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Improving Students' Mathematical Representation through Contextual Teaching Materials with a Scientific Approach: An ADDIE-Based Development Study

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ABSTRACT:
Background: Mathematical representation is a fundamental competence that enables students to express mathematical ideas in multiple forms—verbal, symbolic, visual, and graphical. However, many junior high school students struggle to represent mathematical concepts effectively due to the lack of contextualized instructional materials and the limited application of active learning approaches in classrooms.
Aims: This study aims to develop a valid, practical, and effective contextual teaching material based on the scientific approach to enhance students' mathematical representation skills at the junior high school level.
Methods: The research employed a Research and Development (R&D) design using the ADDIE model, encompassing five stages: Analysis, Design, Development, Implementation, and Evaluation. Validity was assessed by expert review, practicality through teacher and student responses, and effectiveness using a pre-test and post-test design to measure improvements in mathematical representation ability.
Results: The developed teaching material achieved high validity scores from subject matter experts (3.71) and media experts (3.73). Practicality assessments revealed positive responses from both teachers and students, citing ease of use and contextual relevance. Effectiveness was demonstrated through a significant gain in students' post-test scores, indicating improvement in verbal, symbolic, and visual representations.
Conclusion: This study confirms that contextual teaching materials grounded in the scientific approach and developed through the ADDIE model can substantially enhance students' mathematical representation skills. The learning process, which integrates observation, inquiry, experimentation, reasoning, and communication, encourages meaningful student engagement and deepens conceptual understanding. The contextual elements embedded in the material also bridge the gap between abstract mathematical theories and students' everyday experiences. Therefore, the product of this research is not only empirically validated but also pedagogically powerful, and it is strongly recommended for broader implementation in mathematics instruction across junior high schools.
Keywords: Mathematical Representation, Contextual Teaching Materials, Scientific Approach, ADDIE Development Model, Secondary Mathematics Education.
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INTRODUCTION

Mathematical representation plays a vital role in students' understanding of abstract mathematical ideas and their ability to communicate concepts in symbolic, visual, and verbal forms. Despite its importance, many students struggle to express mathematical concepts effectively due to a lack of appropriate instructional materials that promote engagement and contextual learning. Traditional materials often emphasize rote procedures, which hinder the development of deeper conceptual understanding (Bhardwaj et al. 2025 and Ifelebuegu. 2023). This disconnect contributes to students' inability to relate mathematical concepts to real-life situations.

In the Indonesian context, the implementation of the 2013 Curriculum emphasizes a scientific approach that involves observing, questioning, experimenting, reasoning, and communicating. However, in practice, these stages are rarely reflected in the instructional materials used in classrooms. Teachers often face difficulties in translating the curriculum into meaningful learning experiences, especially those that promote higher-order thinking skills and representational abilities (Heffington & Coady. 2023 and Payadnya et al. 2023). The situation demands an innovation in the development of teaching materials that align with national curriculum goals while addressing the cognitive needs of learners.

There is a growing urgency to create contextually rich materials that not only support curriculum implementation but also develop students' capacity to represent mathematical ideas accurately. Given the limitations of existing textbooks and worksheets, this study focuses on designing contextual teaching materials based on the scientific approach through a structured development model. Such materials are expected to bridge the gap between theory and practice while enhancing students' mathematical thinking and communication skills (Rehman et al. 2024 and Uyen et al. 2021). This research responds to the need for innovative pedagogical tools that foster meaningful mathematical learning among junior high school students.

The rationale for this study lies in the intersection between curriculum expectations and students' actual classroom experiences. While policy documents advocate for active, contextual, and meaningful learning, most instructional resources fail to operationalize these principles effectively. Students are rarely provided with opportunities to connect mathematical concepts to their lived experiences, which weakens the transferability of learning and limits representational competence. By integrating contextual scenarios with a scientific pedagogical framework, students can be more actively involved in constructing knowledge and developing representational fluency.

