IJSET
PEDAGOGIC: Indonesian Journal of Science Education and Technology

p-ISSN: 2963-606X
e-ISSN: 2963-0894
Volume. 6, No. 3, 2026

DEVELOPMENT OF JUNIOR HIGH SCHOOL GEOMETRY LEARNING TOOLS BASED ON COMPUTER ASSISTED INSTRUCTION (CAI) AND ORIENTED TO SPATIAL ABILITY

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Article History

Received: 12-05-2026

Revision: 27-05-2026

Accepted: 30-05-2026

Published: 02-06-2026

Abstract. Spatial ability is one of the important competencies in geometry learning that needs to be supported through the use of appropriate media and learning tools. This study aims to develop a geometry learning tool based on Computer Assisted Instruction (CAI) that is oriented towards improving students' spatial ability and to test its validity, practicality, and effectiveness. This research is a development research using the ADDIE model which includes the stages of analysis, design, development, implementation, and evaluation. The products developed consist of a Lesson Implementation Plan (RPP), Student Worksheets (LKS), and CAI-based learning media. The research subjects were 101 eighth-grade students of SMP Negeri 6 Yogyakarta. Data were collected through expert validation sheets, practicality questionnaires, and spatial ability tests. The results of the study showed that all developed tools met the valid criteria based on expert assessment. The trial results also showed that the learning tools had a very good level of practicality and were effective for use in geometry learning. The effectiveness of the tools was demonstrated by the students' spatial ability completion achievement exceeding 81%. Thus, the developed CAI-based geometry learning device is suitable for use to support geometry learning and improve students' spatial abilities.

Keywords: Geometry Learning Devices, Computer Assisted Instruction (CAI); Spatial Ability

Abstrak. Kemampuan keruangan merupakan salah satu kompetensi penting dalam pembelajaran geometri yang perlu didukung melalui penggunaan media dan perangkat pembelajaran yang sesuai. Penelitian ini bertujuan untuk mengembangkan perangkat pembelajaran geometri berbasis *Computer Assisted Instruction* (CAI) yang berorientasi pada peningkatan kemampuan keruangan siswa serta menguji tingkat validitas, kepraktisan, dan keefektifannya. Penelitian ini merupakan penelitian pengembangan dengan menggunakan model ADDIE yang meliputi tahap analisis, desain, pengembangan, implementasi, dan evaluasi. Produk yang dikembangkan terdiri atas Rencana Pelaksanaan Pembelajaran (RPP), Lembar Kerja Siswa (LKS), dan media pembelajaran berbasis CAI. Subjek penelitian adalah 101 siswa kelas VIII SMP Negeri 6 Yogyakarta. Data dikumpulkan melalui lembar validasi ahli, angket kepraktisan, dan tes kemampuan keruangan. Hasil penelitian menunjukkan bahwa seluruh perangkat yang dikembangkan memenuhi kriteria valid berdasarkan penilaian ahli. Hasil uji coba juga menunjukkan bahwa perangkat pembelajaran memiliki tingkat kepraktisan yang sangat baik serta efektif digunakan dalam pembelajaran geometri. Keefektifan perangkat ditunjukkan oleh capaian ketuntasan kemampuan keruangan siswa yang melebihi 81%. Dengan demikian, perangkat pembelajaran geometri berbasis CAI yang dikembangkan layak digunakan untuk mendukung pembelajaran geometri dan meningkatkan kemampuan keruangan siswa.

Kata Kunci: Perangkat Pembelajaran Geometri, Computer Assisted Instruction (CAI), Kemampuan Keruangan

How to Cite: Lestari, T. K. (2026). Development of Junior High School Geometry Learning Tools Based on Computer Assisted Instruction (CAI) and Oriented to Spatial Ability. *PEDAGOGIC: Indonesian Journal of Science Education and Technology*, 6 (3), 615-627. http://doi.org/10.54373/ijset.v6i3.5739

INTRODUCTION

Geometry is an important component of mathematics education because it develops students' ability to visualize, analyze, and understand spatial relationships. According to Jeremko (2004), geometry studies points, lines, planes, solid figures, and the relationships among them. Furthermore, Van de Walle et al. (2010) explain that geometry learning encompasses shape properties, transformations, location, and visualization. Among these aspects, visualization plays a crucial role in helping students recognize and interpret two-dimensional and three-dimensional objects from different perspectives.

