Development of MilleaLab Virtual Reality Media to Enhance Middle School Students' Mathematical Digital Communication Skills

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Abstrak

Penelitian ini bertujuan untuk mengembangkan Virtual Reality (VR) Millealab untuk mendukung kemampuan komunikasi digital matematis siswa SMP. Penelitian menggunakan metode Research and Development (R&D) dengan model ADDIE. Implementasi terbatas dilakukan kepada 6 siswa SMP, sedangkan uji praktikalitas melibatkan 19 responden yang terdiri atas mahasiswa, guru, dosen, siswa, dan masyarakat umum. Hasil observasi menunjukkan bahwa seluruh siswa mampu mengidentifikasi unsur-unsur aljabar, namun 4 dari 6 siswa masih mengalami kesulitan dalam menentukan koefisien dan 2 siswa menunjukkan keraguan dalam menyelesaikan soal aljabar secara mandiri. Meskipun demikian, siswa mampu mengomunikasikan pemahaman matematisnya melalui penyelesaian soal evaluasi setelah menggunakan media VR MilleaLab. Hasil uji praktikalitas menunjukkan bahwa mayoritas responden memberikan tanggapan positif terhadap penggunaan VR dalam pembelajaran matematika. Media ini dinilai menarik, membantu pemahaman konsep, dan meningkatkan minat belajar matematika. Dengan demikian, VR MilleaLab dinilai praktis dan berpotensi mendukung pengembangan kemampuan komunikasi matematis digital siswa SMP.
***Kata Kunci**: Virtual Reality Millealab; komunikasi digital matematis; pembelajaran matematika; siswa SMP.*

Abstract

This study aims to develop Virtual Reality (VR) learning media to support middle school students' mathematical digital communication skills. The study employed a Research and Development (R&D) approach using the ADDIE model. A limited implementation involved 6 middle school students, while the practicality test included 19 respondents from various backgrounds. The results showed that all students were able to identify algebraic elements; however, 4 out of 6 students experienced difficulties in determining coefficients and 2 students showed hesitation in solving algebraic problems independently. Nevertheless, students were able to communicate their mathematical understanding through evaluation tasks after using the MilleaLab VR media. The practicality test indicated that the majority of respondents responded positively to the use of VR in mathematics learning. The VR media was considered engaging, supportive of conceptual understanding, and effective in increasing learning interest. Therefore, MilleaLab VR is practical and has the potential to support the development of students' mathematical digital communication skills.
Keywords: Virtual Reality Millealab; mathematical digital communication; Mathematics Learning; middle school students.

I. INTRODUCTION

A conducive learning environment plays an essential role in supporting students' learning quality. An appropriately designed learning process can reduce boredom and mental fatigue, while simultaneously increasing students' interest and flexibility in learning (Jumrawarsi & Suhaili, 2021). In active learning settings, students are encouraged to interact, ask questions, and discuss with peers, which reduces individual burden during problem-solving activities. Through such strategies, students are expected to achieve improved learning outcomes. However, mathematics learning outcomes in schools remain below expectations, with many studies reporting low student performance (Sari, 2019; Regitanurvikasari, Jana, & Umasugi, 2022).

Algebra is one of the topics in which learning difficulties frequently occur, particularly at the junior high school level. Students often experience misconceptions in operations algebraic expressions, such as difficulties in adding and subtracting constants and coefficients, applying formulas systematically, and connecting one algebraic concept to another (Mulyani et al., 2018; Sari & Afriansyah, 2020). Kartika (2018) further identified deeper challenges, including limited understanding of algebraic fundamentals, difficulties in translating word problems into algebraic forms, and challenges in substituting known values into algebraic equations. These findings indicate that algebra learning requires instructional approaches that not only emphasize conceptual understanding but also encourage students to express and communicate their mathematical thinking clearly.

Mathematical communication is a fundamental component of learning (NCTM, 2000; Rahmawati, Cholily, & Zukhrufurrohmah, 2023). Through communication, students articulate, interpret, and negotiate mathematical ideas orally, in writing, or through representations such as diagrams, graphs, and symbols (Robiah & Nuraeni, 2023; Rasyid, 2020; Ansari, 2012). However, in contemporary learning contexts, communication increasingly occurs within digital environments. Mathematical digital communication therefore refers to students' ability to express, explain, and interpret mathematical ideas using digital media, such as typed text, visual representations, digital symbols, and interactive responses within technology-based learning platforms (Pramuditya et al., 2021; Nasrulloh, Ibrahim, & Solihatin, 2024). Unlike conventional mathematical communication, which often relies on face-to-face oral explanations or handwritten work, digital mathematical communication emphasizes clarity, accuracy, and coherence of mathematical ideas conveyed through digital interfaces. Despite its importance, students' mathematical communication ability remains at a moderate level, particularly in interpreting and expressing mathematical information (Khodijah et al., 2021; Sulastri & Sofyan, 2022).

One instructional innovation with potential to support mathematical digital communication is the integration of Virtual Reality (VR) as learning media (Yumna et a., 2025). Previous studies have shown that VR can increase students' interest, engagement, and learning motivation more effectively than conventional approaches (Tsaaqib et al., 2022). Alfian (2022) also reported that 88% of students rated VR as "very good" in terms of practicality. Beyond its role as a visualization tool, VR provides an interactive digital learning space in which students actively engage with mathematical content, respond to tasks, and communicate their understanding through digital actions and representations (Santika, Nugraha, & Prabawati, 2025). In such environments, students are required to interpret information presented virtually and express their reasoning through structured responses, thereby supporting the development of mathematical communication in digital contexts (Wahyuni et al., 2022).

