriented toward the development of thinking skills. The use of VR within a STEAM approach can provide students with opportunities to explore concepts and problems through interactive virtual environments. Abdika, Agoestanto, and Mariani (2025) demonstrated that integrating the STEAM approach with VR technology represents an innovative alternative that can be applied in mathematics learning. VR in learning can thus be understood as a technology-based medium that provides an interactive three-dimensional environment to support learning experiences through observation, exploration, and interaction. These characteristics make VR relevant to mathematics education, particularly for topics that require visualization and spatial experiences. However, the use of VR as a learning medium depends not only on the characteristics of the technology itself but also on how the medium is implemented and utilized within the learning process. The implementation of VR use therefore represents an important basis for evaluating its application in the present study.

2.2 Virtual Reality in Education

The use of VR in education has developed alongside the growing need for learning environments capable of providing interactive and contextual experiences. Unlike conventional digital learning media, which generally position learners as observers of information presented on a screen, VR enables learners to interact with virtual environments from a three-dimensional perspective. In practice, VR can be used to represent objects or environments that require spatial visualization and direct experience (Marougkas et al., 2023). VR-based software and applications enable learners to observe, manipulate, and explore three-dimensional objects within digital simulation environments. Virtual environments can be used to create and visualize three-dimensional models, simulate processes, and examine different possibilities without requiring physical objects to be used directly. Such digital simulations may improve learning efficiency because students can repeatedly explore and practice without always requiring the materials, physical space, or equipment typically needed in conventional practical learning.

The interactive and simulation-based characteristics of VR also provide opportunities to support the development of higher-order thinking skills. Virtual environments allow learners to try different alternatives, observe the consequences of their actions, evaluate outcomes, and make repeated improvements (Jou & Wang, 2013). Such processes can support creativity, problem-solving, and decision-making because learners have opportunities to learn through experience and exploration. In learning contexts that require practice or simulation, VR can also provide a more controlled environment and reduce potential risks that may arise when learning activities are conducted directly using particular objects, equipment, or materials. The use of VR in education can generally be categorized into two main orientations: entertainment- or gamification-based approaches and simulation-based approaches (Allcoat & von Mühlenen, 2018). Gamification-based approaches utilize the interactive characteristics of VR to create engaging learning experiences through challenges, games, exploration, and activities that encourage learner engagement. In contrast, simulation-based approaches use virtual environments to represent particular conditions, objects, or situations, enabling learners to practice and explore skills in environments that resemble real-world conditions. Although these approaches have different characteristics, both place learner experience and interaction at the center of the learning process.

In higher education, the use of VR is particularly relevant because university students are expected not only to understand concepts theoretically but also to connect knowledge with experience, problem-solving, and application in particular contexts (Goi, 2024). VR can provide learning environments that enable students to engage in independent or guided exploration. Such experiences may expand the forms of interaction available in learning and provide an alternative to the limitations of conventional learning media, particularly for materials that are abstract, complex, or require three-dimensional representation (Mallek et al., 2024).

In mathematics education, these characteristics are particularly relevant because several mathematical concepts require visualization, spatial representation, and an understanding of relationships among objects. The three-dimensional environments provided by VR can be used to present mathematical objects in more concrete forms, giving students opportunities to observe and explore mathematical representations from different perspectives. Thus, VR can support mathematics learning that is not solely oriented toward symbols and procedures but also provides richer visual and spatial experiences (Christou, 2010). Nevertheless, the implementation of VR in education is subject to various limitations. The availability of devices, infrastructure readiness, user competence, content suitability, and educators' ability to integrate technology with learning objectives are among the factors that may determine the successful use of VR (Su, Cheng & Lai, 2022). Therefore, the availability of VR technology does not automatically indicate that it has been utilized optimally. Its use needs to be examined in terms of how the technology is prepared, accessed, operated, and integrated into learning activities. The use of VR in education should consequently be understood as a technology implementation process involving interactions among devices, users, content, and learning activities. Successful implementation is determined not only by the technical capabilities of VR but also by the extent to which the medium can be used in accordance with the instructional design and learning needs. This perspective positions the implementation of VR use as an

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important aspect to consider when evaluating its application as a learning medium, particularly in higher education and mathematics learning.