One of the essential competencies required in geometry learning is spatial ability. The National Council of Teachers of Mathematics (NCTM, 2000) emphasizes that geometry learning should promote visualization, spatial reasoning, and the use of geometric models in problem solving. Sarama and Clements (2009) further state that spatial thinking is a fundamental human ability that contributes significantly to mathematical achievement. Spatial ability includes several dimensions, such as spatial perception, spatial visualization, mental rotation, spatial relations, and spatial orientation (Maier, 1998). These abilities enable students to understand abstract geometric concepts and solve spatial problems effectively.

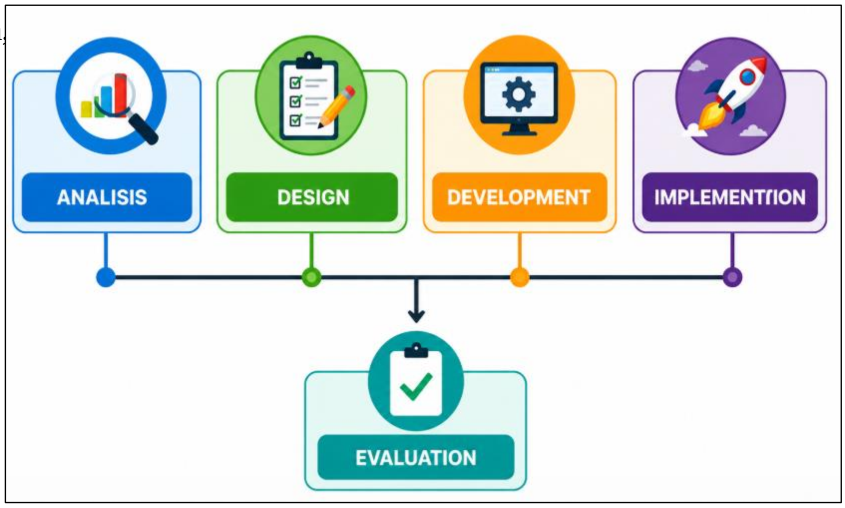
However, students' spatial ability is often underdeveloped in mathematics classrooms. A preliminary study conducted in classes VIIIA, VIIIB, and VIIID of SMP Negeri 6 Yogyakarta revealed that most students demonstrated low achievement on a spatial ability test. Only 15 students obtained scores above 70, while the majority scored below 30 out of 100. Interviews with mathematics teachers also indicated that students tended to rely heavily on teacher explanations, experienced difficulties in visualizing geometric objects, and were less active during discussion activities. These findings suggest that current learning practices have not adequately facilitated the development of students' spatial reasoning skills.

The abstract nature of geometry concepts requires learning approaches that can provide concrete and visual representations. One potential solution is Computer Assisted Instruction (CAI). According to Munir (2015), CAI is a learning system that utilizes computers to deliver instructional materials interactively and actively engage students in the learning process. Mahmood and Mirza (2012) further explain that CAI presents textual and visual information in a logical sequence, enabling students to understand concepts more effectively. Previous studies have also reported that CAI can enhance students' motivation, engagement, and conceptual understanding in mathematics learning (Aliasgari et al., 2010; Tekbiyik & Akdeniz, 2010).

Although CAI has been widely applied in mathematics education, studies focusing on the development of geometry learning tools based on CAI and specifically oriented toward improving students' spatial ability remain limited. Most existing studies emphasize general mathematics achievement rather than spatial ability as a primary learning outcome. Therefore, this study aims to develop geometry learning tools based on Computer Assisted Instruction (CAI) that are oriented toward students' spatial ability and to evaluate their validity, practicality, and effectiveness in supporting geometry learning for Grade VIII students of SMP Negeri 6 Yogyakarta.

METHOD

This research is a research and development research This research aims to develop a CAI-based junior high school geometry learning tool. The tools developed are in the form of lesson plans, student activity sheets, and learning media using the GeoGebra application version 5.0. The research and development model used in this study is the ADDIE (Analysis-Design-Develop-Implement-Evaluate) model. ADDIE is a very effective research model for use today, because it can be used as a guideline that helps in presenting complex situations for the development of learning products and other development products (Branch, 2009). The ADDIE Development Model has 5 stages of development, namely: analysis, design, development, implementation



Gambar 1. Stages of ADDIE Development Model

At the analysis stage, a needs analysis, student characteristics analysis, and material analysis were conducted. Data were collected through classroom observations and interviews with teachers and students to identify learning problems, students' spatial ability needs, and the availability of facilities supporting computer-assisted learning. The material analysis was based on the Core Competencies (KI) and Basic Competencies (KD) of the 2013 Curriculum for

Grade VIII geometry topics. At the design stage, the learning tools were planned, including lesson plans (RPP), student worksheets (LKS), and CAI-based learning media. The design process involved formulating learning objectives, preparing learning materials, designing CAI-based learning activities, and developing assessment instruments aligned with spatial ability indicators.

