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ORIGINAL RESEARCH PAPER

Integrating STEM project into mathematics learning design to improve the students' mathematical literacy

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Abstract
Students need to develop sufficient mathematical literacy. In reality, however, not all students demonstrate good mathematical literacy. The project-based learning (PjBL) model is a recommended teaching model, then STEM is a broad approach. This echo produces a STEM-integrated project learning model. Based on this description, researchers designed and developed Local Instructional Theory (LIT) in the form of mathematics learning with a STEM-integrated project learning model on the topic of lines and angles. This study uses a design research method, which includes three research stages: preliminary, teaching experiment, retrospective analysis. The research subjects were students taking Geometry courses. Data collection techniques used were interviews, documentation, field notes, and written tests that were collected and analyzed to improve HLT. This study was designed in three activities: creating a Joglo house project with maximum STEM-based enlightenment, identifying the concept of lines and angles and measuring angle sizes, then categorizing the types of angles and understanding the relationships between angles. From the results of all the activities that have been carried out, the learning trajectory provides students with activities that are enthusiastic in learning, creative in creating, active in discussions, and group learning to complete an assigned project. The use of LIT produces a design that has a strong theoretical basis because each learning syntax is compiled based on a synthesis of various theories and empirical research results, then validated through research and development stages.

Keywords: lines and angles, mathematical literacy, STEM integrated project learning model

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INTRODUCTION

The development of mathematics education from elementary to higher education levels has focused on problem solving, representation, and mathematical communication, which are collectively known as mathematical literacy. PISA defines mathematical literacy as an individual's capacity to formulate, use, and interpret mathematics in various contexts (OECD, 2014). Mathematical literacy falls under the dimension of general literacy skills (Tutkun & Erdogan, 2014). Mathematical literacy can be defined as mathematical fluency. In short, mathematical literacy is a person's ability to apply mathematics in everyday life (Ojose, 2011). The concept of mathematical literacy leans more towards the understanding of applying mathematics in everyday life than memorizing mathematical formulas (Mevarech & Fan, 2018). Therefore, mathematics teachers should pay attention to the following aspects in their teaching:

(1) mathematical modeling, (2) problem solving, (3) developing analytical and logical skills, (4) developing abstraction, (5) building context and connections, (6) communication (Budi, 2015). This means that mathematics teachers must have good mathematical literacy skills.

Kolar and Hodnik (2021) identified two foundations of mathematical literacy, namely: 1) mathematical thinking, which includes understanding and using mathematical concepts, procedures, strategies, and communication as the basis for mathematical literacy; and 2) problem solving in different contexts (personal, social, professional, scientific) that enable a mathematical approach. Problems related to mathematical literacy in general can be seen from the PISA test results. Since 2000, the average achievement of junior high school students, especially in mathematics, has always been below the total average and out of the standard deviation. Indonesian students' achievements have always been below average from 2000 to 2015 (Ahmad et al., 2018). According to Sari and Wijaya (2017), the mathematical literacy of upper secondary students was classified as very low, with details for the understanding indicator classified as low, while for the indicators of creating mathematical models, using concepts-facts-objects, interpreting and evaluating were in the very low category.

Prospective teachers who will teach mathematics, especially in higher grades, must have sufficient opportunities to develop their mathematical literacy. Teaching how to solve problems is an activity that teachers use to challenge or motivate students so that they are able to understand the problem, are interested in solving it, are able to use all their knowledge to formulate strategies for solving the problem, implement those strategies, and assess whether the answers are correct. Students with poor mathematical literacy will have poor consistency and discipline in carrying out activities in their daily lives. Students' mathematical literacy skills are influenced by their teachers' mathematical literacy. Furthermore, it is very important for teachers to have good mathematical literacy (Yavuz et al., 2013). Teachers must have good mathematical literacy skills, and this also applies to prospective teachers. In reality, not all students are able to demonstrate good mathematical literacy skills in the classroom. Based on the findings, students tend to have difficulty in solving problems related to reasoning skills, representation skills, and mathematical communication between materials. The data shows that students tend not to apply the knowledge they have previously learned, citing reasons such as forgetting, not understanding the previous material, and finding it difficult to find solutions because they do not understand the questions. Efforts are made through appropriate learning tools to engage their thinking processes in the form of communicating, reasoning, problem solving, and mathematical representation to improve their mathematical literacy.