Responding to these needs, this study aims to design and develop a VR-based learning environment using the Millealab platform to enhance junior high school students' digital mathematical communication skills. The developed VR is semi-immersive and accessible through laptops, computers, or smartphones, making it practical for classroom implementation. The instructional content focuses on Grade VII algebra and is supported by structured learning modules that guide students to observe, interpret, and communicate algebraic concepts within the virtual environment. This study offers novelty by integrating digital mathematical communication into VR-based mathematics learning at the junior high school level, extending previous studies that primarily focused on other subjects (Agusty, 2020; Zulherman et al., 2021) or elementary mathematics contexts (Febriana, 2023). Therefore, this study investigates the design, development, validity, and practicality of Millealab-based Virtual Reality media for enhancing students' digital mathematical communication skills in algebra learning.

II. Method

This study employed a qualitative Research and Development (R&D) approach to design, develop, and evaluate a Virtual Reality (VR)–based learning environment aimed at supporting junior high school students' digital mathematical communication skills. A qualitative orientation was adopted to allow an in-depth examination of the development process from multiple perspectives, including students, teachers, and expert validators. The R&D method was implemented using the ADDIE development model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). As the primary objective of this study was to produce a validated and practical VR learning prototype, the implementation stage was conducted on a limited scale.

The VR learning media was developed using the MilleaLab platform, a cloud-based VR system introduced in 2019 (MilleaLab, 2019). The use of VR in this study was motivated by its potential to address learning loss and enhance student engagement through immersive learning experiences (Cahyaningtiyas, 2021; Putri, 2020). VR enables learners to interact with simulated environments that reduce external distractions and support concentration and memory retention (Krisdianto, 2021). As an immersive technology, VR blurs the boundary between real and virtual environments, allowing students to experience learning situations that resemble real-world contexts and fostering positive learning motivation (Siswanto, 2022).

The developed VR media was implemented as a semi-immersive, desktop-based VR environment. Students accessed the VR content using laptops or personal computers through a 360-degree virtual classroom displayed on a standard screen. No head-mounted display (HMD), such as Oculus or VR Cardboard, was used. Consequently, the level of immersion was categorized as desktop VR, which provides visual and navigational interaction within a virtual environment while maintaining practicality and accessibility for classroom use.

The VR content was designed using MilleaLab Creator, which enabled the integration of 3D assets, skybox environments, images, videos, audio narration, and built-in quiz features without requiring coding skills. Students accessed the VR content through MilleaLab Viewer, allowing them to navigate virtual scenes, observe algebraic representations, and interact with learning tasks in 360-degree mode.

1. Analysis

The analysis stage involved identifying learning needs related to students' difficulties in algebra and mathematical communication. A literature review was conducted to determine common misconceptions, required competencies, and characteristics of digital communication in mathematics. The results guided the selection of Grade VII algebra topics and the formulation of learning objectives and communication indicators to be integrated into the VR media.

2. Design

The design stage focused on planning the instructional flow, VR classroom scenarios, and digital communication tasks to be embedded in the virtual environment. This included outlining learning activities, structuring algebra content, designing visual elements, and preparing student modules. The goal was to ensure that the VR experience supports conceptual understanding while enabling students to express and interpret mathematical ideas digitally.

3. Development

In this stage, the VR prototype was constructed using the Millealab platform. The prototype integrated learning materials, visualizations, and communication tasks aligned with the identified indicators. Expert validation was then conducted by a mathematics education lecturer and an experienced mathematics teacher to assess the accuracy of content, clarity of communication components, visual design, and alignment between learning goals and VR activities.

4. Limited Implementation

A small-scale implementation was conducted to examine the practicality of the VR prototype. A group of Grade VII students interacted directly with the VR environment, while observations were carried out to record their learning behaviors and digital mathematical communication processes. Practicality data were also collected through questionnaires administered to students, teachers, lecturers, and general respondents. They viewed the prototype demonstration and provided feedback regarding usability, clarity, engagement, and relevance of the VR media.

5. Evaluation

Evaluation was carried out continuously at each stage through interviews, observations, and questionnaire results. Feedback was used to refine the VR prototype, with specific attention to improving communication components, instructional flow, and technical accessibility. This iterative evaluation ensured that the final prototype met standards of feasibility, practicality, and relevance to learning algebra and digital mathematical communication.

The research subjects included Grade VII students from SMP/MTs as primary users of the VR media, mathematics teachers and lecturers as expert validators, and members of the general public as additional reviewers. Students participated as direct users of the VR media, while teachers and lecturers provided professional judgments on content validity, pedagogical appropriateness, and communication aspects.

Data were collection involved interviews, observations, written tests, and questionnaires. The instrument used to assess students' digital mathematical communication skills was a digitally administered descriptive test (essay-type questions), completed by students using computers. The test measured students' ability to identify algebraic elements, explain reasoning, and express mathematical ideas using written language and mathematical symbols in a digital format.

