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Development of Mathigon Polypad Media to Support Conceptual Understanding of Angles in a Circle for Grade VIII

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Abstract. *Students' lack of understanding of mathematical concepts related to angles in a circle indicates the need for learning media that can visualize concepts dynamically. This research developed Mathigon Polypad media to support grade VIII students' conceptual understanding of angles in a circle, using a Research and Development (R&D) method with the ADDIE development model. The research subjects involved 30 eighth-grade students at a public junior high school in Malang. Validation results showed that the learning media was valid, with an assessment percentage of 93.75% from media experts and 97.73% from material experts. In addition, student and teacher responses indicated that the learning media was practical, with assessment percentages of 87.08% and 90.91%, respectively. Meanwhile, the N-gain score was 0.69, indicating that the learning media met the effectiveness criteria and fell into the medium category. Thus, the Mathigon Polypad learning media developed was proven valid, practical, and effective in supporting eighth-grade junior high school students' conceptual understanding of angles in a circle.*

Keywords: *Mathigon Polypad, conceptual understanding, angles in a circle*

INTRODUCTION

Mathematics learning is an active interaction among teachers, students, and learning resources, which are the main components for achieving learning objectives (Darmawan et al., 2023). Students can develop critical, logical, systematic, and analytical thinking skills through mathematics learning. According to Nalman et al. (2023) and Suendarti and Liberna (2021), conceptual understanding is students' ability to understand mathematical ideas, re-express them in their own words, and apply them in various contexts, which is an important competency that needs to be achieved in learning. Utami et al. (2023) added that when learning mathematics, students must understand mathematical concepts. Regulation of the Director General of Elementary and Secondary Education No.

506/C/PP/2004 states that indicators of conceptual understanding include students' ability to re-explain a concept, classify objects according to their properties, determine examples and non-examples, present concepts through various mathematical representations, compile necessary and sufficient conditions, use certain procedures or operations, and apply concepts to solve problems (Towe & Nama, 2024).

Understanding enables students to connect concepts, grasp the meaning behind each applied procedure, and solve a wider range of mathematical problems with greater variety and creativity (Trihandayani et al., 2025). However, students in Indonesia still have a relatively low level of mathematical conceptual understanding. Based on TIMSS data, Indonesian students' mathematics achievement in 2011 ranked 38th out of 45 countries, while in 2015 it dropped to 45th out of 50 countries (Wibawa et al., 2023). Furthermore, the 2024 OECD report showed that Indonesia's PISA mathematics score still did not reach the international average (Rahayu et al., 2025). These data collectively suggest that Indonesian students' mathematical understanding continues to face significant challenges.

Geometry is a branch of mathematics that emphasizes conceptual understanding because it involves visualizing, reasoning, and representing mathematical objects. However, Riera (2022) stated that geometry is considered a relatively easy branch of mathematics to understand compared to other branches because, at previous levels, students are already familiar with basic geometry concepts such as lines, sectors, and space. One geometry topic eighth-grade junior high school students study is the circle (Indriyani et al., 2023). This material is abstract and requires high visualization skills (Handika et al., 2025). These characteristics often make learning difficult, especially when instruction focuses only on formulas and example problems without building a deep understanding of the concepts (Shallahudin, 2022; Towe & Nama, 2024). As a result, students master problem-solving procedures through memorization rather than understanding the basic concepts, which confuses them when solving problems in different forms. Laili et al. (2021) reinforce this, noting that some students focus more on

memorizing material for exams than on building conceptual understanding, so errors often stem from conceptual misunderstandings.

A frequently challenging topic on circles is the relationship between the central and inscribed angles. This topic requires dynamic visualization skills to help students understand the relationship between angles subtending the same arc. An interview with an eighth-grade mathematics teacher corroborated this, noting that students' daily test performance on circles was suboptimal because it did not meet the minimum completion score of 75. Observations also showed that learning still relied heavily on providing formulas and examples on the board, leaving students with limited opportunities to explore concepts visually and independently. This aligns with Jehadus's (2018, cited in Siregar, 2021) view that developing students' conceptual understanding does not produce optimal results because the learning media used are generally static images. Therefore, media that can dynamically visualize concepts is needed to help students gain a more complete and meaningful conceptual understanding.

