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Development of a Geoboard Assisted Supplementary Learning Book on Triangles and Quadrilaterals to Enhance Students' Mathematical Understanding Ability

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ABSTRACT

This study aimed to develop a geoboard-assisted supplementary book on triangles and quadrilaterals that is valid, practical, and effective in improving junior high school students' mathematical understanding ability. The study employed a Research and Development (R&D) method using the ADDIE model, which consists of five stages: Analyze, Design, Development, Implementation, and Evaluation. The participants were 16 seventh-grade students from one Islamic junior high school (MTs) in East Lombok Regency. Data were collected through expert validation sheets, student response questionnaires, and mathematical understanding tests. The results indicated that the developed supplementary book met the criteria of being highly valid, with a validation score of 82.64% from material experts and 95.00% from media experts. The practicality test obtained an average percentage score of 85.25%, categorized as highly practical, indicating that the book was easy to use, attractive, and capable of encouraging students' active engagement during the learning process. Furthermore, the effectiveness test using the One Sample t-test revealed that the average student learning outcome score was 87.69, which exceeded the school's Minimum Mastery Criterion (MMC) of 70, with a significance value of 0.000 < 0.05. These findings demonstrate that the geoboard-assisted supplementary book is valid, practical, and effective for use in mathematics learning. The use of the geoboard helps students understand geometric concepts more concretely and visually through exploratory learning activities, thereby supporting the improvement of students' mathematical understanding ability. Therefore, the developed supplementary book is feasible to be used as an alternative learning resource in junior high school mathematics instruction.

Keywords: Supplementary Book; Geoboard; Triangles; Quadrilaterals; Mathematical Understanding.

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1. INTRODUCTION

Along with the rapid advancement of science and technology, mathematics has become one of the essential subjects in developing students' logical, critical, systematic, and analytical thinking skills. One of the fundamental competencies that students must possess in mathematics learning is mathematical understanding ability. This ability is not merely related to memorizing formulas, but also encompasses the ability to comprehend concepts, establish relationships among concepts, and apply mathematical concepts in various problem-solving situations Putra et al. (2018). Mathematical understanding serves as an important foundation for developing higher-order thinking skills and supports students' success in solving contextual problems as well as problems

in other disciplines. Majid (2024) explained that mathematical understanding ability contributes to students' capacity to comprehend, interpret, and appropriately apply mathematical concepts in everyday life.

However, the importance of mathematical understanding ability is not yet aligned with the empirical conditions found in the field. Numerous studies have indicated that Indonesian students' mathematical understanding ability remains relatively low across various educational levels. Badraeni et al. (2020) found that students experienced difficulties in understanding the meaning of problems, translating problems into mathematical symbols, and connecting relevant mathematical concepts. Research conducted by Septiani & Aini (2023) also revealed that most students still tend to memorize formulas without understanding the underlying concepts. Furthermore, Nasika et al. (2022) reported that students frequently made errors in applying mathematical concepts because they did not fully understand the fundamental operational principles.

Similar problems were identified based on preliminary observations conducted by the researcher at one Islamic junior high school (MTs) in East Lombok Regency. The observations revealed that students' mathematical understanding ability regarding triangles and quadrilaterals was still relatively low. Most students experienced difficulties in distinguishing the characteristics of plane figures, identifying relationships among geometric elements, and correctly applying formulas for area and perimeter in contextual problem-solving situations. In addition, the learning process remained predominantly teacher centered and focused heavily on formula memorization, resulting in limited opportunities for students to gain concrete and meaningful learning experiences.

The low level of students' mathematical understanding ability is presumed to be influenced by the limitations of teaching materials and learning media that facilitate students' active involvement in constructing mathematical concepts. Setyadi & Saefudin (2019) stated that students' low mathematical understanding was caused by teaching materials that had not effectively encouraged exploratory activities and direct student engagement in the learning process. In addition, Putri & Zulkardi (2020) explained that procedural-oriented mathematics instruction tends to encourage students to memorize formulas without understanding the meaning of the concepts being studied. Research conducted by Nurhasanah et al. (2021) further demonstrated that the limited use of concrete learning media caused students to experience difficulties in visualizing abstract geometric concepts. These conditions indicate the necessity of developing learning tools that not only present theoretical material but also provide visual, manipulative, and contextual learning experiences that enable students to actively construct their own understanding.