3. RESEARCH METHOD

3.1 Research Design

This study employed a quantitative descriptive-exploratory design to evaluate the implementation of VR as a learning medium among Mathematics Education students at the Faculty of Teacher Training and Education, Universitas Kristen Indonesia. The descriptive component was intended to provide an empirical description of the level and distribution of students' responses regarding the implementation of VR in the learning process, while the exploratory orientation was used to obtain an initial understanding of the observed patterns of implementation.

The study did not aim to examine causal relationships or determine the effect of VR on learning outcomes. Instead, the analysis focused specifically on the implementation of VR-based learning as reflected in students' responses to the research instrument. This design was considered appropriate because the study sought to establish an empirical description of the actual implementation of VR in a higher education learning context and provide a basis for subsequent research using more explanatory or confirmatory designs.

3.2 Participants and Data Collection

The participants were students of the Mathematics Education Study Program at the Faculty of Teacher Training and Education, Universitas Kristen Indonesia, who had experienced the use of Virtual Reality as part of the learning process. Data were collected through a structured questionnaire administered after the implementation of VR-based learning. The questionnaire employed a Likert-type response scale to capture students' responses concerning the implementation of VR as a learning medium. The instrument items were developed based on the theoretical characteristics of VR-based learning and the aspects of its implementation in the learning process. The responses obtained from the questionnaire constituted the primary quantitative data analyzed in this study.

3.3 Validity and Reliability of the Instrument

The internal consistency of the questionnaire was examined using data obtained from a single administration of the instrument. This approach was used to determine the extent to which the items consistently measured the construct of VR-based learning implementation. Thus, reliability assessment in this study refers to the internal consistency of the instrument rather than test-retest reliability. The reliability coefficient was used as evidence of the consistency of the instrument before the descriptive analysis was conducted. The interpretation of the reliability coefficient followed commonly accepted criteria for evaluating the internal consistency of measurement instruments.

3.4 Data Analysis

Data analysis was conducted using descriptive statistical procedures to describe the distribution and central tendency of students' responses regarding the implementation of VR-based learning. The analysis focused on the following statistical measures:

- a) Mean. The mean was calculated to determine the average response score of students regarding the implementation of VR-based learning. This statistic provided an overall indication of the central tendency of the observed responses.
- b) Standard Deviation (SD). The standard deviation was used to determine the degree of variation in students' responses around the mean. A smaller standard deviation indicates that the responses tend to be concentrated around the average score, whereas a larger standard deviation indicates greater variability among students' responses.
- c) Median. The median was used to identify the middle value of the observed scores after the data were arranged in ascending order. The median provided additional information regarding the central position of the data and complemented the interpretation of the mean.
- d) Frequency and Percentage Distribution. Frequency and percentage distributions were calculated to describe the number and proportion of students within each response category. This analysis provided a more detailed representation of the distribution of students' responses and supported the interpretation of the overall level of VR implementation.

The descriptive findings were subsequently interpreted to determine the observed level of implementation of VR as a learning medium among Mathematics Education students. The interpretation emphasized the empirical pattern of implementation rather than causal claims regarding the effectiveness of VR.

4. RESULTS AND DISCUSSION

4.1 Results Validity and Reliability of the Instrument

The instrument's validity and reliability were examined to ensure the quality and consistency of the questionnaire. Construct validity was considered in evaluating whether the questionnaire items adequately represented the intended construct. Internal consistency reliability was assessed using Cronbach's alpha based on a preliminary test involving 10 respondents and 25