This study adopts the ADDIE model as a reliable instructional design framework due to its systematic stages of analysis, design, development, implementation, and evaluation. The ADDIE model is widely used in educational research and has shown success across various domains, including mathematics, nursing, and technology-enhanced learning (Wu et al. 2021 and Yang et al. 2021). Its application ensures that the developed materials are pedagogically sound, empirically tested, and aligned with learners' needs. Thus, the study not only contributes theoretically to the literature on instructional design but also offers practical benefits for mathematics educators in Indonesia.

Numerous studies have explored the effectiveness of contextual and scientifically grounded instructional designs. Norouzkhani et al. (2025) used the ADDIE model to develop a gamified health management app and found that structured development significantly improved user engagement and outcomes. Similarly, Mohammad Basir et al. (2025) demonstrated the successful application of ADDIE in constructing health education modules, emphasizing the importance of expert validation and contextual adaptation. Das et al. (2025) also employed ADDIE to design an obesity education module, resulting in improved learner comprehension and practical application. These studies reinforce the utility of the ADDIE model in developing context-specific educational tools.

In the domain of mathematics education, Sebastian & Kuswanto. (2025) showed that augmented reality-based physics e-books improved visual and critical thinking skills—highlighting the value of representational media in science learning. Wahyuni et al. (2025) developed an Android-based algebra application, confirming that technology-enhanced, constructivist learning environments enhance mathematical understanding. Fahrudin et al. (2025) developed a project-based physics literacy model, which aligns with the current study's focus on integrating science and representation. Putri et al. (2025), and Rakhmawati & Dewanto. (2025), Şimşek et al. (2025) emphasized the role of multimodal, digital, and inclusive learning tools in supporting students with diverse needs and improving engagement in content-rich subjects.

While previous studies validate the success of the ADDIE model across educational domains, few have directly focused on developing contextual mathematics teaching materials aimed at enhancing representational skills in junior high schools. Most existing research concentrates on science, health, or early childhood education, leaving a significant gap in secondary mathematics education. Additionally, although the scientific approach is theoretically well-supported, its practical translation into classroom materials remains underexplored. This study addresses this gap by combining contextual mathematics content with the five stages of the scientific approach and applying the ADDIE model for systematic development and evaluation.

The primary aim of this study is to develop, implement, and evaluate a contextual teaching material based on the scientific approach to improve students' mathematical representation skills. It is hypothesized that instructional materials developed through the ADDIE model will demonstrate high levels of validity, practicality, and effectiveness. The study assumes that such materials will facilitate meaningful engagement, promote conceptual understanding, and enable students to express mathematical ideas more accurately. Furthermore, the research is expected to offer a replicable model for other educators seeking to implement curriculum-driven, learner-centered teaching tools in mathematics classrooms.

METHOD

Research Design

This study employed a Research and Development (R&D) approach utilizing the ADDIE model as its instructional design framework. The ADDIE model includes five systematic stages: Analysis, Design, Development, Implementation, and Evaluation, each contributing to the production of a valid, practical, and effective instructional product (Mohammad Basir et al., 2025). The research aimed to

develop contextual mathematics teaching materials integrated with the scientific approach to improve students' mathematical representation skills. The study followed a mixed-methods approach, combining qualitative validation and feedback with quantitative testing of student outcomes. Qualitative elements included expert reviews and user feedback, while the quantitative component assessed pre- and post-test gains in mathematical representation ability. The design was implemented in a real classroom context to ensure ecological validity. The ADDIE model was selected for its flexibility, systematic structure, and strong empirical support in similar instructional product development studies (Lee et al. 2024 and Zheng et al. 2021). By following a structured development process, the research sought to ensure both instructional integrity and empirical robustness.

Participants

The participants in this study included one mathematics teacher and a cohort of 30 eighth-grade students from a public junior high school in Indonesia. The school was selected through purposive sampling based on the availability of facilities, relevance of the curriculum, and willingness to participate. The teacher had more than five years of teaching experience and was familiar with the principles of contextual learning. Students were between 13 and 14 years old and had prior exposure to the mathematical topics involved. All participants were informed about the purpose of the study, and parental consent was obtained to ensure ethical compliance. The implementation stage involved classroom trials using the developed teaching materials. The selection of participants ensured alignment with the target demographic of the designed materials. The limited but focused sample allowed for manageable yet informative implementation and evaluation of the instructional product.