One alternative that can be used to support mathematics learning is the use of a geoboard. A geoboard is a mathematics learning medium in the form of a pegboard used together with rubber bands to create various geometric shapes, such as triangles and quadrilaterals. This medium enables students to visualize geometric concepts concretely through manipulative and exploratory activities Moyer (2001). The use of geoboards in mathematics learning can help students understand the relationships among sides, angles, area, and perimeter of plane figures more meaningfully because students are directly involved in the process of constructing geometric forms. Research conducted by Utami &Wutsqa (2017) showed that the use of geoboards improved junior high school students' understanding of geometric concepts through exploratory activities. Similar findings were reported by Sari et al. (2022), who stated that geoboard media assisted students in visualizing plane geometry concepts and increased students' learning activities during the instructional process. Furthermore, research conducted by Hidayat & Widodo (2021) revealed that the use of manipulative media such as geoboards enhanced student engagement and helped reduce misconceptions in geometry learning.

In addition to the use of learning media, the availability of supplementary books also plays an important role in supporting the learning process. Supplementary books are additional teaching materials designed to complement the main textbook by providing more contextual, interactive, and systematic learning activities (Kusna, A. 2019). The use of supplementary teaching materials

is considered capable of helping students learn independently and strengthening their understanding of concepts learned in the classroom. Research by Prastowo (2018) explained that systematically developed teaching materials could enhance students' engagement in mathematics learning. Furthermore, research conducted by Lestari et al. (2021) demonstrated that activity-based supplementary books improved students' problem-solving abilities and conceptual understanding compared to the use of conventional textbooks. Nevertheless, most supplementary books currently used in schools still focus primarily on routine exercises and have not been integrated with manipulative media that support concrete exploration of mathematical concepts. In fact, the integration of supplementary books with manipulative learning media can create more active, exploratory, and meaningful learning experiences for students.

Based on the literature review, numerous studies have investigated the use of geoboards in mathematics learning. Several studies have shown that geoboards are effective in improving geometric visualization skills, understanding of plane geometry concepts, and student engagement in mathematics learning Utami & Wutsqa (2017); Hidayat & Widodo (2021); Sari et al. (2022). Other studies also indicated that geoboard media could help students understand the concepts of area and perimeter through direct manipulative activities Rahmawati et al. (2020). On the other hand, research on the development of mathematics teaching materials has also been widely conducted in various forms, such as modules, student worksheets (LKPD), and contextual or problem-based supplementary books aimed at improving students' mathematical abilities Prastowo (2018); Lestari et al. (2021); Setyadi & Saefudin (2019). However, most previous studies have focused either on the separate use of geoboards without integration into supplementary teaching materials or solely on the development of teaching materials without involving concrete manipulative media in the learning process. Moreover, previous research has primarily emphasized improving learning outcomes and student activities, while studies specifically developing a geoboard-assisted supplementary learning book on triangles and quadrilaterals to enhance students' mathematical understanding ability remain very limited. Therefore, the novelty of this study lies in the development of a supplementary learning book integrated with exploratory activities assisted by geoboards, enabling students to construct their understanding of triangles and quadrilaterals visually, concretely, and meaningfully.

Therefore, this study aims to develop a geoboard-assisted supplementary learning book on triangles and quadrilaterals that is valid, practical, and effective in enhancing students' mathematical understanding ability. The research questions addressed in this study are as follows: (1) how valid is the developed geoboard-assisted supplementary learning book on triangles and quadrilaterals, (2) how practical is the use of the supplementary learning book in the learning process, and (3) how effective is the geoboard-assisted supplementary learning book in improving students' mathematical understanding ability?.