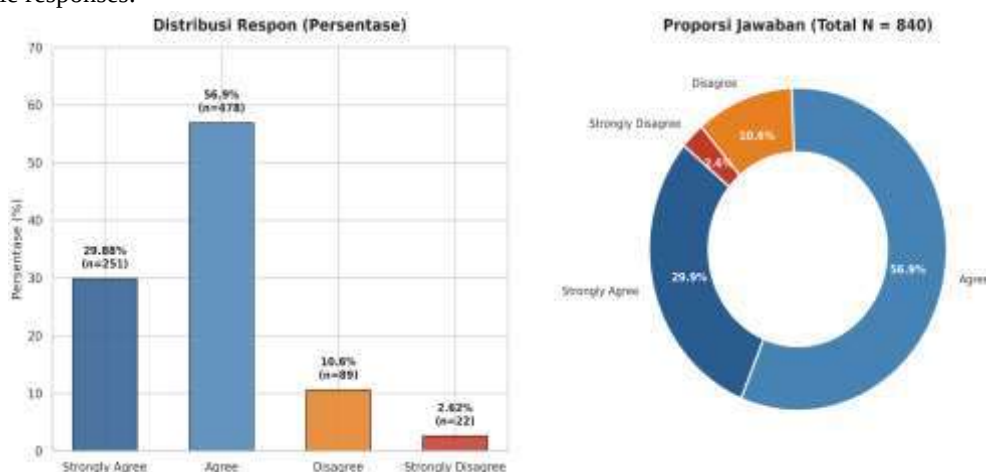
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questionnaire items. The reported item variance was 9.67, with a total score variance of 83.60. The resulting Cronbach's alpha coefficient was 0.931, exceeding the commonly accepted threshold of 0.70. This result indicates that the questionnaire demonstrated excellent internal consistency and was highly reliable for measuring the intended construct. However, Cronbach's alpha evaluates internal consistency rather than construct validity; therefore, additional evidence, such as expert judgment or factor analysis, is needed to establish construct validity.

4.2 Frequency of Virtual Reality Use

Response Category	Score	Frequency (f)	Percentage (%)
Strongly Agree	4	251	29.88
Agree	3	478	56.90
Disagree	2	89	10.60
Strongly Disagree	1	22	2.62
N		840	100%

The questionnaire data were collected from 42 Mathematics Education students who responded to 20 statements, resulting in a total of 840 item-level responses. The responses were analyzed using a four-point Likert scale, ranging from Strongly Disagree (1) to Strongly Agree (4). The results indicate that the majority of responses were positive, with 251 responses (29.88%) classified as Strongly Agree and 478 responses (56.90%) classified as Agree. Combined, these categories accounted for 729 responses (86.79%), indicating a predominantly positive response pattern among the participants. In contrast, 89 responses (10.60%) were categorized as Disagree, while 22 responses (2.62%) were classified as Strongly Disagree. Together, these negative responses accounted for 111 responses (13.21%). Overall, the findings demonstrate that participants tended to express favorable perceptions of the aspects examined in the questionnaire. However, the proportion of negative responses suggests that some aspects may require further attention and improvement. These findings provide a descriptive overview of participants' responses across the 20 questionnaire statements, rather than an indication of the percentage of students who held positive or negative perceptions, since each participant contributed multiple responses.



4.3 Implementation of Virtual Reality Implementation

Mean	3.14
Median	3
Standard Deviation	0.711984559

The Analysis implementation of Virtual Reality (VR)-based learning among Mathematics Education students was generally positive. The mean score for implementation of VR was 3.14, with a median of 3.00 and a standard deviation of 0.711984559. The mean score, which was close to the median, indicates that students' responses were generally concentrated around the central response category. The median value of 3.00 further indicates that the central position of the responses was

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located at the positive response level. Meanwhile, the standard deviation of 0.711984559 indicates a relatively moderate variation in students' responses, suggesting that the implementation of VR was experienced relatively consistently across the respondents.

This pattern is further supported by the frequency distribution. Of the 840 responses, 475 responses (56.9%) were in the Agree category and 251 responses (39.88%) were in the Strongly Agree category, resulting in a combined positive response of 87%. In comparison, 83 responses (10.6%) were categorized as Disagree and 18 responses (2.62%) as Strongly Disagree. The predominance of positive responses indicates that most Mathematics Education students perceived the implementation of VR positively within the learning process. The concentration of responses in the Agree and Strongly Agree categories suggests that VR was not merely introduced as an available technology but was sufficiently implemented and experienced by students as part of the learning activities.

The findings are consistent with the fundamental characteristics of VR as an interactive and immersive learning medium. By providing a three-dimensional virtual environment, VR allows students to observe, explore, and interact with learning objects in ways that may be difficult to achieve through conventional two-dimensional learning media. In Mathematics Education, this characteristic is particularly relevant because some mathematical concepts require visualization, spatial representation, and interaction with objects or environments. The implementation of VR therefore provides an alternative learning environment in which students can experience mathematical representations in a more interactive manner.