Advances in digital technology offer opportunities to develop more innovative mathematics learning and encourage active student engagement. In mathematics learning, technology helps students understand abstract concepts through dynamic representations (Cholily et al., 2025). However, learning about angles in a circle has largely relied on static images in textbooks and on whiteboards. As a result, understanding often relies on memorizing formulas rather than truly understanding the concepts. One platform that can address these limitations is Mathigon Polypad. This platform provides interactive digital manipulatives such as points, lines, geometric shapes, and digital protractors (Sujadi et al., 2025). Through these features, students can explore mathematical concepts directly by moving points and measuring angles using the provided digital protractor, allowing them to discover mathematical relationships through direct exploration rather than simply observing static images.

Several previous studies have demonstrated the positive impact of using Mathigon Polypad in mathematics learning. Putra et al. (2025) stated that discovery learning-based Polypad can increase student engagement in geometry. Naufal and

Kowiyah (2025) showed that Polypad-assisted e-modules effectively help students understand fraction concepts concretely. Mulyaningsih et al. (2025) also showed that using Polypad in STEM-based learning strengthens students' understanding of geometric nets. In addition, Ridwan et al. (2026) found that Mathigon Polypad can support understanding of mathematical concepts in quadrilateral material.

The novelty of this research lies in the development of Mathigon Polypad media specifically designed for the topic of angles in a circle. The media utilizes point manipulation and the Protractor Tool as the core of structured exploration activities to support students in independently constructing conceptual understanding. The research aims to develop valid, practical, and effective Mathigon Polypad learning media to support understanding of the relationship between central and inscribed angles of a circle in grade VIII. The product is designed as a concept-discovery tool that encourages students to interact directly with mathematical objects in a dynamic way.

RESEARCH METHOD

The research used the Research and Development method with the ADDIE development model. According to Hilmiyati et al. (2024), this method aims to develop learning tools while testing their effectiveness to ensure a high-quality product (Hilmiyati et al., 2024). Meanwhile, the ADDIE model was chosen as the development approach because it provides sequential, adaptive stages for producing learning products (Rosmiati & Siregar, 2021). The ADDIE model includes five stages: Analysis, Design, Development, Implementation, and Evaluation (Sugiyono, 2016, cited in Kartina et al., 2023). The following is a description of each stage.

1. In the analysis stage, the analysis process includes needs analysis, curriculum analysis, and student characteristics. The researcher identified development needs through observations of teaching and learning activities and interviews with mathematics teachers. The curriculum analysis also considers learning outcomes and objectives to ensure media development aligns with students' required skills. The student characteristics analysis provides an overview of

students' initial abilities and learning styles. This analysis helps ensure the product fits students' conditions and needs.

2. In the design stage, the Mathigon Polypad learning media was systematically designed by constructing a prototype with a concept-discovery flow for students. Furthermore, the research instruments included validation sheets, response questionnaires, and evaluation tests tailored to indicators of mathematical concept understanding.
3. In the development stage, the learning media were developed based on the previous stage's design and submitted to media and materials experts to ensure suitability. The validity testing stage also included assessing the research instruments to ensure they were suitable for use.
4. In the implementation stage, the media that passed the validation process were used with eighth-grade students. The implementation activity began by measuring students' initial abilities through a pretest, followed by media use, and then a posttest to evaluate students' mastery of concepts. Additionally, the researchers gave a response questionnaire to the observing teacher and students to assess the practicality of using the media during teaching and learning activities.
5. In the evaluation stage, the researchers thoroughly reviewed the results. The results included an assessment of the media's validity, practicality, and effectiveness, which served as the basis for concluding the feasibility of the Mathigon Polypad media in supporting eighth-grade students' understanding of angles in circles.

The research data were obtained through assessments by two validators, distribution of response questionnaires, and the implementation of pretests and posttests. The validation instrument used a 1–4 Likert scale, as shown in Table 1.