In STEM learning, skills and knowledge are learned simultaneously by students. STEM is an interdisciplinary approach to learning various academic concepts that are linked to the real world by applying the principles of science, mathematics, engineering, and technology. It connects schools, communities, workplaces, and the global world, providing space for the development of STEM literacy and, with it, the ability to compete in the new economy (Maass et al., 2019).

STEM as a goal-oriented experience that (1) demands ways of thinking relevant to STEM, (2) requires the development of productive and adaptive ways to navigate complexity, (3) allows for a variety of approaches and practices (Roberts et al., 2022), (4) recruits interdisciplinary solution processes, and (5) facilitates the growth of learning innovation for all students regardless of their background (English, 2018). Teacher behaviors that encourage students to express their ideas, along with future-oriented mathematics and STEM-based problem programs, can foster students' confidence and problem-solving dispositions (Goldman & Zielezinski, 2016; Roberts et al., 2022). Specifically, mathematics-based modeling and STEM have been recommended to develop diverse ways of thinking that encourage adaptive and innovative students to develop new knowledge, skills, and willingness to overcome problems. These are problems that are currently unsolved and will remain so in the future (English, 2023).

The application of the STEM approach is also very much in line with the demands of the Industrial Revolution 4.0 era, where life is developing rapidly with digital technology being utilized in every field of work. In this era, human resources are required to have skills in science, technology, engineering, and mathematics in order to cope with life. Inadequate education in mathematics and science has led to a shortage of qualified workers, resulting in a gap in the global industry.

Therefore, the STEM approach is very important in education to develop quality human resources with learning skills, namely critical thinking, creativity, innovation, and the ability to communicate and collaborate in their future workplaces. Project-Based Learning (PjBL) is a recommended teaching model, while STEM is a broad strategy. This combination has resulted in an integrated STEM project learning model. The STEM-integrated project learning model is a learning model that forms students into groups to complete a project that integrates science, technology, engineering, and mathematics. The STEM-integrated project learning model emphasizes contextual learning through complex activities such as giving students the freedom to explore, plan learning activities, carry out projects collaboratively, and ultimately produce a final product. The integrated STEM project learning model is project-based learning that integrates STEM fields. The integrated STEM project learning process in guiding students consists of five steps, each of which aims to achieve a specific process. The stages in an effective integrated STEM project learning model are as follows.

Stage 1 Reflection. The objective of the first stage is to introduce students to the context of the problem and inspire them to immediately begin investigating. This phase is also intended to connect what is known with what needs to be learned.

Stage 2 Research. The second stage is student research. Lecturers provide science lessons, select readings, or other methods to gather relevant sources of information. More learning occurs during this stage, with students' learning progress solidifying their abstract understanding of the issues. During the research phase, lecturers more frequently guide discussions to determine whether students have developed conceptual and relevant understanding based on the project.

Stage 3 Discovery. The discovery stage generally involves bridging research and known information in project development. Students begin to learn independently and determine what is still unknown. The STEM integrated project learning model divides students into small groups to present possible solutions to problems, collaborate, and build cooperation with their peers in the group. Other models use this step in developing students' abilities to build habits of mind from the process of planning to designing.

Stage 4 Application. At the application stage, the goal is to test products/solutions in solving problems. In some cases, students test products made from predetermined specifications, and the results obtained are used to improve the previous steps. In other models, at this stage students learn a broader context outside of STEM or connect between STEM disciplines.

Stage 5 Communication. The final stage in every project is to create a product/solution by communicating with friends and classmates. Presentations are an important step in the learning process to develop communication and collaboration skills, as well as the ability to accept and apply constructive feedback. Often, assessment is based on the completion of the final steps of this phase.