Instrument

Three primary instruments were used to collect data: expert validation sheets, user response questionnaires, and mathematical representation tests. The validation sheets were designed to assess the content accuracy, instructional design, language, and graphic quality of the teaching materials. These were completed by two subject-matter experts and one media design expert, using a four-point Likert scale. The user response questionnaire gathered feedback from both the teacher and students on the practicality and user-friendliness of the materials. To measure students' mathematical representation skills, a test comprising tasks that required verbal, symbolic, and visual representations was developed and administered before and after the intervention. The test was aligned with the content of the teaching materials and reviewed for content validity. Instrument development and application followed best practices in educational research to ensure credibility and relevance (Sillat et al. 2021 and Zamiri & Esmaeili. 2024) These instruments collectively supported comprehensive evaluation across the ADDIE stages.

Data Analysis Plan

Data were analyzed using a combination of qualitative and quantitative techniques to ensure triangulation and robust interpretation. Expert validation scores were analyzed using descriptive statistics, specifically the calculation of average scores to determine content validity levels. Questionnaire responses were summarized using frequency and percentage analysis to assess the practicality of the materials from user perspectives. For effectiveness, students' pre- and post-test scores were compared using normalized gain scores to measure learning improvement. The gain score formula was employed to evaluate the extent to which mathematical representation abilities

increased after using the developed materials. A gain score above 0.3 was considered a moderate to high level of improvement, indicating instructional effectiveness. All data analyses were conducted manually and supported with appropriate tabulation and visualization. The analysis framework aligned with the procedures adopted in similar ADDIE-based development research (Abuhassna et al. 2024 and Yan et al. 2025), ensuring methodological rigor and comparability with prior findings.

RESULTS AND DISCUSSION

Results

The development of the contextual teaching material followed the ADDIE model and yielded several key findings based on validation, practicality, and effectiveness. Validation by subject-matter experts resulted in an average score of 3.71, while media experts rated the material at 3.73, both of which are within the "very valid" range. These high scores suggest that the content is pedagogically sound, linguistically appropriate, and visually engaging. Practicality was measured through teacher and student feedback, both indicating that the material was easy to implement, contextually relevant, and engaging for students. Effectiveness was measured using pre-test and post-test scores of students' mathematical representation abilities. The analysis yielded a normalized gain score of 0.45, which falls in the "moderate to high" category, indicating that the material successfully improved student outcomes. These findings demonstrate that the teaching materials meet the required standards for classroom implementation. The figure below presents a visual summary of validation and effectiveness results:

