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E-Miracle: An inquiry-realistic digital module to support students' 6C competencies

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Abstract

The increasing demand for twenty-first-century competencies requires mathematics learning environments that not only support conceptual understanding but also foster students' broader competencies, such as critical thinking, creativity, communication, collaboration, character, and citizenship (6C). However, classroom practices in geometry often emphasize procedural knowledge, limiting students' opportunities to construct mathematical meaning through exploration and contextual reasoning. This study aimed to develop an inquiry–realistic digital module, namely E-Miracle, using Scratch to support the development of students' 6C competencies in learning about quadrilaterals. The study employed an educational design research approach consisting of three iterative phases: preliminary design, teaching experiment, and retrospective analysis. During the preliminary phase, the structure of the digital module and the learning trajectory were designed by integrating inquiry-based learning principles with contextual problems inspired by Realistic Mathematics Education. The prototype was subsequently refined through expert validation and small-scale implementation. The results indicate that the developed module achieved high validity according to expert judgment. Furthermore, the module's practicality was demonstrated through classroom implementation, where both teachers and students used it effectively during learning activities. Students actively engaged in collaborative exploration and contextual problem solving through Scratch-assisted tasks. The findings suggest that the E-Miracle module provides a learning environment that supports the development of students' 6C competencies, particularly in collaborative exploration, the communication of ideas, and creative problem-solving. These results imply that integrating inquiry-based learning, realistic mathematical contexts, and digital technology can provide meaningful learning experiences that foster deeper mathematical understanding.

Keywords:
6C competence, Digital module, E-Miracle, Inquiry-realistic

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1. INTRODUCTION

The background of this research is to follow up on the Indonesian Government's policy regarding the implementation of deep learning to develop the skills needed in the 21st century, namely the 6C competencies (Critical Thinking, Communication, Creativity, Collaboration, Citizenship, and Character). The 6C competencies are crucial for students to be more adaptive and ready to face and adapt to future changes. Recent international assessments have indicated persistent challenges in students' higher-order mathematical competencies. Based on PISA 2022, Indonesia's average score is 366 (Wijaya et al., 2024). Only 18% of students achieve a minimum level 2 mathematical proficiency in conceptual understanding, mathematical reasoning skills have continued to decline since 2000, complex problem-solving skills are inadequate, and mathematical critical thinking skills are also in the low category (Anggraeni et al., 2022; Kembara et al., 2022; Pratiwi et al., 2022). The results of the Programme for International Student Assessment (PISA) show that many students still experience difficulties in solving non-routine problems, interpreting contextual mathematical situations, and explaining their reasoning processes. These competencies are closely related to several elements of the 6C competencies, particularly critical thinking, communication, collaboration, and creativity, which are essential for solving complex problems in contemporary learning environments. Although PISA does not directly measure the full framework of the 6C competencies, the assessment tasks emphasize reasoning, problem solving, and the ability to apply mathematical knowledge in real-world contexts. Consequently, the relatively low performance of students in such tasks suggests that the development of higher-order competencies related to the 6C framework remains a significant challenge in mathematics education. Therefore, strengthening learning environments that foster reasoning, collaboration, and meaningful problem-solving becomes an important priority in improving students' mathematical competencies.

Recent discussions on twenty-first-century education emphasize the importance of developing a set of competencies that enable learners to navigate complex social and technological environments. These competencies are frequently conceptualized within the framework of the 6C competencies, which include critical thinking, communication, creativity, collaboration, citizenship, and character. Rather than representing isolated skills, these competencies are interrelated capacities that support students in constructing knowledge, engaging in collaborative problem solving, and making responsible decisions in real-world contexts. Several studies have highlighted that the development of these competencies requires learning environments that move beyond procedural instruction toward learning experiences that emphasize inquiry, reflection, and meaningful engagement with disciplinary knowledge (Prananta, 2021; Rosidin et al., 2024). In mathematics education, such learning environments are particularly important because mathematical understanding involves reasoning, communication of ideas, and the ability to connect abstract concepts with contextual situations.

Despite the growing emphasis on deep learning in educational policy, its implementation in mathematics classrooms remains challenging. Several studies have reported that mathematics teaching materials still tend to emphasize procedural practice and direct explanation of formulas. As a result, students often engage in routine problem solving without fully understanding the underlying mathematical concepts. Such learning conditions may limit students’ opportunities to develop reasoning, communication, and collaborative problem-solving skills (Alnasyan et al., 2024; Zafrullah et al., 2025). In response to these challenges, many educational reforms have emphasized the importance of learning approaches that promote deeper understanding rather than procedural memorization. Deep learning approaches encourage students to construct conceptual understanding, connect new knowledge with prior experiences, and apply ideas in diverse contexts. Within mathematics education, such approaches support the development of reasoning, communication, and reflective thinking during problem solving. Learning environments that encourage exploration, discussion, and collaborative inquiry therefore, become essential for supporting students’ deeper engagement with mathematical concepts. Thus, instructional strategies that facilitate active exploration and meaningful learning experiences are crucial for improving students’ conceptual understanding in mathematics.