In this study, the material used is lines and angles. It is important to study the relationship between angles when two parallel lines are intersected by another line because this material is widely used by students in their daily lives. The basic competency in lines and angles is to analyze the relationship between angles as a result of two parallel lines being intersected by a transversal line and to solve problems related to the relationship between angles as a result of two parallel lines being intersected by a transversal line.

Various studies have shown that Project-Based Learning (PjBL) and STEM approaches can improve students' critical thinking, problem-solving, and mathematics learning outcomes. Other studies have also reported that STEM approaches have the potential to improve mathematical literacy through contextual learning. However, most of this research focuses on testing the effectiveness of learning models, rather than on developing a Local Instruction Theory (LIT) that explains students' learning trajectories throughout the learning process. Furthermore, research integrating project-based learning models with STEM within a Design Research framework to produce LIT on lines and angles at the university level is still very limited. The novelty of this research lies in the development of a Local Instruction Theory (LIT) through a design research approach, resulting in a mathematics learning trajectory based on a STEM-integrated project learning model. Furthermore, this research integrates mathematical literacy as a primary objective within each syntax of the STEM-integrated project learning model.

Based on this description, the researcher will design and develop a Local Instruction Theory (LIT) in the form of mathematics learning using a STEM-integrated project learning model on lines and angles. This research was conducted to contribute to classroom activities in understanding the concept of lines and angles using the STEM integrated project learning model.

RESEARCH METHOD

This study used a research design method, which included three stages of research, namely preliminary, teaching experiment, and retrospective analysis. Research design is a research method conducted in collaboration between teachers and researchers with the aim of developing local instruction theory (LIT) to improve the quality of learning. The research subjects were students who took the geometry course. In the preliminary stage, the researcher conducted a literature review on lines and angles, read the syllabus, and determined the course objectives and sub-objectives as a basis for developing a learning trajectory for learning about lines and angles. Next, the researchers designed a hypothetical learning trajectory (HLT) as an overview of the learning process. In this HLT, a series of learning activities on lines and angles were developed using an integrated STEM project learning model containing assumptions consisting of learning objectives, learning activities, and assumptions about student thinking.

In the second stage of the design experiment (pilot experiment and teaching experiment), the researcher tested the HLT that had been designed on six students who were not subjects of the study. Next, there were improvements to the HLT, which were used as guidelines for the next stage, namely the teaching experiment. In the teaching experiment stage, the improved HLT was tested on the research subjects. After a series of activities were carried out, the researchers observed and analyzed what happened during the learning process. The researchers evaluated the conjectures contained in the learning activities.

Next, in the third stage of retrospective analysis, the data obtained in the second stage is analyzed to determine whether it is in accordance with the conjecture that has been designed, and the results will be used to develop activities for subsequent learning. The general objective of retrospective analysis is to develop Local Instruction Theory (LIT). Researchers analyze and compare HLT with actual learning to answer the research questions.

The data collection techniques used were interviews, documentation, field notes, and written tests which were collected and analyzed to improve HLT. Analysis was carried out by researchers to increase reliability and validity in this research. Observation and interview data were analyzed using thematic analysis (Creswell, 2007). The analysis was carried out through six stages, namely: (1) transcribing the results of interviews and observation notes, (2) reading the data repeatedly to obtain a comprehensive understanding, (3) coding student behavior and responses related to mathematical literacy, (4) grouping codes into themes, (5) reviewing and verifying themes based on all data, and (6) interpreting themes to explain the development of students' mathematical literacy during the implementation of learning. Each theme is then mapped to a mathematical literacy indicator so that changes in student abilities can be explained systematically. Data credibility was obtained through triangulation methods by comparing the results of classroom observations, student interviews, documentation, and results of mathematical literacy tests.