The development stage involved producing the initial draft of the learning tools and media. The products were then validated by experts and revised based on suggestions and feedback to ensure their validity and suitability for classroom implementation. At the implementation stage, the validated learning tools were tested with Grade VIII students of SMP Negeri 6 Yogyakarta. This stage aimed to examine the practicality and effectiveness of the developed products in supporting geometry learning and improving students' spatial ability. Finally, the evaluation stage was conducted to assess the quality of the developed learning tools. Evaluation focused on three aspects: validity, practicality, and effectiveness. Validity was determined through expert judgment, practicality through teacher and student responses as well as implementation observations, and effectiveness through students' spatial ability achievement after using the developed learning tools.

Product Trial Design and Subject

The trial phase was conducted to obtain empirical data for evaluating the practicality and effectiveness of the developed learning tools, as well as to provide input for product revision. In addition, the research instruments were tested prior to implementation. The trial involved 101 Grade VIII students of SMP Negeri 6 Yogyakarta in the 2016/2017 academic year, consisting of 34 students from class VIIIA, 34 students from class VIIIB, and 33 students from class VIIID. These students participated in the implementation of the developed learning tools, including the lesson plans (RPP), student worksheets (LKS), and CAI-based learning media.

Data Collection Techniques and Instruments

Table 1. Collection techniques, assessment instruments, results, and data sources

Data Collection Techniques	Assessment instruments	Assessment results	Data Source
Tests	Spatial Ability Issues	Test scores	Students

The instruments in data collection consist of validation instruments, practicality instruments and effectiveness instruments. Validation instruments are used to measure the validity of mathematics learning tools, namely in the form of validation sheets which are then developed through assessment by validators. The validation sheet consists of validation sheets for lesson plans, worksheets, and learning media. In addition, there is also a validation of research instruments consisting of spatial ability test instruments.

Table 2. Scale

Rating	Score
Excellent	5
Good	4
Enough	3
Less	2
Very Less	1

Practicality instruments will be used to measure the level of practicality of development products consisting of assessment sheets by teachers, assessment sheets by students, and observation sheets on learning implementation. Then, the effectiveness instrument to be used aims to measure the effectiveness of the developed product. The instrument to be used is a spatial ability test. The spatial ability test presented is in the form of 5 description test questions. The indicators of each question will represent the achievement of spatial ability.

Table 3. Spatial capability grid

Indicator	Description of the question indicator	Question Number
Spatial Perception	The ability to observe objects vertically or horizontally.	1
Visualization	Ability to show changes or arrangement of a two- or three-dimensional building	2
Mental Rotation	Ability to rotate two- or three-dimensional objects precisely and accurately	3
Spatial Relationship	The ability to understand the structure of an object and its relationship to each other	4
Spatial Orientation	The ability to observe an object from a variety of circumstances	5

Data Analysis Techniques

The data analysis technique was carried out to determine the categories of learning tools using CAI which was developed based on valid, practical, and effective quality criteria. Then the data from this research consists of two types, namely quantitative data and qualitative data. In the analysis of validity and validity data, quantitative data is converted into five-scale qualitative data.

Table 4. Quantitative to qualitative data conversion

Interval	Categories
$X > \bar{x}_i + 1{,}8\ sb_i$	Excellent
$\bar{x}_i + 0{,}6sb_i < X \leq \bar{x}_i + 1{,}8\ sb_i$	Good
$\bar{x}_i - 0{,}6\ sb_i < X \leq \bar{x}_i + 0{,}6sb_i$	Pretty good
$\bar{x}_i - 1{,}8sb_i < X \leq \bar{x}_i - 0{,}6\ sb_i$	Less good
$X \leq \bar{x}_i - 1{,}8\ sb_i$	Very bad

The quality of the developed learning tools was evaluated in terms of validity, practicality, and effectiveness. Validity was determined through expert judgment on the lesson plans (RPP), student worksheets (LKS), and CAI-based learning media. The learning tools were considered valid if each component achieved at least a good category and was deemed suitable for use with minor revisions.