Interview guides were used to assess content accuracy, communication clarity, and visual design. Observation sheets captured students' readiness, interaction with digital technology, communication behaviors, and learning responses during VR use. Questionnaires gathered practicality data related to usability, engagement, learning experience, and perceived support for digital mathematical communication.

Data were analyzed using descriptive analytical techniques following the stages of data reduction, data presentation, and conclusion drawing (Sugiyono, 2015). Validation results, observation notes, test responses, and questionnaire data were organized based on predetermined indicators and presented in narrative and tabular forms. Conclusions were drawn by synthesizing validation and practical findings to determine the feasibility of the VR prototype for supporting digital mathematical communication in algebra learning.

III. Result and Discussion

The analysis stage revealed that Grade VII students experience persistent difficulties in understanding the basic elements of algebraic expressions, particularly in identifying variables, constants, coefficients, and terms within contextual problems. Observations and literature analysis indicated that these difficulties are closely related to students' limited ability to interpret symbolic representations and communicate mathematical ideas in digital forms.

Additionally, students showed a strong preference for visual and interactive learning experiences. Conventional instructional media were perceived as less engaging and insufficient in supporting students' active involvement, especially in expressing mathematical understanding. These findings indicate the need for a learning environment that not only visualizes abstract algebraic concepts but also facilitates students' digital mathematical communication through interaction with digital content.

Based on this analysis, the topic *Elements of Algebraic Expressions* was selected as the instructional focus, and Virtual Reality (VR) was chosen as the learning medium due to its potential to provide immersive visualization and interactive digital communication opportunities.

Based on the analysis results, a VR-based learning environment was designed and developed using the MilleaLab platform. The VR environment simulates a virtual classroom and integrates instructional content, interactive navigation, and mathematical representations aligned with the learning objectives. To provide a clear overview of the developed VR environment, the main interface of the MilleaLab-based VR learning media is presented in Figure 1.

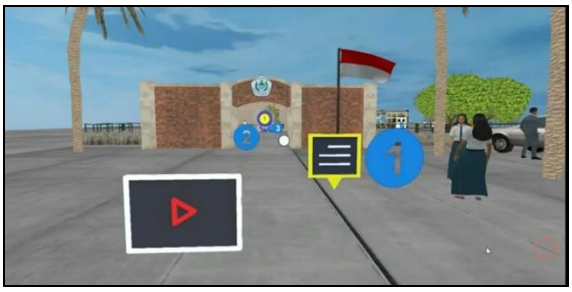

Figure 1. VR Learning Environment.

The interface includes interactive navigation points, instructional panels, and guiding visual cues that help students move through the learning activities systematically. This design ensures that students can focus on learning tasks while gradually adapting to the digital environment.

The VR learning environment consists of several scenes arranged according to the instructional sequence, including apperception, concept explanation, example exploration, and evaluation. Each scene is designed to support specific learning objectives and digital communication activities. The overall structure of the VR learning scenes is illustrated in Figure 2.

To support students' understanding of abstract algebraic concepts, algebraic elements were presented as three-dimensional (3D) objects embedded in the virtual learning environment. These objects represent variables, constants, coefficients, and algebraic terms through contextual visual forms, such as matchstick patterns and symbolic displays.

Figure 3 presents examples of how these mathematical objects are integrated into the VR scenes. Through these visual representations, students are able to observe algebraic structures from multiple perspectives and relate symbolic expressions to concrete visual contexts, thereby supporting the interpretation and communication of mathematical ideas in a digital environment.

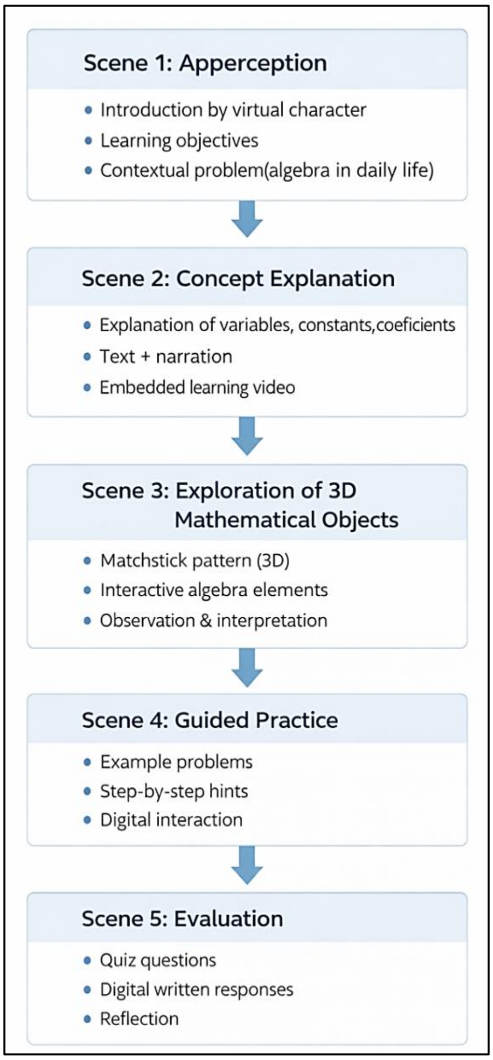

Figure 2. Structure of VR Learning Scenes.

Translate teks:
Do you know the value of 2 + △ = 7?
What is the value of △ + △ + △ = 9?
Remember that 2△ = △ + △.
In this lesson, you will learn the meaning of △ and other related elements.