RESULTS AND DISCUSSION

This study was designed in three activities consisting of creating a Joglo house project with maximum enlightenment based on STEM, identifying the concepts of lines and angles and measuring the size of angles, then categorizing the types of angles and understanding the relationship between angles. The learning model used is an integrated STEM project learning model. Before and after the activities, pre-tests and post-tests were conducted to assess students' mathematical literacy. The following are the activities from integrated STEM project learning model.

Activity 1 Creating a Joglo house project with maximum illumination based on STEM

Student activities

Before the lesson begins, the lecturer forms groups. After that, students watch a contextual video to identify the problems presented. After watching the video, students are asked to identify the problems and find possible solutions to those problems through a project that will be designed together with their groupmates. Then, students are asked to work on the project assignment that has been given in groups. Student activities can be seen in Figure 1.

Figure 1. Video showing

Activity results

After watching the contextual video provided, students discussed with their groups to identify the problems in the video and possible solutions that could be used as a basis for working on the student worksheet (See Figure 2).

Figure 2. Students create Cycle 1 Joglo house project

Based on the video shown, each group will solve the problems in the student activity sheet that has been provided. Students will create a Joglo house project with different lighting arrangements and different line arrangements to form different angles. The projects produced by each group will be tested with different lighting arrangements to achieve maximum illumination.

Activity 2 Identifying the concepts of lines, angles, and measuring angles

Student activities
Students create a Joglo house project. At this stage, students work on student worksheet in groups. The worksheet covers lines and angles related to the previous project activity. The worksheet in this second activity covers the concepts of lines and angles and measuring angles.

Activity results
In Activity 2, students were able to identify the concepts of lines and angles and measure and determine the size of angles, but they were not yet able to explain them in detail. In the process carried out by students to complete the Joglo house project, this is an effort to improve the characteristics of STEM learning. Then, after the group presentation is complete, other groups are invited to ask questions or respond. The lecturer gives other groups the opportunity to convey other concepts of completion. Then, the lecturer conducts a discussion and helps and assists students in finding the concepts of lines and angles as well as measuring and determining the measure of angles. Student activities can be seen in Figure 3.

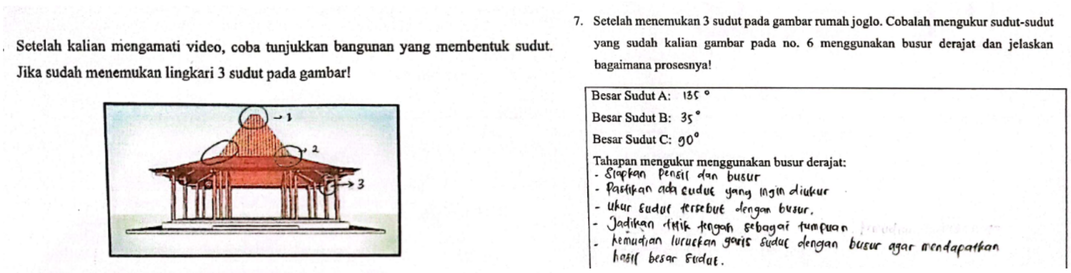


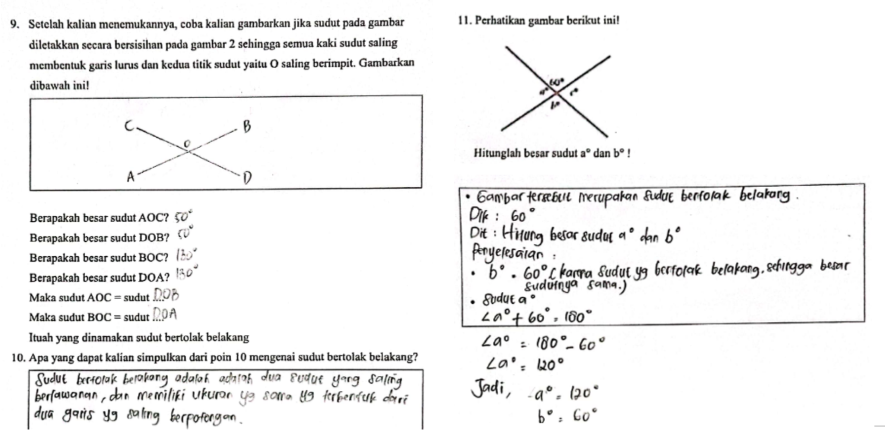
Figure 3. Student worksheet group answers