Table 1. Likert Scale

Score	Criteria
4	Strongly Agree
3	Agree
2	Disagree
1	Strongly Disagree

Source: Adapted from Pradana & Marwadi, 2021

The validation results and questionnaire responses were analyzed using a percentage formula. The percentage was calculated by comparing the obtained score with the maximum achievable score, as shown in the following formula.

$$Percentage = \frac{Total\ Score\ Obtained}{Maximum\ score} \times 100\%$$

Source: Kustantina et al., 2022

After obtaining the validation percentage results, the researcher adjusted them to the media validity criteria in Table 2. The media and instruments were declared valid for application if the percentage score obtained exceeded 60% or was categorized as valid or very valid.

Table 2. Criteria for assessing media validity

Interval	Category
81% - 100%	Very Valid
61% - 80%	Valid
41% - 60%	Fairly Valid
21% - 40%	Less Valid
< 20%	Invalid

Source: Jazuli et al., 2023

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Meanwhile, the questionnaire response percentages are adjusted to the media practical criteria in Table 3. If the percentage score is above 60% (practical or very practical), the media is declared practical.

Table 3. Criteria for assessing media practicality

Interval	Category
81% - 100%	Very Practical
61% - 80%	Practical
41% - 60%	Fairly Practical
21% - 40%	Less practical
< 20%	Impractical

Source: Jazuli et al., 2023

An overview of the level of mastery of the material before and after implementing learning media was obtained by calculating the mean scores of all students' pretests and posttests. This calculation uses the following equation.

$$\bar{X} = \frac{\sum x}{n}$$

Explanation:

$\bar{X}$ = the mean student score

$\sum x$ = the sum of all student scores

n = the total number of students

Material mastery is calculated using the N-Gain value based on the pretests and posttests obtained. The equation for calculating the N-Gain value is presented below.

$$N - Gain = \frac{Postest\ Score - \ Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

Source: Kumalasari et al., 2023

The average N-gain result for all students is categorized according to the criteria in Table 4. The media is considered effective if it achieves an N-gain value of ≥ 0.3, placing it in either the medium or high category.

Table 4. N-Gain assessment criteria

Interval	Category
$\mathrm{N-Gain} \geq 0{,}7$	High
$0{,}3 \leq \mathrm{N-Gain} \leq 0{,}7$	Medium
$\mathrm{N-Gain} \leq 0{,}3$	Low

Source: Harianja et al., 2024

RESULTS AND DISCUSSION

The research resulted in the development of Mathigon Polypad learning media on the relationship between central and inscribed angles in a circle, using the ADDIE model. The media was designed to facilitate concept discovery by allowing students to directly manipulate mathematical objects, thereby supporting their understanding of mathematical concepts. The following sections present the results and discussion of each stage of the development process.

Analysis Stage

This stage involves analyzing learning needs, the curriculum, and student characteristics (Saullila et al., 2023). Based on observations during learning activities and interviews with eighth-grade mathematics teachers, students still struggle to understand abstract concepts, including circles. Daily assessment results reinforce this, showing that student achievement has not yet reached the Minimum Mastery Criterion (KKM) of 75. So far, many learning activities still rely on lecture methods and conventional media learning. As a result, students do not understand concepts well and only memorize formulas. This is supported by Shallahudin (2022), who found that learning that presents only formulas and example problems causes students to lack a deep understanding of concepts.

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Curriculum analysis was conducted to ensure the learning media aligned with the learning outcomes so the intended core and basic competencies could be achieved optimally (Iskandar et al., 2023). The curriculum analysis showed that the relationship between central and inscribed angles in a circle is included in the Grade VIII mathematics curriculum and is a topic students are expected to master. Therefore, developing learning media for this topic is highly relevant and necessary. An analysis of student characteristics revealed that grade VIII students are generally 13–14 years old and are accustomed to using digital devices in their daily activities. This familiarity with digital technology provides a strong basis for considering Mathigon Polypad digital learning media as well-suited to students' needs and contemporary learning preferences.

Design Stage

At this stage, the prototypes and research instruments were designed as the foundation for developing the learning media (Yanti et al., 2023). Figure 1 shows the prototype flow design of the media developed using Mathigon Polypad.