Figure 3. 3D Representation of Algebraic.

The prototype development stage involved a validation process to ensure that the VR-based learning media aligned with the learning needs of Grade VII students and effectively supported the development of digital mathematical communication skills. The validation focused on three key aspects, material presentation, digital mathematical communication, and graphics and language, and was conducted through interviews with a university expert and a junior high school mathematics teacher.

The expert validator, Siska Firmasari, M.Pd., from Universitas Swadaya Gunung Jati Cirebon, provided in-depth insights regarding the conceptual accuracy of the algebra content, specifically the topic of algebraic elements, and how it should be presented effectively for young learners. She highlighted that the module's explanation of interaction features such as pointers was too general because it relied on a single image, which could confuse students with no prior VR experience. She also recommended revising one of the evaluation questions by replacing an application-type item with a word problem to support preparation for the national Minimum Competency Assessment (AKM).

These findings were summarized into improvement recommendations for material clarity and visual detailing, particularly the need for separate visuals for each interaction feature and clearer definitions of their functions. The corresponding revision plan for the evaluation questions is presented in Table 1.

Table 1.
Recommendations for Improving Evaluation Items

No	Initial Item Type	Revised Item Type	Notes
1	Application	Application	Maintain original format
2	Application	Word problem	Revised to contextual problem

The expert also evaluated the VR environment and suggested adding a clear tutorial demonstrating how interaction tools function in the virtual space, replacing the mysterious background music with a more cheerful tone, and providing a more structured navigation guide so students can easily direct the pointer toward the standpoints and pop-up information.

She also recommended inserting an introductory segment delivered by the virtual character before the learning video to stimulate student interest. These suggestions collectively reinforced the need for improved material presentation, stronger digital communication support through tutorial videos, and refined visual-linguistic elements such as clearer navigation cues and appropriate background music.

The validation continued with mathematics teacher Rizky Kriswandari, S.Pd., from SMP Plus Ulil Albab Cirebon, who emphasized that the module was already comprehensive in describing the steps for downloading, installing, and logging into the VR viewer. He confirmed that the module objectives were aligned with the VR learning goals and that the material was presented in a systematic and coherent manner. He also noted that the evaluation questions were sufficient to assess student learning outcomes using the VR environment. These findings highlight the strength of the material presentation aspect and the module's consistency with the intended instructional goals. A summary of the alignment between the module and VR objectives is shown in Table 2.

Table 2.
Alignment Between Module and VR Objectives

Aspect	Description
Module Objective	Provides step-by-step instructions for conducting VR-based learning
VR Objective	Supports achievement of the defined learning objectives in algebra
Material Structure	Both module and VR materials are organized systematically

Regarding the VR environment, the teacher noted that the use of audiovisual elements would make the learning experience engaging and easy to understand for students who are already familiar with digital gaming environments. He explained that the integration of 3D visualization and clear written and spoken language within the VR space could greatly enhance student motivation, especially in a school context where technology integration in the classroom is still limited. He also emphasized that the immersive experience provided by VR would encourage student participation and interest in learning algebra. Although no revisions to the VR display were requested, the teacher recommended providing close guidance during implementation because many students might be unfamiliar with VR technology and require assistance to interact with it effectively.

Overall, the expert and teacher validations contributed significantly to refining the prototype. Revisions focused on improving the clarity of interaction explanations in the module, enhancing item variety in the evaluation section, adding a tutorial and introductory segment in the VR environment, adjusting background audio for better learning conditions, and strengthening visual cues for navigation. These improvements were essential to ensure that the VR-based learning media effectively supported students' development of digital mathematical communication skills and provided a clear, structured, and engaging learning experience.

During the limited implementation, students showed strong enthusiasm when first accessing the VR learning environment. Most students expressed curiosity and excitement while navigating the virtual classroom and interacting with the 3D objects. Verbal reactions such as interest and enjoyment were observed, particularly during the exploration of learning scenes.

Importantly, no significant motion sickness was reported. Since the VR was accessed using a desktop-based 360° mode rather than fully immersive head-mounted displays, students did not experience dizziness or visual discomfort. Although some students initially felt hesitant when operating the VR interface, this hesitation decreased after brief guidance, and students were able to continue learning independently. These findings indicate that semi-immersive VR provides a safe and engaging learning experience while maintaining student comfort.

Students' digital mathematical communication skills were observed during the limited implementation of the VR-based learning media. The observation focused on students' readiness to engage with VR technology, their technological literacy while navigating the virtual environment, and their ability to interpret and express algebraic ideas through digital representations. To summarize these observations in a structured manner, students' preparation stages, technological adaptation, and digital mathematical communication performance during the limited implementation are presented in Table 3.