Activity 3 Categorizing types of angles and understanding the relationships between angles

Student activities
Students are given a worksheet on lines and angles, covering the types of angles and the relationships between angles. In this activity, students are given contextual problems to discuss and solve in groups. Then the lecturer helps students to identify the types of angles and the relationships between angles, and asks representatives from each group to present the results of their discussion.

Activity results
In Activity 3, students were able to categorize the types of angles and understand the relationships between angles because they had been discussed in the previous meeting. In activity 3, students appeared more enthusiastic and excited. In addition, the lecturer also played an important role in guiding and assisting students in solving problems if there were students who experienced difficulties. Student activities can be seen in Figure 4.

The results of the activities show that our conjecture is correct. Through a series of activities, students discovered the concepts of lines and angles and improved their mathematical literacy through the Joglo house STEM project. Although STEM projects are rarely carried out in learning, they remained enthusiastic and excited about making the joglo house project. This can build enthusiasm for learning and motivate students to learn about the material discussed.



9. Setelah kalian menemukannya, coba kalian gambarkan jika sudut pada gambar diletakkan secara bersisihan pada gambar 2 sehingga semua kaki sudut saling membentuk garis lurus dan kedua titik sudut yaitu O saling berimpit. Gambarkan dibawah ini!

Berapakah besar sudut AOC? 50°
Berapakah besar sudut DOB? 50°
Berapakah besar sudut BOC? 130°
Berapakah besar sudut DOA? 130°
Maka sudut AOC = sudut DOB
Maka sudut BOC = sudut DOA
Ituah yang dinamakan sudut bertolak belakang

10. Apa yang dapat kalian simpulkan dari poin 10 mengenai sudut bertolak belakang?

Sudut bertolak belakang adalah adalah dua sudut yang saling berlawanan, dan memiliki ukuran yg sama yg terbentuk dari dua garis yg saling berpotongan.

11. Perhatikan gambar berikut ini!

Hitunglah besar sudut a° dan b° !

• Gambar tersebut merupakan sudut bertolak belakang.
Dik : 60°
Dit : Hitung besar sudut a° dan b°
Penyelesaian :
• b° = 60° (karena sudut yg bertolak belakang, sehingga besar sudutnya sama.)
• Sudut a°
∠a° + 60° = 180°
∠a° = 180° − 60°
∠a° = 120°
Jadi, ∠a° = 120°
b° = 60°

Figure 4. Student worksheet group answers

Additionally, through a project and context with questions that help students with the material on lines and angles, students are enthusiastic and motivated in answering questions, discussing in groups, and expressing their opinions. The learning path that suits the characteristics of students is shown in Figure 5.