2. METHODS

This study employed the Research and Development (R&D) method, which aimed to produce a learning product in the form of a geoboard-assisted supplementary learning book on triangles and quadrilaterals, as well as to examine the validity, practicality, and effectiveness of the developed product. According to Mesra (2023), research and development is a research method used to produce a particular product while simultaneously testing its feasibility and effectiveness in the learning process. The product developed in this study was a supplementary mathematics learning book on triangles and quadrilaterals for seventh-grade students of Islamic junior high school (MTs), integrated with the use of geoboard media.

The development model employed in this study was the ADDIE model (Analyze, Design, Development, Implementation, and Evaluation). The ADDIE model was selected because it provides systematic development procedures and is considered suitable for the development of mathematics learning materials. The stages of the development process conducted in this study are presented in Figure 1 below.

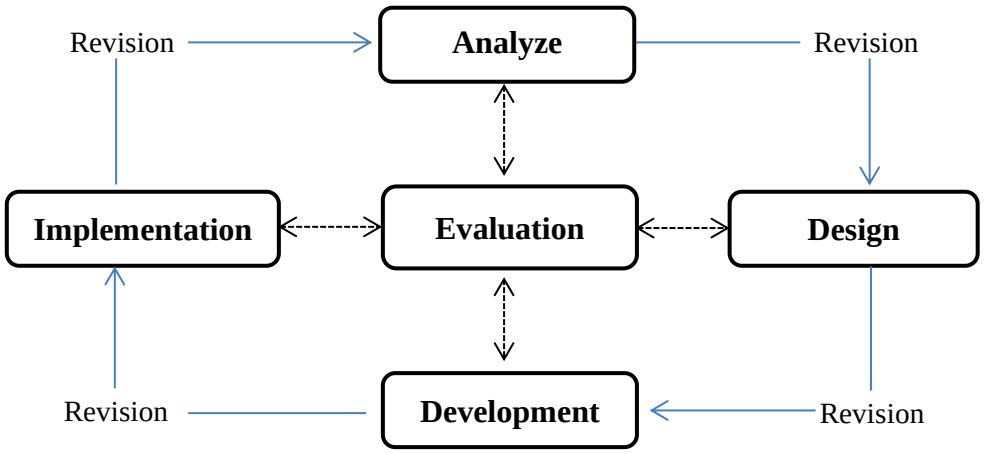

Figure 1. ADDIE Model Framework Mesra (2023)

The development model employed in this study was the ADDIE model, which consists of five stages: Analyze, Design, Development, Implementation, and Evaluation. In the Analyze stage, the researcher conducted a needs analysis, curriculum analysis, and identification of problems in mathematics learning related to students' mathematical understanding ability. The Design stage involved designing the structure, content, and activities of the geoboard-assisted supplementary learning book. Subsequently, the Development stage was carried out by developing the product and conducting validation by material experts and media experts. In the Implementation stage, the product was tested on students to determine its practicality and effectiveness. Finally, the Evaluation stage was conducted through product revision and refinement based on the results of validation and field testing.

The subjects of this study were 16 seventh-grade students at one Islamic junior high school (MTs) in East Lombok Regency. The research instruments used in this study consisted of the following:

a. Interview Guidelines

The interview guidelines were used during the needs analysis stage to obtain information from mathematics teachers regarding learning conditions, students' difficulties, the use of teaching materials, and the need for learning media on the topics of triangles and quadrilaterals.

b. Validation Sheets

The validation sheets were used to assess the feasibility of the supplementary learning book and the research instruments. The validation process was conducted by material experts, media experts, and mathematics education practitioners by evaluating aspects of content, presentation, language, visual appearance, and the appropriateness of geoboard integration.

c. Teacher and Student Response Questionnaires

The questionnaires were used to determine the level of practicality and users' responses toward the geoboard-assisted supplementary learning book. The aspects measured included ease of use, attractiveness of the design, usefulness of the content, and students' engagement during the learning process.

d. Mathematical Understanding Ability Test

The test was used to measure students' mathematical understanding ability after using the geoboard-assisted supplementary learning book. The indicators of mathematical understanding ability assessed in this study included the ability to understand concepts, classify objects based on particular properties, select and apply appropriate solution procedures, and apply mathematical concepts in solving contextual problems.