Practicality was assessed through teacher and student responses after implementation. The learning tools were categorized as practical if both teachers and students rated them at least in the good category, indicating that the products were easy to use and supported the learning process effectively. Effectiveness was measured through students' spatial ability test results. The developed learning tools were considered effective if at least 80% of students achieved the minimum mastery criterion (KKM) on the spatial ability assessment.

RESULTS

The results of this development research are in the form of CAI-based learning tools to improve spatial abilities in junior high schools which include lesson plans and worksheets, and valid, practical, and effective learning media.

Table 5. Results of analysis of the validity of RPP and LKS

Yes	**Validator**	**RPP**		**LKS**	
		Total Score	Categories	Total Score	Categories
1	I	74	B	58	B
2	II	86	B	70	B
Average		80	B	64	B
Maximum Score		105		80	

Based on Table 5, it is known that the results of the RPP validation obtained an average score of 80 out of a maximum score of 105 and LKS had an average score of 64 out of a maximum score of 80. Then, the scores obtained showed that the RPP and LKS were in the good category. So it can be said that RPPs and LKS that use the computer assisted instruction method in flat side room building materials can be declared valid and have been suitable for revision if they will be used in research.

The next validation is the validation of learning media. The application used in learning media is the GeoGebra application. The results of media validation were obtained from two teams of experts, namely mathematics education lecturers at the University of Yogyakarta. The quality assessment of learning media is based on general aspects, software engineering, and visual communication. The media validation sheet can be viewed in full in Appendix 1c. Then the data and results from the validation analysis have been obtained in full attached to attachment 3c.

Table 6. Media validity analysis results

No	Validator	Learning Media	
		Total Score	Categories
1	I	62	B
2	II	85	B
Average		73.5	B
Maximum Score		90	

Based on Table 6, it is known that the results of media validation obtained an average score of 73.5 out of a maximum score of 90. Then, the score obtained shows that the media is in the good category. So it can be said that media that use the computer assisted instruction method on flat side room building materials can be declared valid and have been suitable for revision if it will be used in research. The results of the product revision after validation are draft 2 of the CAI-based learning tool.

The practicality data was obtained from the results of teacher assessments, student assessment results, and the results of observation of learning implementation. In the results of the teacher assessment, the assessment was given by two teachers who teach grade VIII.

Table 7. Teacher assessment results

Assessment Aspects	**Assessment Score**		**Average**
	Teacher 1	**Teacher 2**	
RPP	32	31	31.5
LKS	64	57	60.5
Learning Media	26	24	25
Total	122	112	117
Maximum score			135
Conclusion			Excellent

Based on table 7, the developed learning tools received an average score of 117 out of a maximum score of 135. Thus, the learning tools developed are classified as very good, so that the lesson plans and worksheets developed using CAI are oriented towards spatial ability to meet practical criteria.

In addition, the results of practicality were also reviewed from the average results of student assessments of the learning tools. The results of student assessments are divided into two data, namely student assessments of worksheets and learning media. In the LKS assessment, class VIIIA has an average score of 52, class VIIIB is 51, and the average of class VIIID is 52 out of a maximum score of 60. Meanwhile, the average assessment results of students from the three classes against the developed LKS were 51.67. Based on the student assessment criteria, the LKS developed are included in the very good category so that the LKS is declared practical. Then, in the students' assessment of learning media, class VIIIA has an average score of 42, class VIIIB is 41, and the average of class VIIID is 43. Meanwhile, the average assessment results of students from the three classes on the developed learning media were 42 out of a maximum score of 50. Based on the student assessment criteria, the learning media developed is included in the very good category so that the learning media is declared practical.