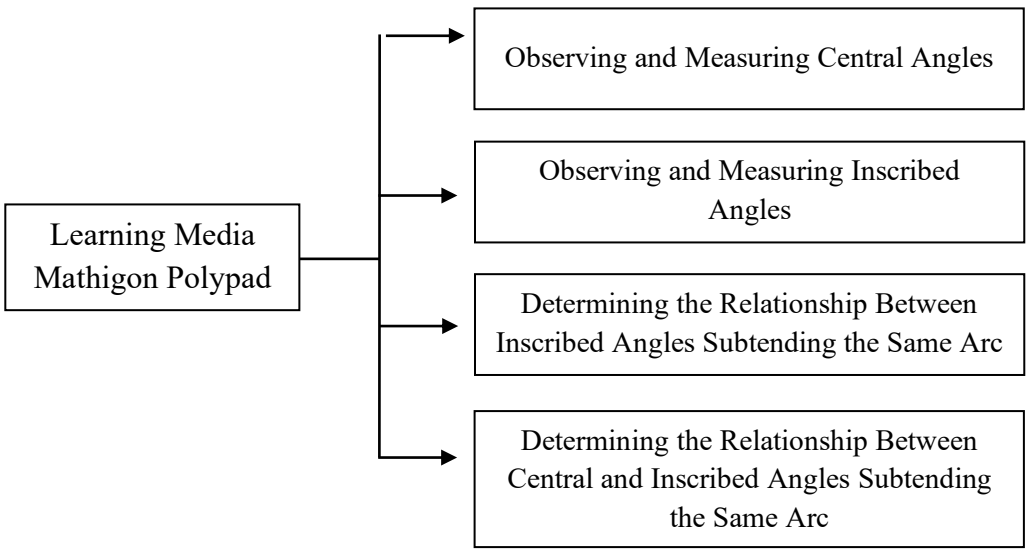

Figure 1. Prototype of the learning media flow

Based on Figure 1, the prototype shows the flow of learning activities designed around the discovery learning approach, guiding students to discover concepts independently through structured exploration. The selection of the

discovery learning model is based on the characteristics of the material on central and inscribed angles, which require dynamic visual exploration so students can understand the relationship between angles in depth, not just memorize it.

Mathigon Polypad was used to design the learning media because it provides interactive geometry features that allow students to directly manipulate mathematical objects, such as points, and use digital protractors to measure angles on the screen. Furthermore, the platform can be accessed directly through a web browser without requiring additional software installation (Imron et al., 2024). These features make Mathigon Polypad practical and effective for supporting digital learning through visual exploration.

Meanwhile, the research instruments were designed to assess three aspects: validity, practicality, and effectiveness of the learning media (Alfarisy et al., 2023). Researchers assessed validity through validation by material and media experts, as well as validation of student and teacher response questionnaires and pretest and posttest questions. Furthermore, practicality was assessed using student and teacher response questionnaires to determine how easily the learning media supported learning activities. Effectiveness was assessed using an evaluation test (pretest and posttest) based on five indicators of mathematical conceptual understanding, as presented in Table 5.

Table 5. Indicators of understanding of mathematical concepts

No.	Indicator
1.	Classifying objects according to the properties of a concept
2.	Restating a concept in one's own words
3.	Presenting concepts in the form of mathematical representations
4.	Using appropriate mathematical procedures
5.	Applying concepts to solve problems

Development Stage

The learning media is arranged to be as ready as possible for use in the learning process. (Fauziyyash et al., 2023). The content follows the discovery

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learning sequence, beginning with exploration of central and inscribed angles in a circle, followed by discovering the relationship between inscribed angles subtending the same arc. In the final stage, students independently conclude the relationship between a central angle and an inscribed angle subtending the same arc. Figure 2 shows the initial display of the learning media.