Data analysis was conducted to determine the validity, practicality, and effectiveness of the geoboard-assisted supplementary learning book on triangles and quadrilaterals. The data

were obtained from expert validation sheets, student response questionnaires, and mathematical understanding ability tests. Validity analysis was conducted by calculating the percentage scores from the evaluations provided by material experts and media experts, which were then interpreted based on the product feasibility criteria (Table 1). The supplementary learning book was considered feasible if it achieved at least the "valid" category. Practicality analysis was obtained from student response questionnaires using a four-point Likert scale. The data were analyzed using practicality percentage scores and interpreted according to the product practicality criteria (Table 2). The supplementary learning book was considered practical if it achieved at least the "practical" category.

Table 1. Validity Criteria of the Supplementary Learning Book

Score (%)	Criteria	Description
81–100	Very Valid	Suitable for use without revision
61–80	Valid	Suitable for use with minor revisions
41–60	Less Valid	Not suitable for use because major revisions are required
0–40	Invalid	Not permitted for use

Source: Adapted from Ernawati & Sukadiono (2017)

Table 2. Practicality Criteria of the Supplementary Learning Book

Score (%)	Criteria	Description
81–100	Very Practical	Can be used without revision
61–80	Practical	Can be used with revisions
41–60	Less Practical	Not recommended for use
0–40	Impractical	Cannot be used

Source: Adapted from Novitasari et al. (2024)

The effectiveness analysis was conducted using a one-shot case study design through the administration of a posttest after the implementation of the geoboard-assisted supplementary learning book. The data were analyzed descriptively by calculating the mean score, highest score, lowest score, and standard deviation. Furthermore, a normality test was conducted using the Shapiro–Wilk test, followed by hypothesis testing using a One-Sample t-test assisted by SPSS version 25, by comparing the students' mean learning outcomes with the minimum mastery criterion (KKM) score of 70. The product was considered effective if the significance value was less than 0.05.

3. RESULT AND DISCUSSION

This study aimed to develop a geoboard-assisted supplementary learning book on triangles and quadrilaterals that is valid, practical, and effective in improving students' mathematical understanding ability. The development process was carried out using the ADDIE model, which includes the stages of Analyze, Design, Development, Implementation, and Evaluation. This section presents the results of product development at each ADDIE stage, including the results of the needs analysis, the process of designing and developing the supplementary learning book, the results of expert validation, the practicality and effectiveness testing results, as well as the evaluation and revision of the product based on validators' suggestions and field trial findings. In addition, the findings of this study are compared with previous studies to strengthen the evidence regarding the use of geoboard-assisted supplementary learning books in mathematics learning.

a. Analyze Stage

The analysis stage was conducted to identify learning needs, students' characteristics, the condition of the teaching materials used, and the problems encountered in mathematics learning, particularly on the topics of triangles and quadrilaterals. The analysis was carried out through classroom observations, interviews with mathematics teachers, and a review of the learning tools used at school.

The interview results indicated that the mathematics learning process was still dominated by lecture methods and routine exercises, causing students to be relatively passive during classroom activities. The teacher explained that most students experienced difficulties in understanding the basic concepts of plane geometry, particularly in distinguishing the characteristics of triangles and quadrilaterals, determining relationships among geometric elements, and understanding the concepts of area and perimeter conceptually. Students generally memorized formulas without understanding their origins or meanings. This condition caused students to experience difficulties when faced with contextual problems or problems requiring the application of concepts in different situations.