Table 8. Student assessment results

Aspects	Facilities	Benefits	Fun to use
A. LKS			
Maximum score	35	10	15
VIIIA	31	9	13
Categories	SB	SB	SB
VIIIB	29	9	13
Categories	B	SB	SB
VIIID	30	9	13
Categories	SB	SB	SB
B. Learning Media			
Maximum score	30	5	15
VIIIA	26	4	12
Categories	SB	B	B
VIIIB	25	4	12
Categories	B	B	B
VIIID	26	4	13
Categories	SB	B	SB

Apart from the results of the two assessments, the practicality of the learning tools developed was also seen based on the results of the observation sheet of learning implementation. The average observation results of classroom learning implementation in the three classes were 94% of teacher activities carried out, and 92.67% of student activities were carried out. This shows that the learning tools developed are practical to be applied in learning. The spatial ability in this study consists of 5 description questions. Each question represents each indicator of spatial ability, namely: 1) Spatial orientation; 2) Spatial visualization; 3) Mental rotation; 4) Spatial relationship; and 5) Spatial perception.

Table 9. Spatial ability test results

Yes	Remarks	Classes		
		VIIIA	**VIIIB**	**VIIID**
1	Highest score	100	100	100
2	Lowest value	43	37	40
3	Average score	81,08	80,61	83,54
4	Overall average		81,74	
5	Presentation of completeness	79%	77%	86%
6	Percentage of completeness of overall spatial ability		81%	

Based on the table above, it shows that in all three classes there are students who get the maximum score. So that from this it can be indicated that there are students who are capable of all aspects of spatial ability. However, there are also students who are only able to understand less than two aspects of spatial learning. In the table, it can also be seen that the average score of class VIIIA is 81.08 with a completion percentage of 79%. The average score of VIIIB is 80.61 with a classical completion percentage of 77%, while the average of class VIIID is 83.54 with a completion percentage of 86%. Then, the overall average score of students on the spatial ability test is 81.74 with a percentage of 81%. Thus, it can be concluded that mathematics learning tools (RPP, LKS, and learning media) developed using CAI are effectively reviewed from the spatial ability of students because the percentage of spatial ability is $\geq 80\%$.

DISCUSSION

Validity of Learning Tools

Based on the expert validation results, the developed learning tools achieved a good category, indicating that the lesson plans (RPP), student worksheets (LKS), and GeoGebra-based learning media met the required standards of content, language, presentation, and instructional design. The average validation scores of 80 for the RPP, 64 for the LKS, and 73.5 for the learning media demonstrate that the developed products are suitable for supporting geometry learning and can be implemented after minor revisions based on expert recommendations.

The positive validation results suggest that the learning tools successfully integrated the principles of Computer Assisted Instruction (CAI) into geometry learning. According to Munir (2015), CAI facilitates interactive learning by combining instructional materials with technology-based activities that actively engage students in the learning process. In this study, the integration of GeoGebra enabled students to visualize and manipulate three-dimensional objects dynamically, which is particularly important in learning geometry concepts that are often abstract and difficult to imagine through conventional instruction. From the perspective of spatial ability development, the validity of the learning media indicates that the activities and visual representations provided were aligned with the components of spatial ability proposed by Maier (1998), including spatial visualization, spatial relations, and mental rotation. The use of dynamic geometric representations allows students to observe objects from different viewpoints and explore relationships among geometric elements, which are essential skills in understanding solid geometry.

These findings are consistent with previous studies reporting that technology-supported geometry learning can improve students' understanding of abstract concepts and facilitate spatial reasoning (Aliasgari et al., 2010; Tekbiyik & Akdeniz, 2010). Furthermore, GeoGebra has been widely recognized as an effective tool for enhancing visualization and conceptual understanding in mathematics learning because it enables students to interact directly with mathematical objects rather than merely observing static figures. Therefore, the high validity of the developed learning tools indicates not only their technical feasibility but also their potential to support meaningful geometry learning and foster students' spatial ability development.

Practicality of Learning Tools

The practicality of the developed learning tools was evaluated through teacher assessments, student responses, and observations of learning implementation. The teacher assessment yielded an average score of 117 out of a maximum score of 135, which falls into the very good category. This result indicates that the lesson plans, worksheets, and CAI-based learning media were considered easy to implement, aligned with instructional objectives, and capable of supporting teachers in delivering geometry content effectively. The high practicality score also suggests that the learning tools were designed in a way that reduced instructional difficulties and facilitated classroom management.

Students' responses further confirmed the practicality of the developed products. The average score for the worksheets was 51.67 out of 60, while the learning media obtained an average score of 42 out of 50, both categorized as very good. These findings indicate that students perceived the learning tools as easy to use, engaging, and helpful in understanding geometry concepts. The positive responses are particularly important because students' acceptance of learning media influences their willingness to participate actively in learning activities.