These challenges indicate the need for learning resources that support more exploratory and student-centered learning environments. In particular, teaching materials that integrate contextual problems, inquiry activities, and interactive technology may provide students with opportunities to construct mathematical understanding more actively. When designed appropriately, such learning resources can support the implementation of deep learning by encouraging students to explore concepts, discuss ideas with peers, and reflect on their reasoning processes (Hakim et al., 2021). The teaching materials available in mathematics subjects are still procedural and tend to be oriented, not yet able to encourage students to be actively involved in discovering concepts, the use of technology is still minimal, the limited e-modules do not support the creation of meaningful learning, and have not been designed systematically and do not support strengthening the 6C competencies (Saryadi & Sulisworo, 2023).

Learning still tends to be teacher-centered the use of inadequate learning media has an impact on inhibiting student activities and exploration (Zafrullah et al., 2025). One impact of this problem is the lack of in-depth learning implementation and the underdevelopment of students' 6C competencies. Therefore, innovative, adaptive teaching materials are needed to meet the demands of the current curriculum and keep up with the latest technological developments to improve the expected 6C competencies. Deep learning requires learning resources that can encourage students to not only master content and memorize formulas but also to develop their 6C competencies (Anggraeni et al., 2022; Kembara et al., 2022; Rosidin et al., 2024). Therefore, developing learning resources that meet the demands of the curriculum is essential.

The Indonesian Ministry of Primary and Secondary Education's policy regarding the implementation of Deep Learning in the Independent Learning Curriculum encourages educators to implement innovative learning to create in-depth learning by integrating technology to foster students' 6C competencies. This is in line with 21st-century learning, which requires students and graduates to not only master subject matter but also to possess adaptive, critical, and analytical skills to make the learning process more meaningful (Zafrullah et al., 2025). Therefore, there needs to be a transformation from teacher-centered to student-centered learning. Therefore, the development of E-Miracle (an Inquiry-Realistic-based E-Module to strengthen the 6C competencies in Scratch-assisted Deep Learning) is crucial.

Inquiry-based learning-Realistic emphasizes exploration, active discovery of concepts, and real contextualization, has great potential to overcome the problem of low 6C competency in students (Kumazah & Agyei, 2025; Swidan & Arzarello, 2022). Several studies have explored different strategies for improving students' mathematical understanding through digital learning resources and inquiry-oriented instruction. For instance, previous research has shown that interactive digital modules can support students' engagement and visualization of mathematical concepts. Other studies have highlighted that inquiry-based learning encourages students to investigate problems, formulate hypotheses, and construct explanations through exploration. In addition, research on Realistic Mathematics Education (RME) emphasizes the importance of contextual problems that allow students to develop mathematical ideas through meaningful situations. Based on these findings, it can be interpreted that the integration of contextual learning environments, inquiry processes, and digital technology has the potential to support deeper mathematical learning.

Although previous studies have examined digital learning modules, inquiry-based instruction, and Realistic Mathematics Education separately, studies that integrate these components within a single instructional design framework remain relatively limited. Some studies have focused on the development of digital mathematics modules to support students' learning, while others have investigated the use of inquiry-based learning to promote conceptual understanding. In addition, research on Scratch-based learning environments has primarily emphasized computational thinking or programming skills rather than mathematical conceptual development. Therefore, studies that integrate inquiry-based exploration, realistic contextual problems, Scratch-assisted visualization, and the development of 6C competencies within a digital mathematics module are still relatively scarce in the literature.

Previous research only analyzed the development of interactive e-modules without the use of other media in their implementation (Hidayat & Aripin, 2023; Hidayat et al., 2025; Johar et al., 2025; Purnomo et al., 2024; Sahrudin et al., 2025; Yumiati et al., 2024), or analyzed the development of Scratch media for learning, or only measured the effectiveness of implementing one of the inquiry-based learning models or the realistic mathematics education approach separately (Fauzan et al., 2024; Johar et al., 2025; Palinussa et al., 2025; Sutarni et al., 2024). Previous studies have explored several aspects related to this research topic. Some studies have focused on the development of digital learning modules for mathematics instruction, while others have investigated the use of Scratch programming environments to support students' computational or mathematical thinking. In addition, a number of studies have examined the implementation of inquiry-based learning or Realistic Mathematics Education separately in mathematics classrooms. However, relatively limited research has attempted to integrate these elements within a single instructional design framework. In particular, studies that combine inquiry-based exploration, realistic contextual problems, Scratch-assisted visualization, and the explicit development of students' 6C competencies remain scarce. Therefore, this study aims to develop an inquiry–realistic digital module, namely E-Miracle, that integrates contextual exploration, inquiry learning activities, and Scratch-assisted interactive features to support deep learning in geometry learning. The collaboration of interactive learning models with the help of Scratch can encourage students not only to memorize formulas, but also to understand the concepts thoroughly so they can apply them in real life (Iskrenovic-Momcilovic, 2020; Kumazah & Agyei, 2025; Larsen & Lockwood, 2013; Listiawati et al., 2023; Suharta et al., 2025).