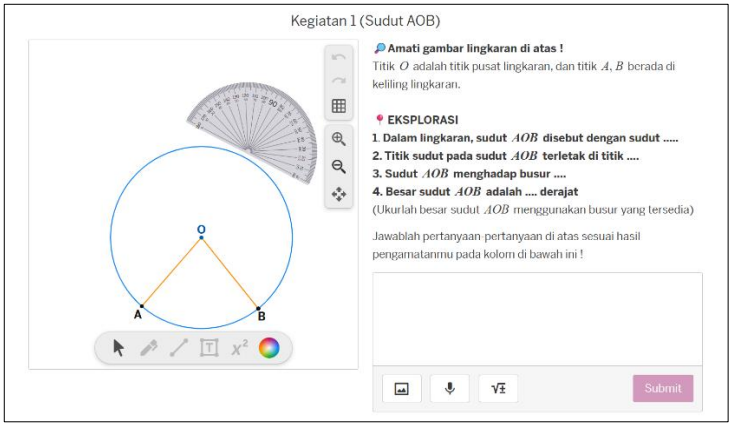

Figure 2. Initial view of learning media

Based on Figure 2, the initial section presents a series of questions that guide students to observe, identify, and measure central angles using the provided digital protractor. Figure 3 shows the final display of the learning media.

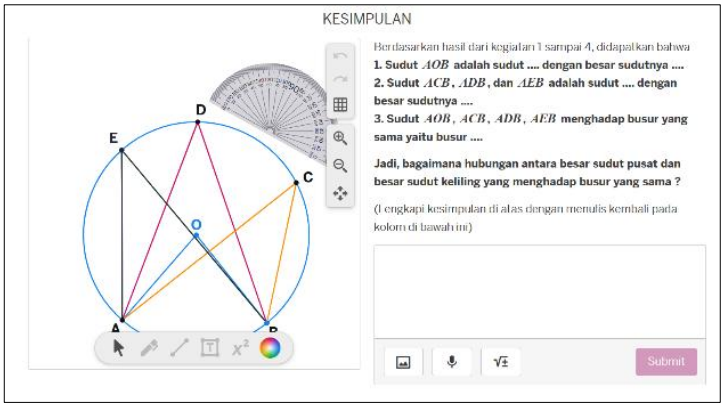

Figure 3. Final view of the learning media

Based on Figure 3, the final section of the activity is designed to allow students to independently draw conclusions based on the findings obtained during the exploration process and previous discoveries. The conclusion section includes a fill-in-the-blank field for students to complete, making the conclusion-drawing process an active part of learning.

The next stage involved validation by two validators: a mathematics education lecturer and a mathematics teacher at the public junior high school where the research was conducted. The validation aimed to ensure that the media met educational standards and were suitable for use (Pawitra & Kusumadewi, 2025; Ediyanto et al., 2024). Based on the validators' feedback, fill-in-the-blank statements about the relationship between inscribed angles subtending the same arc were revised into open-ended questions to encourage concept discovery through exploration. The evaluation questions were also adjusted to align with the indicators of mathematical conceptual understanding. After these revisions, the media was considered ready for implementation (Madar & Lesari, 2022). Table 6 presents the validation results of the learning media and research instruments.

Table 6. Results of learning media validation

No.	Validated Aspects	Percentage (%)	Category
1.	Media Expert Validation	93.75%	Very Valid
2.	Material Expert Validation	97.73%	Very Valid
3.	Student Response Questionnaire	95.83%	Very Valid
4.	Teacher Response Questionnaire	96.59%	Very Valid
5.	Evaluation Questions	97.50%	Very Valid
	Overall Average	96.28%	Very Valid

Based on the validation results, the learning media obtained an average overall score of 96.28%, indicating high validity. Material experts gave the highest percentage (97.73%), indicating that the learning media content was accurate and aligned with learning outcomes and teaching methods. Media experts gave 93.75%, indicating that the media's display and navigation buttons met the standards for good learning media. Other supporting aspects, such as evaluation questions, student response questionnaires, and teacher response questionnaires, each received 97.50%, 95.83%, and 96.59%, respectively, and were categorized as highly valid. The high validation percentage indicates that the Mathigon Polypad media is ready

for implementation in terms of material, display, language, and other supporting instruments.

Implementation Stage

Learning media that met the validation criteria were implemented in classroom learning (Mahuda et al., 2021). The implementation involved 30 Grade VIII students and was observed by two teachers. The activities were conducted over two meetings. The first meeting (2 lesson periods) consisted of a pretest to measure students' initial abilities, followed by a general introduction to the learning material. The second meeting (3 lesson periods) involved students' direct use of the Mathigon Polypad learning media, followed by a posttest to assess their conceptual understanding after using the media and a student response questionnaire. During the learning process, students actively and independently explored geometric objects using the media under the teacher's guidance. The pretest and posttest were conducted using Google Forms, while student response data were collected through a paper questionnaire. Table 7 presents the results of the student response questionnaire.