Furthermore, classroom observations revealed that the use of concrete learning media in mathematics instruction was still very limited. Geometry learning was predominantly conducted through abstract explanations on the board without involving manipulative activities that would allow students to construct concepts independently. These findings are consistent with the study conducted by Setyadi and Saefudin (2019), which stated that students' low mathematical understanding was influenced by learning processes that did not involve exploratory activities and the use of concrete media. Nurhasanah et al. (2021) also explained that students' difficulties in understanding geometric concepts were caused by limitations in visualizing abstract mathematical objects.

Based on the results of the needs analysis, the researcher developed a supplementary learning book integrated with the use of geoboards as manipulative media. The use of geoboards was selected because they can help students visualize geometric shapes concretely through exploratory activities using pegboards and rubber bands. Thus, the learning process was expected to shift from formula memorization toward the active construction of concepts by students. These findings support the study conducted by Moyer (2001), which stated that manipulative media can help students understand geometric concepts more meaningfully through direct experience.

b. Design Stage

The design stage was carried out based on the results of the previously conducted needs analysis. At this stage, the researcher designed the structure and content of the geoboard-assisted supplementary learning book on triangles and quadrilaterals according to the characteristics of seventh-grade MTs students. The supplementary learning book was designed by integrating exploratory activities, geometric visualization, contextual exercises, and learning reflections to support the improvement of students' mathematical understanding ability.

The structure of the book consisted of an introduction, core materials, geoboard-assisted exploratory activities, practice exercises, evaluations, and learning reflections. The introductory section contained instructions for using the book, learning outcomes, learning objectives, and an introduction to the use of geoboards. In the main section, the materials were presented gradually, beginning with the introduction of triangle and quadrilateral concepts through contextual objects closely related to students' daily lives. Students were then guided to explore geometric shapes using geoboards so that the concepts of sides, angles, perimeter, and area could be discovered independently.

The learning activities were designed based on exploratory and constructivist approaches. Students were not directly provided with formulas; instead, they were guided to construct concepts through activities such as observing, forming shapes on the geoboard, comparing shapes, calculating area units, and discussing their findings. This approach aimed to provide students with more meaningful learning experiences and prevent them from focusing solely on mechanical procedures. This finding is in line with the study conducted by Utami & Wutsqa (2017), which stated that the use of geoboards in geometry learning could improve students' exploratory activities and conceptual understanding.

In addition to the content aspect, the visual design of the book also became an important consideration in product development. The book was designed using combinations of colors, illustrations, activity icons, and an attractive layout to increase students' learning motivation. An engaging visual presentation is important in supporting students' involvement during the learning process Prastowo (2018).

c. Development Stage

At the development stage, the initial design of the supplementary learning book was transformed into a tangible product (prototype). The book was developed using Canva by considering aspects of readability, visual appearance, material suitability, and the integration of geoboard-assisted activities. The final product consisted of three main sections, namely the introductory section, the core section, and the evaluation section, as shown in Figure 2.

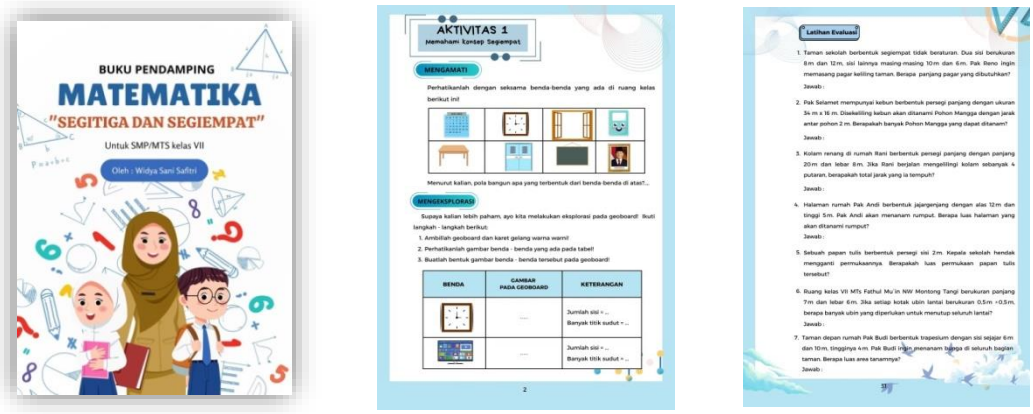

Figure 2. Sections of the Supplementary Learning Book

The introductory section consists of the book cover, book identity, instructions for use, learning outcomes, and learning objectives. The core section contains materials on triangles and quadrilaterals integrated with exploratory activities using geoboards. In this section, students are guided to construct plane figures directly using rubber bands on the pegboard and subsequently observe the characteristics of the resulting shapes. Furthermore, the evaluation section contains contextual problems designed to measure students' mathematical understanding ability.