The high practicality of the learning media can be explained by the characteristics of Computer Assisted Instruction (CAI), which emphasizes interactive learning experiences and active student engagement (Munir, 2015). Through GeoGebra, students were able to manipulate and explore geometric objects dynamically rather than relying solely on static diagrams. This feature helped reduce the abstractness of geometry concepts and allowed students to construct understanding through direct exploration. Such findings support the view of Tekbiyik and Akdeniz (2010) that CAI-based learning environments can increase students' motivation and participation by providing interactive and visually rich learning experiences.

Furthermore, classroom observations showed that teacher activities reached 94% and student activities reached 92.67%, indicating that the developed learning tools were implemented successfully and encouraged active participation during the learning process. These findings are consistent with previous studies showing that technology-assisted learning environments promote greater student engagement and interaction compared to conventional instruction (Aliasgari et al., 2010). Therefore, the high level of practicality demonstrated in this study not only reflects the ease of use of the developed tools but also indicates their potential to create a more active, student-centered, and meaningful geometry learning environment.

The Effectiveness of Learning Tools on Spatial Abilities

The effectiveness of the developed learning tools was evaluated through students' spatial ability test results, which covered five indicators: spatial orientation, spatial visualization, mental rotation, spatial relations, and spatial perception. The findings revealed that the overall average spatial ability score reached 81.74, with 81% of students achieving mastery. This result indicates that the developed CAI-based learning tools successfully met the effectiveness criterion and were able to facilitate students' understanding of geometric concepts related to three-dimensional objects.

The effectiveness of the learning tools was consistently observed across all classes. Class VIIIA achieved an average score of 81.08 with a mastery level of 79%, class VIIIB obtained an average score of 80.61 with 77% mastery, and class VIIID achieved the highest average score of 83.54 with 86% mastery. The relatively similar achievement across classes suggests that the developed learning tools can be applied effectively to students with different learning characteristics. Furthermore, several students achieved perfect scores, indicating that the learning activities were capable of supporting the development of all dimensions of spatial ability.

The positive results can be explained by the characteristics of CAI-based learning and the use of GeoGebra as an interactive visualization tool. Geometry concepts, particularly solid figures, are often difficult for students because they require the ability to mentally manipulate objects and visualize relationships among geometric elements. Through dynamic visualization, students were able to observe geometric transformations, explore different perspectives, and interact directly with three-dimensional representations. This learning experience reduced the abstract nature of geometry and enabled students to construct spatial understanding more effectively.

These findings support the theory proposed by Maier (1998), which states that spatial ability consists of several interconnected components, including spatial perception, visualization, mental rotation, spatial relations, and spatial orientation. The interactive features provided by GeoGebra allowed students to develop these components simultaneously through exploration and manipulation of geometric objects. Moreover, the results align with the findings of Clements and Sarama (2009), who emphasized that spatial reasoning plays a crucial role in understanding mathematical concepts, particularly geometry.

The findings are also consistent with previous studies demonstrating the positive impact of technology-assisted learning on students' spatial development. Aliasgari et al. (2010) reported that computer-assisted instruction helps students understand abstract mathematical concepts more effectively through visual representation and interactive learning activities. Similarly, Guay and McDaniel (1977) found that spatial ability is positively associated with mathematical achievement. Therefore, the effectiveness of the developed learning tools not only reflects improved test performance but also indicates that CAI-based instruction can serve as an effective strategy for strengthening students' spatial reasoning and supporting geometry learning at the junior secondary level.

CONCLUSION

The results of the study indicate that the geometry learning device based on Computer Assisted Instruction (CAI) oriented towards spatial ability, consisting of lesson plans, worksheets, and GeoGebra-assisted learning media, has met the criteria of validity, practicality, and effectiveness. The validity of the device is demonstrated by the results of expert assessments stating that the device is in accordance with the aspects of content, presentation, language, and learning objectives. The practicality of the device is reflected in the responses of teachers and students which are in the very good category and the high implementation of learning in the classroom. Meanwhile, the effectiveness of the device is demonstrated by the average achievement of students' spatial ability of 81.74 with a classical completion level reaching 81%. These findings indicate that the integration of CAI in geometry learning can help students visualize, manipulate, and understand geometric objects more concretely, thereby supporting the development of spatial abilities. Therefore, the developed learning device is worthy of being used as an alternative learning resource and mathematics learning media to improve the spatial abilities of eighth-grade junior high school students.

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