Table 3.
Combined Observation Results of Limited Implementation

No	Student	Preparation Stage	Technological Literacy	Digital Mathematical Communication
1	Student 1	Showed strong interest and focus while reading the module before entering the VR class.	Demonstrated good technological literacy and quickly adapted to VR navigation and interaction tools.	Successfully expressed algebraic elements using digital symbols and interacted with 3D objects to interpret algebraic relationships.
2	Student 2	Read the module while simultaneously practicing the instructions inside the VR environment.	Demonstrated good technological literacy and understood VR instructions without difficulty.	Interpreted algebraic elements through 3D representations and responded to tasks using appropriate digital expressions.
3	Student 3	Carefully read and followed the module instructions before entering the VR class.	Demonstrated strong technological literacy and operated VR features	Identified variables, constants, and coefficients through visual cues and expressed algebraic

No	Student	Preparation Stage	Technological Literacy	Digital Mathematical Communication
			accurately.	ideas using digital notation.
4	Student 4	Read the module systematically and attentively until completion before entering VR.	Demonstrated good technological literacy and followed VR interaction steps accurately.	Communicated algebraic concepts effectively after receiving scaffolding, showing improved clarity in expressing algebraic elements.
5	Student 5	Initially hesitant but became confident after receiving guidance during the preparation stage.	Showed improvement in technological literacy after assistance in using VR features.	Able to express basic algebraic structures using 3D objects and simple digital representations after guided support.
6	Student 6	Quickly understood the module instructions and followed the learning steps efficiently.	Demonstrated good technological literacy and promptly applied VR interaction techniques.	Clearly identified algebraic elements and expressed algebraic relationships through digital symbols within the VR environment.

As shown in Table 3, most students demonstrated adequate technological literacy and were able to adapt to the VR environment after minimal guidance. Students actively explored the virtual space, interacted with three-dimensional mathematical objects, and followed the instructional flow as designed. From a mathematical perspective, all students were able to identify basic algebraic elements such as variables, constants, and coefficients through visual cues provided in the VR environment. However, several students experienced difficulties in determining coefficients greater than one and in constructing complete algebraic expressions independently, indicating the need for additional scaffolding.

In addition to learning performance, students' qualitative experiences while using the VR headset were also documented to capture their user experience (UX). Most students expressed enthusiasm and curiosity when first entering the virtual environment. No students reported experiencing motion sickness, dizziness, or visual discomfort during the learning session. Initial hesitation observed in some students was related to unfamiliarity with VR technology rather than physical discomfort, and this hesitation decreased after brief guidance.

To further illustrate students' engagement and the authenticity of the VR-based learning implementation, visual documentation of students interacting with the VR environment using VR headsets is presented in Figure 4.

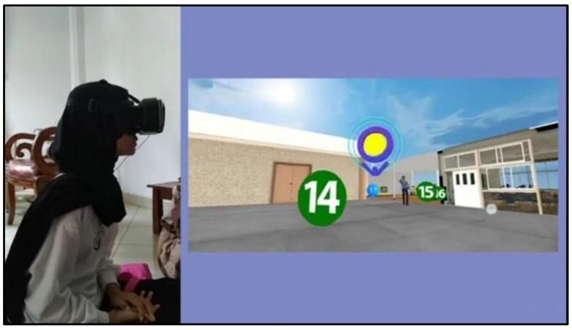

Figure 4. Student Interaction.

In terms of technology literacy, most students showed strong adaptability when interacting with the VR system. They were able to follow instructions fluently, understand module guidance, and operate VR features with minimal difficulty. One student required additional assistance, yet demonstrated notable improvement after being guided, confirming that VR usage remained accessible even for those with lower initial familiarity.

The observation of digital mathematical communication shows that students were able to interact with VR features, complete the learning sequence, and explore the virtual objects meaningfully. Most students displayed consistent interest and engagement throughout the session. However, their performance on algebra tasks revealed persistent challenges, particularly in determining coefficients greater than one. Although all students were able to identify algebraic elements, several required further scaffolding in constructing algebraic expressions accurately. Individual performance for each student is summarized in Table 4.

Table 4.
Task-Based Results of Students' Digital Mathematical Communication

No	Student	Observation Results	Digital Mathematical Communication Outcomes
1	Student 1	Able to identify algebraic elements but still struggled when determining coefficients involving more than two terms.	Task 1 & Task 2 (Student 1): Correctly identified variables and constants; misinterpreted coefficient values greater than 1.
2	Student 2	Identified algebraic elements but made errors in forming algebraic expressions, especially when determining coefficients greater than 1.	Task 1 & Task 2 (Student 2): Showed understanding of basic elements; inaccurate coefficient assignment in multi-term expressions.
3	Student 3	Identified algebraic elements but made similar errors in forming expressions, especially related to coefficients greater than 1.	Task 1 & Task 2 (Student 3): Correctly identified variables; inconsistent in determining correct coefficient values.
4	Student 4	Able to identify algebraic elements but showed hesitation when solving problems; performed well after receiving guidance.	Task 1 & Task 2 (Student 4): Completed tasks correctly after scaffolding; improved confidence in identifying elements.
5	Student 5	Made mistakes identifying coefficient 1 and listing algebraic elements completely, but was able to identify general components.	Task 1 & Task 2 (Student 5): Understood basic structures; incomplete identification of constants and coefficients.
6	Student 6	Identified algebraic elements accurately but still made errors determining coefficients greater than 1.	Task 1 & Task 2 (Student 6): Correct variable recognition; misinterpreted multi-term coefficient values.

The practicality questionnaire, completed by 19 respondents (7 university students, 4 teachers, 1 lecturer, 5 junior high school students, and 3 general participants), also showed overwhelmingly positive responses. Across all groups, VR-based learning was perceived as engaging, motivating, and helpful in improving conceptual understanding of algebra. Respondents highlighted that the immersive experience strengthened comprehension and made the content more accessible, especially for learners who typically struggle with abstract concepts.