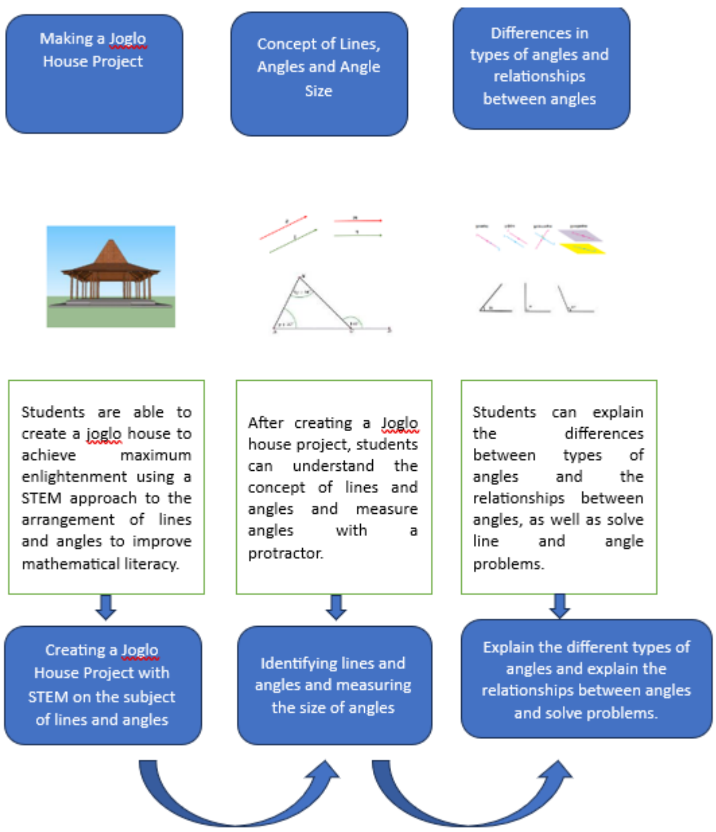


Figure 5. Learning trajectory for line and angle topic

Based on Figure 5, it shows that the learning path consists of three activities, namely, making a Joglo house project, discovering the concepts of lines and angles and measuring angles, explaining the differences between types of angles, and explaining the relationship between angles. From the activities that have been carried out, it shows that students can develop their understanding through the material on lines and angles from the informal to the formal stage through a STEM-based Joglo house project.

At the beginning of the learning process, namely the reflection stage, the lecturer invited students to learn science, namely about the Joglo House Project related to two subjects, namely mathematics on lines and angles and natural sciences. There are many rooms in a traditional Joglo house, as well as the use of many lights. This can certainly lead to wasteful use of electricity. Therefore, this learning design takes the traditional Joglo house project with maximum lighting. Creating a Joglo house with maximum lighting by placing lights in different positions will help find the right placement for each room to get maximum lighting and save electricity, especially in the use of lights.

In the research stage, students were asked to watch videos about Joglo traditional houses to use as material for their experiments in designing Joglo traditional houses. Next, in the discovery stage, students discussed in groups to find out more about Joglo traditional houses. They could search for the information they needed on the internet using their mobile phones. The use of the internet is an application of technology in learning, which is used to facilitate the acquisition of information in the search for knowledge. With the use of the internet, information can be obtained more quickly, without wasting a lot of time. Students appear enthusiastic in searching for information through Google. The use of the right context can motivate students to solve problems (Kadir & Masi, 2014).

In the application stage, students were asked to create traditional Joglo house designs using available tools and materials such as styrofoam boards, ice cream sticks, and glue. In the initial stage, students spent a lot of time thinking about what designs they would create. However, the results of each group's creations produced the expected traditional Joglo houses, which were orderly structures that helped guide them in learning about lines and angles. Through activity sheets, students are given guiding questions to determine the concept of lines and angles.

The final stage is communication, which is when students present their project results. Students are capable enough to present their project work in front of the class. The role of teachers is very much needed to continue training students so that their mathematical literacy develops to the maximum extent possible (Supianti et al., 2022).

Overall, it can be said that the learning activities in this lesson were appropriate based on STEM characteristics. The learning outcomes were that students created a Joglo house project using a STEM approach, students understood the concepts of lines and angles and measured angles using a protractor, and students explained the different types of angles, understood and explained the relationship between angles, and solved problems related to lines and angles in real life.

Furthermore, student test results improved according to mathematical literacy indicators, including identifying and understanding the concept of various angle types, developing problem-solving plans for determining angle sizes, interpreting solutions, and reviewing results obtained when determining angle sizes from calculations. During the problem-orientation phase, most students were able to identify important information from real-world contexts and transform it into mathematical models of relationships between angles. In the initial implementation, only 43% of students were able to formulate the model correctly, while in the final implementation, this increased to 87%. During the project investigation phase, students used the concepts of parallel lines, corresponding angles, alternate interior angles, and opposite angles to determine angle measurements in the project design. Upon completion, students re-evaluated their measurements and explained the mathematical rationale supporting their solutions.