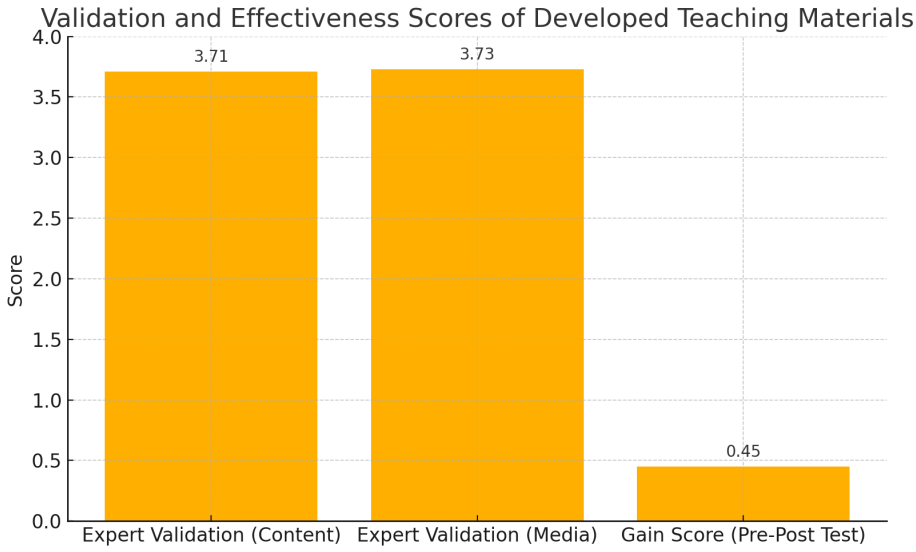

Figure 1. Validation and Effectiveness Scores of Developed Teaching Materials

Figure 1 illustrates the core quantitative findings from the expert validation and student effectiveness assessments. The average score of 3.71 from content experts indicates a high level of agreement regarding the relevance, accuracy, and pedagogical quality of the materials developed. Similarly, the media experts provided a score of 3.73, reflecting strong approval of the design, layout, clarity, and visual appeal of the instructional content. Both scores surpass the commonly accepted

threshold for validity in instructional product evaluation, thereby confirming the internal consistency and professional appropriateness of the materials.

In terms of effectiveness, the gain score of 0.45 signifies a moderate to high improvement in students' mathematical representation abilities after the use of the developed teaching materials. This result is particularly noteworthy considering the short intervention period, suggesting that the contextualized and scientific approach-based materials had a meaningful impact. The improvement reflects students' enhanced ability to express mathematical ideas in verbal, symbolic, and visual forms—skills central to mathematics learning and assessment standards.

The convergence of high validity, positive user response, and measurable student learning gains strongly supports the instructional effectiveness of the developed product. It also provides empirical evidence that structured instructional design models like ADDIE, when combined with the scientific approach, can produce impactful learning tools for junior high school mathematics. This graphical summary thus serves not only as a representation of data but also as a validation of the research model's practical application in real classroom settings.

Discussion

The results of this study underscore the effectiveness of integrating contextual learning with a scientific pedagogical approach through a structured development model. The high validation scores confirm the internal coherence and appropriateness of the material content, aligning with prior studies that emphasize expert involvement in material development (Haas et al. 2021 and Kaldaras & Haudek. 2022). These findings support the claim that instructional materials must be contextually rich and systematically validated to ensure meaningful learning outcomes (Edelson et al. 2021). Furthermore, the practicality of the materials, as perceived by teachers and students, affirms the usability and relevance of the contextual tasks and problems designed. The students' engagement with realistic problems likely contributed to their ability to internalize mathematical concepts more effectively (Susanti. 2025 and Zhu et al. 2024).

The gain score of 0.45 obtained in this study suggests a significant improvement in students' ability to represent mathematical concepts in verbal, symbolic, and visual forms. This aligns with Sebastian and Kuswanto (2025), who found that media-enhanced instructional materials significantly improve visual representations in science learning. The combination of scientific approach stages—observing, questioning, experimenting, reasoning, and communicating—encouraged students to engage in multiple levels of cognitive processing (Idris et al. 2022 and Soysal. 2024). These stages promote the development of representational skills, as students are not merely passive recipients but active participants in the learning process (Davoodi. 2024 and Silma et al. 2024). In this regard, the ADDIE model proved to be an effective framework to manage the complexity of material design and implementation (Crompton et al. 2024 and Spatioti et al. 2022).

This study also addresses a notable gap in the literature by applying the ADDIE model in a secondary mathematics context, where previous research had focused primarily on health, technology, or early childhood education (Crompton et al. 2024 and Shakeel et al. 2023). The findings suggest that the model is highly adaptable and effective for subject-specific content development. Furthermore, by emphasizing real-world contexts, the materials encourage knowledge transfer and improve problem-solving skills among students (Nurjamin et al., 2025; Baser & Sahin, 2025). The

interdisciplinary nature of the scientific approach promotes critical thinking and reasoning across various learning dimensions (Chang et al. 2022 and Romero Ariza et al. 2024). Hence, this research contributes both theoretically and practically to the advancement of curriculum-driven instructional development in mathematics education.

Another important contribution of this study lies in the integration of multiple data sources—expert validation, user feedback, and pre-post testing—to ensure triangulated evidence for product effectiveness. This triangulation ensures the robustness of findings, echoing the methodological recommendations by researchers in educational technology and curriculum studies (Karanfiloğlu & Akın Bulut. 2025 and Liu. 2024). Such rigorous evaluation processes enhance the credibility of the developed product and serve as a model for future instructional design efforts. The use of quantitative gain scores combined with qualitative feedback reflects best practices in instructional development research (Garone et al. 2022). Ultimately, this study supports the growing call for instructional products that are both data-driven and contextually grounded.