Table 7. Results of the student response questionnaire

No.	Statements	Average Score	Percentage (%)	Category
1.	This learning media is easy to use and operate on my device.	3.43	85.75%	Very Practical
2.	The sentences used in this learning media are clear and easy to understand.	3.50	87.5%	Very Practical
3.	The steps for discovering concepts in this media are presented gradually, making them easy to follow.	3.43	85.75%	Very Practical
4.	The appearance of this learning media is attractive and visually comfortable.	3.53	88.25%	Very Practical
5.	The text in this learning media is easy to read	3.37	84.25%	Very Practical
6.	The images in this media are clear and help me understand the material.	3.50	87.5%	Very Practical
7.	The activities in this media help me discover the concept related to the relationship between central and inscribed angles more easily.	3.63	90.75%	Very Practical

8.	I am more interested in learning using this media than in conventional learning.	3.43	85.75%	Very Practical
9.	This learning media can be accessed easily anytime and anywhere	3.53	88.25%	Very Practical
	Overall Average	3.48	87.08%	Very Practical

In Table 7, statement 7 received the highest average score (3.63, or 90.75%), indicating that the activities in the learning media helped students discover the relationship between central and inscribed angles more easily. In addition, teachers who served as observers also assessed the media's practicality. Table 8 presents the results of the teacher response questionnaire.

Table 8. Results of the teacher response questionnaire

Respondents	Total Score	Maximum Score	Percentage (%)	Category
Mathematics Teacher 1	42	44	95.45%	Very Practical
Mathematics Teacher 2	38	44	86.36%	Very Practical
Overall Average			90.91%	Very Practical

Based on Tables 7 and 8, the average student response was 87.08%, while the teacher response was 90.91%, both categorized as very practical. The teacher suggested accessing the media on a larger-screen device, such as a laptop or computer, because some students had difficulty operating the digital protractor on a mobile phone's small screen. However, this limitation did not affect the overall practicality assessment. The positive responses from both students and teachers indicate that the Mathigon Polypad media is easy to use, has an attractive appearance, and helps students understand mathematical concepts.

Evaluation Stage

The final stage of ADDIE development involved a comprehensive product feasibility assessment based on the results of each previous stage (Sela et al., 2023).

At this stage, the researcher measures students' conceptual understanding by analyzing pretests and posttests and calculating the N-Gain to determine the media's effectiveness.

Table 9. Students' pretest and posttest results

Information	Pretest	Posttest
Average Score	34.37	81.67
N-Gain	0.69	
Category	Medium	

Referring to Table 9, students' average pretest score was 34.37, with a maximum score of 92 and a minimum score of 0, indicating that students' initial understanding was still relatively low and varied. After learning using Mathigon Polypad media, students' average posttest score increased to 81.67, with a maximum score of 100 and a minimum score of 34. The increase of 47.30 points and an N-Gain score of 0.69, categorized as medium, indicate an improvement in students' conceptual understanding after learning using Mathigon Polypad media.

This improvement in conceptual understanding is supported by Mathigon Polypad's characteristics, which provide dynamic visualizations through direct manipulation of geometric objects (Ochogboju & Díez-Palomar, 2025). In geometry learning, digital media lets students explore, manipulate, and construct representations of mathematical objects, helping them identify object characteristics and relationships between concepts (Ponte et al., 2023). Similarly, Veronika and Liliana (2025) explained that technology can transform abstract mathematical concepts into dynamic visual representations, making them more concrete and easier for students to understand. Through Mathigon Polypad, students can move points on the circumference of a circle, allowing the connected line segments to adjust accordingly, and measure the resulting angle magnitudes using a digital protractor. These activities enable students to investigate the relationship between central and inscribed angles subtending the same arc. This aligns with Manurung et al. (2024), who stated that conceptual understanding involves connecting information and recognizing relationships between concepts.