The developed product was subsequently validated by three validators consisting of a material expert, a media expert, and a mathematics education practitioner. The material expert validation covered aspects of content suitability, conceptual accuracy, language use, and

material presentation. The results of the material expert validation obtained a validity percentage of 82.64%, which was categorized as "very valid." The validator stated that the materials presented were aligned with the learning outcomes and were capable of supporting students' conceptual understanding gradually. Nevertheless, the validator provided several suggestions, such as simplifying several instructional sentences and adding more contextual examples to the topic of plane figure area.

Meanwhile, the media expert validation obtained a validity percentage of 95.00%, which was also categorized as "very valid." The assessed aspects included visual appearance, readability, layout, color usage, and the integration of geoboard activities within the book. The validator suggested improvements regarding font size consistency and the addition of more detailed instructions for using the geoboard to help students follow the learning activities more easily.

The validation results indicated that the developed supplementary learning book had fulfilled both content and media feasibility aspects and was therefore suitable for use in mathematics learning. These findings are consistent with the study conducted by Lestari et al. (2021), which stated that systematically and interactively designed teaching materials can improve the quality of mathematics learning. Furthermore, the use of manipulative media such as geoboards has been proven effective in helping students understand geometric concepts concretely and visually Rahmawati et al. (2020).

d. Implementation Stage

The implementation stage was conducted through product trials to determine the practicality and effectiveness of the geoboard-assisted supplementary learning book. The trials were carried out in two stages, namely a small-group trial and a large-group trial.

The small-group trial involved four seventh-grade students and aimed to evaluate the readability, ease of use, and initial student responses toward the developed supplementary learning book. The results of the questionnaire analysis showed an average percentage score of 86.75%, which was categorized as "very practical." The students stated that the book was easy to use, visually attractive, and that the geoboard activities helped them understand plane geometry concepts more clearly.

Subsequently, the large-group trial was conducted with 16 seventh-grade students. The results of the student response questionnaire analysis obtained a percentage score of 85.25%, which was also categorized as "very practical." These findings indicate that the supplementary learning book could be effectively implemented in mathematics learning and received positive responses from students. During the learning process, students appeared more actively engaged in discussions, experimented with constructing shapes using geoboards, and participated in concept exploration activities. These activities demonstrate that the integration of the supplementary learning book and geoboards was able to create a more interactive and meaningful learning environment. These findings support the study conducted by Hidayat & Widodo (2021), which stated that the use of manipulative media can enhance students' engagement in geometry learning.

The effectiveness of the supplementary learning book was tested using a pre-experimental one-shot case study design. After students participated in learning activities using the geoboard-assisted supplementary learning book, they were administered a mathematical understanding ability test. Before conducting the hypothesis test, a normality test was first performed using the Shapiro–Wilk test. The test results showed a significance value of 0.126 (> 0.05), indicating that the data were normally distributed.

Furthermore, a One-Sample t-test was conducted using SPSS version 25 by comparing the students' mean learning outcomes with the school's minimum mastery criterion (KKM) score of 70. The test results showed a significance value of 0.000 (< 0.05) with a mean posttest score of 87.69. These findings indicate that the average mathematical understanding ability of students after using the geoboard-assisted supplementary learning book was significantly higher than the school's predetermined KKM score.