Encouraging students to express their ideas, along with future-oriented math and STEM-based problem-solving programs, can foster students' confidence and problem-solving dispositions (Goldman & Zielezinski, 2016). This research contributes to the development of the Mathematics Education discipline, particularly in the development of project-based mathematics learning designs integrated with the STEM approach to improve students' mathematical literacy. The contribution of this research lies not only in the product of the learning design, but also in the development of a conceptual foundation through the development of Local Instruction Theory (LIT).

The development of LIT allows various previous research findings to be used not only as literature reviews but also systematically integrated as a basis for developing learning syntax, student activities, and evaluation components. Thus, this research produces a conceptual model explaining how the integration of project-based learning with STEM facilitates mathematical thinking, contextual problem-solving, mathematical communication, and metacognitive reflection, all key components of mathematical literacy.

The use of LIT results in a design with a strong theoretical foundation because each learning syntax is developed based on a synthesis of various theories and empirical research results, then validated through research and development stages. This approach expands the methodology for developing learning designs in Mathematics Education, which has traditionally adopted a single primary theory.

This research strengthens the direction of developing Mathematics Education that is oriented toward 21st-century competencies by placing mathematical literacy as a primary learning outcome. Through the integration of STEM projects built on Local Instruction Theory (LIT), this study provides evidence that learning designs developed from theoretical synthesis have greater potential in producing contextual, meaningful learning and are able to improve students' abilities in using mathematics to understand and solve real-life problems.

CONCLUSION

From the results of all activities that have been carried out, the learning trajectory of the material of lines and angles with the STEM integrated project learning model provides enthusiastic student activities in learning, students who are creative in creating, students who are active in discussions, and students are able to study in groups to complete an assigned project. The learning outcomes obtained by students provide good results, students are able to solve problems with everyday problems. In the presentation of project results, students display the expected results, students are able to explain the concept of lines and angles. In addition, the STEM integrated project learning model in this study provides knowledge to lecturers to become facilitators and motivators who do not provide knowledge directly like conventional learning.

The research findings show that the implementation of the STEM integrated project learning model developed through Local Instruction Theory (LIT) is able to support the development of students' mathematical literacy, especially in the ability to formulate contextual problems and apply mathematical concepts in project completion. Mathematics lecturers are advised to use STEM integrated project-based learning designs by following the learning trajectory developed in this study, because it is proven to help students connect mathematical concepts with real problems. The investigation, product development, and reflection stages deserve greater time allocation because, based on observations and interviews, these three stages contribute most to students' mathematical literacy development. Learning assessment should not only focus on the final project outcome but also utilize mathematical literacy indicators throughout the learning process, so that student development can be continuously monitored.

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DECLARATION

Author contribution
All authors contribute in the research and/or writing the paper, and approved the final manuscript.

Nita Hidayati	Conceptualizing the research idea, leading the investigation, and setting up the methodology.
Attin Warmi	Assisting the investigation, reviewing the validity of the methodology, analyzing the data, and writing the original draft.
Hanifah	Assisting the investigation, reviewing the validity of the methodology, analyzing the data, and writing the original draft.
Latifah Darojat	Assisting the investigation, reviewing the paper, enriching the data analysis, and translating the paper into English.
Shahrun Niza Sofian	Assisting the investigation, reviewing the paper, and enriching the data analysis.
Epin Hidayat	Assisting the investigation, reviewing the paper, and enriching the data analysis.

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Conflict of interest
All authors declare that they have no competing interests.

Ethics declaration
We as authors acknowledge that this work has been written based on ethical research that conforms with the regulations of our institutions and that we have obtained the permission from the relevant institutes when collecting data. We support the International Journal on Education Insight (IJEI) in maintaining the high standards of personal conduct, practicing honesty in all our professional practices and endeavors.

The use of artificial intelligence
We do not use any generative AI tools to write any part of this paper.

Additional information
Not available.

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