Implications

This study offers practical implications for curriculum developers, educators, and educational policymakers. First, it demonstrates that the ADDIE model can be effectively adapted for subject-specific instructional material development, particularly in mathematics education. Second, it provides evidence that contextualized and scientifically grounded materials can significantly enhance students' mathematical representation abilities. Third, the research highlights the importance of incorporating student-centered pedagogical strategies in material design. These findings suggest that future mathematics instruction should prioritize active engagement and contextual relevance. Lastly, the study encourages broader implementation of validated and tested teaching materials to promote quality education at the secondary level.

Limitations

Despite its contributions, this study has several limitations. The sample size was limited to a single class in one school, which may affect the generalizability of the findings. The duration of implementation was relatively short, spanning only a few instructional sessions. As such, long-term retention and transfer of representational skills were not assessed. The study also relied on researcher-developed instruments, which, although validated, may have subjective limitations. Furthermore, technological limitations prevented the integration of multimedia components into the teaching materials. The effectiveness of the materials across different topics within mathematics was not examined. Future studies should include broader samples and diverse contexts to confirm the robustness of the findings.

Suggestions

Future research should expand the implementation of the developed materials across different schools and regions to test their scalability and generalizability. Researchers are encouraged to incorporate digital technologies into contextual learning materials to enhance interactivity and engagement. It would be beneficial to explore the long-term impact of contextual materials on students' problem-solving and reasoning abilities. Additional focus should also be given to teacher training to maximize the effective delivery of such materials. Comparative studies using different instructional design models could provide further insights into optimal strategies for instructional

development. Finally, integrating multimodal assessments may offer richer insights into students' representational competencies across diverse learning styles.

CONCLUSION

This study concludes that the development of contextual mathematics teaching materials based on the scientific approach, structured through the ADDIE model, is a viable and effective strategy to enhance junior high school students' mathematical representation skills. The materials demonstrated strong content and media validity, as reflected in expert evaluations, indicating that they meet professional standards for instructional use. Furthermore, feedback from teachers and students confirmed the materials' practicality, showing that they are user-friendly, contextually relevant, and capable of promoting active learning in mathematics classrooms.

The implementation of the materials resulted in a significant improvement in students' ability to represent mathematical ideas through verbal, symbolic, and visual means, as evidenced by the moderate-to-high gain score. This suggests that the combination of contextual content and scientific learning stages—observing, questioning, experimenting, reasoning, and communicating—can facilitate deeper conceptual understanding and engagement. The structured application of the ADDIE model ensured that each development phase was systematically addressed, contributing to the instructional coherence and learning impact of the final product.

Importantly, this research fills a gap in the instructional design literature by demonstrating that the ADDIE model can be effectively applied to mathematics education at the secondary level, where such applications remain limited. The integration of contextual real-life scenarios and scientific pedagogical principles also supports national curriculum goals and promotes 21st-century learning competencies. Therefore, the findings of this study provide both theoretical and practical contributions, recommending the broader adoption of similar instructional products in diverse educational settings. Future research may build upon this model to further improve instructional innovation, enhance digital integration, and expand impact across various learning domains.

AUTHOR CONTRIBUTION STATEMENT

Abdullah Jamaludin is the sole author of this study and was responsible for the entire research process. He conceptualized the study design, conducted the needs analysis, and formulated the research objectives. He developed the contextual teaching materials, coordinated the validation process with subject-matter and media experts, and facilitated the implementation of the materials in the classroom. The author also collected and analyzed both quantitative and qualitative data, interpreted the findings, and wrote all sections of the manuscript, including the introduction, methodology, results, and discussion. He revised the manuscript based on critical reflection and ensured the final draft adhered to the academic standards required for international publication. The author confirms that this work is original, has not been published elsewhere, and has been approved in its final form.

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