Moreover, the results indicate that VR has strong potential for developing digital mathematical communication skills. Its interactive features encouraged students to interpret, follow, and respond to mathematical information within a digital environment, thereby providing meaningful practice aligned with 21st-century learning competencies. Nonetheless, some respondents noted the need for cautious use of VR regarding eye-strain and student comfort, suggesting that implementation should be limited to safe durations.

Overall, the practicality testing demonstrates that VR media is feasible, effective, and pedagogically valuable for enhancing student engagement, mathematical understanding, and digital mathematical communication skills. These findings reinforce the potential of VR as an instructional tool for mathematics education across diverse user groups.

From a practical perspective, the use of the MilleaLab platform offers a significant advantage for mathematics teachers, as it functions as a no-code VR content creation tool. This allows teachers to design and develop their own VR-based learning environments without requiring programming skills. As a result, the VR media developed in this study is not only pedagogically feasible but also realistic for classroom implementation, particularly in schools where teachers have limited technical backgrounds. This practicality strengthens the potential scalability of VR integration in mathematics education.

Nevertheless, several technical constraints were identified during limited implementation. Some students reported increased device temperature when accessing VR content via smartphones, and the initial loading process required a stable internet connection and sufficient data quota. Although these issues did not significantly disrupt the learning process, they highlight important infrastructural considerations for broader implementation. Additionally, extended VR use may cause eye strain or discomfort for certain students, indicating that VR-based learning should be applied within controlled time durations. Addressing these technical and infrastructural challenges is essential to ensure equitable and sustainable use of VR in school mathematics learning.

Following the limited implementation and practicality testing, several revisions were made based on expert validation from university lecturers and junior high school mathematics teachers. These revisions were intended to improve the clarity, usability, and instructional alignment of both the VR learning environment and the accompanying module.

The first revision focused on improving the clarity of interaction features described in the module. Validators noted that explanations of several VR interaction functions were insufficient for first-time users. In response, the module content was revised to include more explicit descriptions and step-by-step guidance to support students in navigating the VR environment independently.

Another important revision involved strengthening students' initial readiness before entering the VR learning activities. During implementation, several students appeared unprepared when directly engaging with the virtual environment. To address this issue, an apperception or concept-activation section was added to the module. This section was designed to introduce key algebraic ideas and learning

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objectives in advance, helping students build cognitive readiness and reduce confusion during VR interaction.

Revisions were also made to the structure and variation of word-problem items. Expert validators recommended increasing the diversity of problems to better reflect the expected cognitive demands of learning algebraic elements. Consequently, several evaluation items were redesigned as contextual word problems that incorporated multiple representations and real-life situations, allowing students to better express their mathematical understanding in digital form.

In addition to content revisions, improvements were made to the overall learning flow presented in the student module. During the limited implementation, the module did not clearly indicate the sequence of learning steps, which caused uncertainty for some users when transitioning between activities in the VR environment. As a result, students occasionally hesitated when determining what actions to take next during the learning process. To illustrate the initial condition of the module before these improvements were applied, the original layout without a structured learning flow is shown in Figure 5.

Figure 5. Module Before Addition.

Based on this limitation, a structured learning flowchart and a tutorial video were subsequently incorporated into the module. These additions were intended to guide students systematically through the VR-based learning process, from initial preparation to content exploration and task completion, thereby reducing confusion and supporting independent learning. The revised version of the module, which includes the structured learning flow and tutorial video, is presented in Figure 6.

Figure 6. Module After Addition of Learning Flow and Tutorial Video.

Finally, the background music (BGM) within the VR environment was replaced with audio more appropriate for mathematical learning. Validators noted that the earlier BGM was less supportive for tasks requiring symbolic and conceptual focus. The updated version, presented in Figure 7. provides a calmer and more conducive atmosphere for mathematical reasoning.

Figure 7. Updated BGM for VR Environment.

Overall, these revisions significantly strengthened the instructional quality, accessibility, and technical readiness of the VR learning prototype, ensuring that it meets both expert expectations and student learning needs prior to broader implementation.

IV. CONCLUSION

The use of Virtual Reality (VR) in mathematics learning demonstrates strong potential to enhance both student engagement and conceptual understanding, particularly in learning abstract algebraic concepts. The validation results from expert lecturers and junior high school mathematics teachers confirm that the algebra content presented in the VR environment aligns well with the intended learning objectives and appropriate for Grade VII students. Furthermore, the practicality testing involving various groups of users shows that VR can increase students' interest and motivation, providing an interactive and immersive learning experience that supports deeper mathematical comprehension.

Students generally responded positively to VR learning activities and showed enthusiasm when exploring mathematical concepts through three-dimensional and interactive representations. Although some students initially experienced difficulties in navigating the VR system or following the instructions, these challenges were gradually resolved with proper guidance and scaffolding. Nevertheless, a small number of students continued to face difficulties in articulating their mathematical understanding digitally within the VR environment, particularly when forming algebraic expressions independently. This finding indicates that VR-based instruction should be accompanied by structured support to maximize students' digital mathematical communication skills.