4.4 Discussion

From an implementation perspective, the high proportion of positive responses is important because the successful integration of educational technology depends not only on the availability of technological devices but also on whether the technology can be incorporated into actual learning activities. The finding that 87% of responses were positive suggests that the implementation of VR was generally acceptable and feasible from the students' perspective. The mean score of 3.14 and median of 3.00 further reinforce the pattern observed in the frequency distribution, indicating that the overall tendency of responses was toward the positive category. Nevertheless, the 12% negative responses should not be disregarded. The presence of students in the Disagree and Strongly Disagree categories indicates that the implementation of VR was not experienced uniformly by all respondents. Differences in access to devices, technical difficulties, familiarity with immersive technology, digital readiness, or the extent to which VR activities were aligned with instructional needs may contribute to these variations. Therefore, a positive overall implementation should not be interpreted as evidence that all students experienced VR in the same way.

These findings highlight the importance of viewing VR implementation as a process that requires continuous refinement. The relatively favorable response provides empirical support for the use of VR as a learning medium in higher education, while the variation in responses indicates the need for adequate preparation, technical guidance, appropriate learning content, and alignment between VR activities and learning objectives. In this respect, evaluating implementation is important because it provides information about the actual use of VR in the learning environment rather than relying solely on the technological potential of the medium. The findings therefore suggest that VR-based learning has been implemented at a generally favorable level among Mathematics Education students, while continued attention to implementation conditions is necessary to ensure a more consistent learning experience.

Analysis of Virtual Reality Implementation was conducted to examine the central tendency and variability of students' responses regarding the implementation of Virtual Reality as a learning medium. The analysis included the mean, median, and standard deviation. The results show that the mean score of X1 was 3.14, with a median of 3.00 and a standard deviation of 0.711984559. The mean score indicates that students' responses tended to approach the central response category. The median value of 3.00 further indicates that the middle position of the observed responses was located at category 3, suggesting that the overall response pattern was centered around a favorable level of VR implementation. The standard deviation of 0.711984559 indicates a relatively limited variation in students' responses. This finding suggests that the responses were relatively concentrated around the mean, although some differences in students' perceptions of VR implementation were still present. The proximity between the mean and median also indicates that the central tendency of the data was relatively consistent. Taken together, the descriptive statistics indicate that the implementation of Virtual Reality was generally perceived positively by the students. The mean score approaching category 3, combined with a median of 3.00 and a relatively moderate standard deviation, suggests that students tended to provide consistent responses regarding their experience with the use of VR in the learning process. These findings provide an empirical basis for further examining the extent to which VR can be implemented as a learning medium in higher education, particularly in Mathematics Education.

5. CONCLUSION

This study examined the implementation of Virtual Reality (VR) as a learning medium among 42 Mathematics Education students. Based on 840 item-level questionnaire responses, the findings revealed a predominantly positive response pattern, with 86.79% of responses categorized as Agree or Strongly Agree. The weighted mean score was 3.14 on a four-point Likert scale, while the median was 3.00. These results indicate that students generally perceived the implementation of VR favorably. Nevertheless, 13.21% of

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responses fell into the Disagree and Strongly Disagree categories, suggesting that some aspects of VR implementation may require further improvement. The findings suggest that VR offers potential as an interactive and immersive learning medium in Mathematics Education. Its educational value may be enhanced when virtual environments are aligned with learning objectives and supported by appropriate instructional design, technical assistance, and student preparation. However, the positive response pattern reflects students' perceptions of VR implementation and should not be interpreted as direct evidence of improved learning outcomes. Future research should investigate the relationship between VR implementation and measurable student learning outcomes, as well as examine the factors influencing students' experiences with VR-based learning. Such research would provide a stronger empirical basis for evaluating the educational effectiveness of VR and informing its sustainable integration into higher education.

ETHICAL CONSIDERATIONS

This study was conducted at an educational institution with which the researcher is professionally affiliated. No formal approval or exemption was obtained from an institutional research ethics committee. A total of 42 Mathematics Education students participated voluntarily in the study. Participants' autonomy was respected throughout the data collection process. Confidentiality was considered in the handling and reporting of the questionnaire data, and the findings were reported in aggregate form to avoid identifying individual participants. The study's ethical procedures and the absence of formal ethics approval are disclosed transparently.

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