Media development based on the principles of discovery learning provides students with the opportunity to independently gain conceptual understanding through a series of structured activities (Ghifari, 2024). Students are guided to observe and measure central angles, observe and measure inscribed angles, identify relationships between inscribed angles, and discover the relationship between central and inscribed angles subtending the same arc. This process aligns with the characteristics of discovery learning, which places students at the center of learning and encourages active participation throughout the learning process (Jumira et al., 2025). Through this process, students can construct their own understanding, so the concepts they acquire are based not only on memorizing formulas but also on the experience of discovering mathematical relationships. This aligns with Mumtaza et al. (2024), who stated that concepts discovered independently tend to be more memorable and longer-lasting. Furthermore, Junaidi et al. (2025) demonstrated that activity-oriented learning models can support students' understanding of mathematical concepts.

The effectiveness of the developed media is reflected in improved students' test results. The average pretest score of 34.37 increased to 81.67 in the posttest, resulting in an N-Gain value of 0.69, which falls into the medium category. These findings indicate improved students' conceptual understanding after learning with Mathigon Polypad combined with discovery learning. The results are consistent with Maemunah et al. (2025), who reported positive outcomes from combining discovery learning with digital learning media. The N-Gain result also supports the interpretation that the developed media increased students' conceptual understanding, in line with the effectiveness criteria discussed by Wahab et al. (2021). This increase is supported by activities involving the observation, measurement, and exploration of geometric objects in a circle, which provide students with opportunities to directly understand the relationship between central and inscribed angles. These results align with research by Sahabudin et al. (2026), which states that presenting material through dynamic visualization and discovery activities can help students build a more meaningful conceptual understanding.

The high level of media validity, with a media expert assessment of 93.75% and a material expert assessment of 97.73%, indicates that the developed media met the eligibility criteria for appearance, presentation, and suitability to the learning objectives. Meanwhile, the practicality level, based on student responses of 87.08% and teachers' responses of 90.91%, indicates that the media can support learning activities. Learning activities become more focused because they are presented in stages, and the available features encourage active student involvement during the learning process. These results strengthen the research of Naufal & Kowiyah (2025) and Ridwan et al. (2026), which showed that exploratory activities and dynamic visualizations in Mathigon Polypad make it easier for students to understand mathematical concepts. However, this study contributes differently because the media is specifically designed to facilitate discovery of the relationship between the central and inscribed angles of a circle through systematic discovery learning.

Overall, the research results show that the Mathigon Polypad media meets the criteria of validity, practicality, and effectiveness in supporting eighth-grade students' understanding of angles in circles. The media's advantage lies in its ability to visualize abstract geometric concepts dynamically. This aligns with Schoenherr et al. (2024), which shows that visualization in mathematics learning positively influences student learning outcomes. In addition, the media allow students to manipulate mathematical objects, guide concept discovery through structured activities, and access it without installing additional applications. However, this media still has several limitations, including the need for electronic devices and a stable internet connection. A stable, high-speed internet connection is crucial for supporting smooth digital learning (OECD, 2023).

Furthermore, using media on mobile phones is not optimal because of the relatively small screen size, so laptops or computers are recommended. Another limitation is that the developed media uses an access link that is valid for only two weeks, so it cannot be used continuously without the developer updating the access link. Therefore, future development can focus on providing more permanent access, optimizing the display across devices, and expanding the material on the circle sub-topic and other geometry topics. Further research with larger, more diverse groups

of participants is also needed to examine the media's effectiveness in supporting students' mathematical conceptual understanding more broadly.

CONCLUSION

The development of Mathigon Polypad media on the relationship between the central and inscribed angles in a circle used the Research and Development (R&D) method with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The assessments conducted by the two validators indicated that the developed media and research instruments were valid, with an average validity score of 96.28%. Based on the results of the student response questionnaire (87.08%) and the teacher response questionnaire (90.91%), the media was declared very practical. In addition, the increase in the average pretest score from 34.37 to 81.67 in the posttest and the N-Gain value in the medium category (0.69) showed that the media effectively supported students' conceptual understanding. Thus, the Mathigon Polypad learning media was declared adequate and efficient in supporting grade VIII junior high school students' understanding of the concept of angles in a circle.

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