The improvement in students' mathematical understanding ability is presumed to have occurred because students gained more concrete learning experiences through manipulative activities using geoboards. Students not only received information passively but were also directly involved in constructing concepts through exploration and group discussions. These findings are consistent with the studies conducted by Moyer (2001) and Utami & Wutsqa (2017), which stated that the use of manipulative media in geometry learning can improve students' conceptual understanding and mathematical visualization abilities.

e. Evaluation Stage

The evaluation stage was conducted continuously based on the results of expert validation and product trials. The purpose of the evaluation was to refine the geoboard-assisted supplementary learning book on triangles and quadrilaterals so that it would better suit students' needs and the learning process. Product revisions were carried out based on suggestions from material experts, media experts, and students' responses during the trial implementation. The revisions made are presented in Table 3 below.

Table 3. Results of Product Evaluation and Revision

No.	Validators'/Trial Feedback	Revision Actions
1	The language used in several activity instructions was still too lengthy and difficult for students to understand	Simplified the instructional sentences to make them more communicative and appropriate for seventh-grade students' developmental level
2	Contextual examples in the topic of plane figure area were still limited	Added a greater variety of examples related to students' daily lives
3	Instructions for using the geoboard were not sufficiently detailed	Added step-by-step instructions for using the geoboard accompanied by illustrative images
4	Font sizes in several sections were inconsistent	Adjusted the font sizes and font types to make them more uniform and readable
5	The colors on several pages were too striking	Revised the color combinations to make them more visually comfortable for students
6	The evaluation questions still predominantly emphasized procedural skills	Revised the questions by adding conceptual understanding and contextual problems
7	Some students were still confused when using the geoboard for the first time	Added introductory activities on how to use the geoboard before the main materials

Based on the revision results, the developed supplementary learning book became more systematic, user-friendly, and aligned with students' characteristics. Improvements in the aspects of content, visual appearance, and learning activities also contributed to increasing students' engagement during the learning process. Therefore, the evaluation stage functioned not only as a process of technical product revision but also as an effort to improve the overall quality of learning.

In general, the evaluation process demonstrated that the revisions made were able to improve the quality of the supplementary learning book in terms of content, visual design, and learning implementation. The findings of this study strengthen previous research indicating that the development of teaching materials integrated with manipulative media can improve the quality of mathematics learning and help students understand geometric concepts more concretely and meaningfully Lestari et al. (2021); Rahmawati et al. (2020). Furthermore, the integration of geoboard-assisted exploratory activities into the supplementary learning book constitutes one of the novelties of this study, distinguishing it from previous studies that generally focused only on the separate use of media or teaching materials.

4. CONCLUSION

This study successfully developed a geoboard-assisted supplementary learning book on triangles and quadrilaterals using the ADDIE model (Analyze, Design, Development, Implementation, and Evaluation), which fulfilled the criteria of validity, practicality, and effectiveness. The expert validation results indicated that the supplementary learning book possessed excellent quality in terms of content, presentation, language, and media design, making it suitable for use in mathematics learning. Furthermore, the practicality test results demonstrated that the supplementary learning book was easy to use, visually attractive, and capable of encouraging students' active engagement during the learning process.

The effectiveness test results showed that the use of the geoboard-assisted supplementary learning book was able to improve students' mathematical understanding ability. Exploratory activities using geoboards helped students understand the concepts of triangles and quadrilaterals in a more concrete, visual, and meaningful manner, enabling students not only to memorize formulas but also to understand the underlying concepts. Therefore, the integration of supplementary learning books and manipulative geoboard media can serve as an alternative teaching material that supports more active, contextual, and concept-oriented mathematics learning.

Nevertheless, this study still has several limitations, including the limited number of research participants and the implementation of the product, which was restricted only to the topics of triangles and quadrilaterals. In addition, the research design employed in this study did not involve a comparison class; therefore, the effectiveness of the product has not been directly compared with other learning models or teaching materials. Accordingly, future studies are expected to involve a larger number of participants, employ more rigorous experimental designs, and develop geoboard-assisted supplementary learning books for other mathematics topics in order to obtain more comprehensive findings.

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