From a technical perspective, this study recommends minimum device specifications to ensure smooth implementation of VR-based learning. The VR media developed using MilleaLab can be optimally accessed using Android smartphones with at least 4 GB of RAM, a gyroscope sensor, and a stable internet connection for initial content loading. The use of VR headsets such as VR Box or similar devices is recommended to enhance immersion, although the media remains accessible through 360-degree or non-gyroscope modes. To maintain student comfort and device performance, VR sessions should be conducted in short durations and under teacher supervision.

This study is subject to several limitations. The implementation was conducted on a limited scale with a small number of students, and the evaluation focused primarily on validity and practicality rather than measuring learning effectiveness quantitatively. In addition, the study did not compare VR-based learning with conventional instructional methods, and technical factors such as device variability and internet stability may have influenced students' learning experiences.

Despite these limitations, this research contributes to mathematics education by demonstrating the feasibility of developing VR-based learning media using a no-code

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platform, enabling mathematics teachers to design immersive digital learning environments without programming expertise. The study also extends the concept of digital mathematical communication by integrating it into a VR learning context, providing empirical evidence that VR can support students' interaction, interpretation, and expression of mathematical ideas in digital spaces.

The findings of this study have important implications for mathematics instruction, particularly in promoting innovative, technology-enhanced learning environments that align with 21st-century competencies. Future research is recommended to involve larger sample sizes, apply experimental designs to examine the effectiveness of VR-based learning, and explore the long-term impact of VR on students' mathematical communication skills. Further studies may also investigate strategies to optimize VR content design, reduce technical constraints, and integrate VR more seamlessly into regular classroom practice.

REFERENCES

Agusty, A. I. (2020). Millealab Media Pembelajaran Fisika Berbasis Virtual Reality untuk Mengajarkan Topik Pemanasan Global. In *Prosiding Seminar Nasional Fisika (SNF), 4*, 104-110

Alfian, M. (2022). *Pengembangan Media Pembelajaran Berbasis Virtual Reality Millealab pada Materi Sel Elektrolisis*. (Doctoral dissertation, Universitas Sultan Ageng Tirtayasa).

Ansari, B. I. (2012). *Komunikasi Matematik dan Politik*. Banda Aceh: Yayasan Pena.

Berg, L. P., & Vance, J. M. (2017). Industry Use of Virtual Reality in Product Design and Manufacturing: A Survey. *Virtual Reality, 21*(1), 1–17.

Branch, R. M. (2009). *Instructional design: The ADDIE Approach* (Vol. 722). New York: Springer.

Cahyaningtiyas, J. (2021, January 27). *MILLEALAB, Solusi Virtual Reality Terintegrasi bagi Dunia Pendidikan!* MilleaLab.

Cahyaningtiyas, J. (2021, March 17). *Penggunaan Virtual Reality (VR) Popular di Bidang Pendidikan*. MilleaLab.

Febriana, D. (2023). *Pengembangan Media Pembelajaran Virtual Reality berbantu Millea Lab pada Mata Pelajaran Matematika di Sekolah Dasar*. (Doctoral dissertation, Universitas Sultan Ageng Tirtayasa).

Jerald, A. V., Rabara, S. A., & Bi, D. P. (2016, March). Secure IoT Architecture for Integrated Smart Services Environment. In *2016 3rd International Conference on Computing for Sustainable Global Development (INDIACom)* (pp. 800-805). IEEE.

Jumrawarsi, J., & Suhaili, N. (2021). Peran Seorang Guru dalam Menciptakan Lingkungan Belajar yang Kondusif. *Ensiklopedia Education Review, 2*(3), 50–54.

Kadir. (2008). Kemampuan Komunikasi Matematik dan Keterampilan Sosial Siswa dalam Pembelajaran Matematika. *SEMNAS Matematika dan*

Pendidikan Matematika 2008, 2, 339–350.

Kartika, Y. (2018). Analisis Kemampuan Pemahaman Konsep Matematis Peserta Didik Kelas VII SMP pada Materi Bentuk Aljabar. *Jurnal Pendidikan Tambusai, 2*(2), 777-785.

Khodijah, A. S., Pramuditya, S. A., & Asnawati, S. (2021). Kemampuan Komunikasi Matematis Siswa pada Materi Sistem Persamaan Linear Dua Variabel. *Pedagogy: Jurnal Pendidikan Matematika, 6*(1), 139–146.

Krisdianto, B. F. (2021, November 12). *Dosen UNAND Mengganggas Sekolah Percontohan Virtual Reality di Padang*. Beritasumbar.com.

Lowood, H. E. (2022, September 8). *Virtual Reality*. Encyclopedia Britannica.

Lyman, C. (2023, March 6). *Apa itu Virtual Reality dan Cara Kerjanya?* Pintu.co.id.

MilleaLab. (2019). *MilleaLab*. Millealab.com.

Mulyani, A., Indah, E. K. N., & Satria, A. P. (2018). Analisis Kemampuan Pemahaman Matematis Siswa SMP pada Materi Bentuk Aljabar. *Mosharafa: Jurnal Pendidikan Matematika, 7*(2), 251-262.

Nasrulloh, I., Ibrahim, N., & Solihatin, E. (2024). Improving Mathematical Problem-Solving Skills through the Development of Interactive Digital Modules. *Mosharafa: Jurnal Pendidikan Matematika*, *13*(1), 17–28. https://doi.org/10.31980/mosharafa.v13i1.1972

Pramuditya, S. A., Wahyudin, Nurlaelah, E. (2021). *Kemampuan Komunikasi Digital Matematis*. Media Sains Indonesia.

Principles, N. C. T. M. (2000). *Standards for School Mathematics.* Reston, VA: National Council of Teachers of Mathematics.

Priyono, P. E. (2022). *Komunikasi dan Komunikasi Digital*. Guepedia.

Putri, Z. N. (2020). *Program VR Ambassador Berhasil Mencetak Ribuan Pionir Virtual Reality*. Gurubinar.id.

Rahmawati, A., Cholily, Y. M., & Zukhrufurrohmah. (2023). Analyzing Students' Mathematical Communication Ability in Solving Numerical Literacy Problems. *Mosharafa: Jurnal Pendidikan Matematika*, *12*(1), 59–70. https://doi.org/10.31980/mosharafa.v12i1.752

Rasyid, M. A. (2020). Kemampuan Komunikasi Matematis dalam Pembelajaran Matematika. *Jurnal Edukasi: Kajian Ilmu Pendidikan, 5*(1), 77–86.

Regitanurvikasari, Jana, P., & Umasugi, S. M. (2022). Efektivitas Model Edutainment terhadap Hasil Belajar Siswa Kelas X di SMA Negeri 1 Gamping. *Mosharafa: Jurnal Pendidikan Matematika*, *11*(3), 471–482. https://doi.org/10.31980/mosharafa.v11i3.738

Robiah, S., & Nuraeni, R. (2023). Pengaruh kepercayaan diri terhadap kemampuan komunikasi matematis siswa mts pada materi himpunan. *Jurnal Inovasi Pembelajaran Matematika: PowerMathEdu*, *2*(2), 215–228. https://doi.org/10.31980/pme.v2i2.1423

Santika, S., Nugraha, D. A., & Prabawati, M. N. (2025). Enhancing Mathematical Modeling and Ethnomathematics Learning Through Virtual Reality: A Case Study in Higher Education. *Mosharafa: Jurnal Pendidikan Matematika*, *14*(1), 167–182. https://doi.org/10.31980/mosharafa.v14i1.2021

Sari, F. K., Rakimahwati, R., & Fitria, Y. (2019). Hubungan Minat Dengan Hasil Belajar Peserta Didik pada Pembelajaran Matematika Kelas VI SDN 25 Jati Tanah Tinggi. *Jurnal Basicedu, 3*(2), 397-405.

Sari, H. M., & Afriansyah, E. A. (2020). Analisis Miskonsepsi Siswa SMP pada Materi Operasi Hitung Bentuk Aljabar. *Mosharafa: Jurnal Pendidikan Matematika, 9*(3), 439-450.

Siswanto, H. (2022). *Pengaruh Lingkungan dan Gaya Belajar terhadap Motivasi Belajar Siswa pada Mata Pelajaran SKI di MA Pancasila Kota Bengkulu*. (Doctoral dissertation, UIN Fatmawati Sukarno Bengkulu).

Sugiyono (2015). *Metode Penelitian Kombinasi (Mix Methods)*. Bandung: Alfabeta.

Sugiyono. (2016). *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Bandung: PT Alfabet.

Sugiyono. (2018). *Metode Penelitian Kombinasi (Mixed Methods)*. Bandung: CV Alfabeta.

Sulastri, E., & Sofyan, D. (2022). Kemampuan Komunikasi Matematis Ditinjau dari Self-Regulated Learning pada Materi Sistem Persamaan Linear Dua Variabel. *Plusminus: Jurnal Pendidikan Matematika*, *2*(2), 289–302. https://doi.org/10.31980/plusminus.v2i2.1105

Tsaaqib, A., Buchori, A., & Endahwuri, D. (2022). Efektivitas Penggunaan Media Pembelajaran Virtual Reality (VR) pada Materi Trigonometri terhadap Motivasi dan Hasil Belajar Matematika Siswa SMA. *JIPMat, 7*(1), 11–19.

Wahyuni, E., Hidayati, D., & Romanto, R. (2022). Kesiapan Guru terhadap Pembelajaran Berbasis Teknologi. *Jurnal Pendidikan dan Konseling, 4*, 2556–2560.

Walsh, K. R., & Pawlowski, S. D. (2002). Virtual Reality: A Technology in Need of IS Research. *Communications of the Association for Information Systems, 8*(1), 20.

Wohlgenannt, I., Simons, A., & Stieglitz, S. (2020). Virtual Reality. *Business and Information Systems Engineering, 62*(5), 455–461.

Yumna, H. A., Anggraheni, M. T., Ashidiqi, F., Hanifah, N. P., Annam, M. R., & Ardiansyah, A. S. (2025). Peningkatan Literasi Numerasi Siswa Melalui Roblox Virtual Reality Berbasis Bangunan Bersejarah Semarang. *Radian Journal: Research and Review in Mathematics Education*, *4*(3), 114–121. https://doi.org/10.35706/radian.v4i3.13173

Zulherman, Z., Amirulloh, G., Purnomo, A., Aji, G. B., & Supriansyah, S. (2021). Development of Android-based Millealab Virtual Reality Media in Natural Science Learning. *Jurnal*

Pendidikan Sains Indonesia (Indonesian Journal of Science Education), *9*(1), 1-10.

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