According to Prayogi and Estetika (2019), the characteristics of deep learning are 1) Mindful learning, which is full awareness in learning, 2) Meaningful learning, which is meaningful learning, and 3) Joyful learning, which is enjoyable learning. These conditions encourage the author to be able to innovate to create interactive e-modules that can support the optimization of deep learning that has the character of mindful, meaningful, and joyful learning. E-Miracle is relevant to the characteristics of deep learning, which is able to encourage students to be actively involved in learning and hone their critical thinking and analytical skills through the process of discovering concepts through real contexts or problem orientations related to everyday life, so that students' 6C competencies can be further developed (Kumazah & Agyei, 2025; Listiawati et al., 2023).

Based on the identified research gap, this study aims to develop and evaluate a digital mathematics learning module called E-Miracle (E-Module Inquiry Realistic Mathematics Learning) designed to support deep learning in geometry. The module integrates inquiry-based learning processes, contextual problems inspired by Realistic Mathematics Education, and interactive Scratch-assisted visualizations to facilitate students' conceptual understanding and the development of 6C competencies. This study is conducted as a development research, focusing on the design, validation, and practical implementation of the developed learning module in mathematics learning. Through this development process, the study seeks to examine the validity, practicality, and potential effectiveness of the E-Miracle module in supporting meaningful mathematics learning.

2. METHOD

This research employs the Design Research method, as outlined in the model by Gravemeijer and Cobb (2006) and van den Akker (2013). This model consists of three main phases: (1) Preliminary Design: The initial stage focuses on identifying problems, formulating hypotheses, and designing e-miracle designs. At this stage, researchers collect initial data through interviews with teachers, designing e-miracle designs to be tested, and validating e-miracles to experts (2) Teaching experiment. At this stage, the designed e-miracle is tested directly in class. Researchers conduct observations and observe the implementation of e-miracles, and collect data from the learning process. This experiment aims to see the effectiveness of e-miracles in deep learning and provide tests to measure the extent to which students' 6C competencies can develop with the application of e-miracles (3) Retrospective analysis: The analysis stage is carried out after the experiment is completed, where the collected data is analyzed in depth to evaluate the success of the design, identify supporting or inhibiting factors for research, and reflect on the underlying theory and analyze students' 6C competencies in the application of e-miracles. The results of this analysis are used to revise the design and formulate new principles for subsequent research.

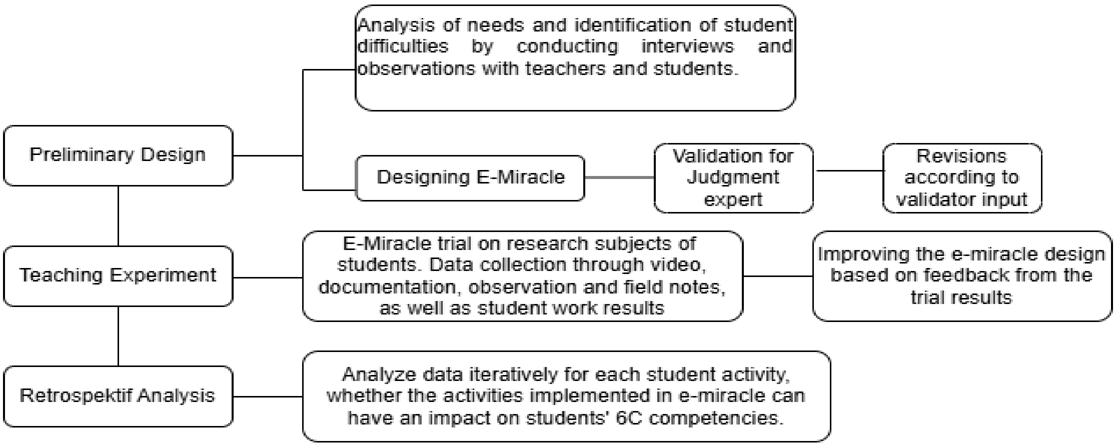


Figure 1. Design research flow

Figure 1 illustrates the overall flow of the design research conducted in this study. The process is organized into several interconnected stages, beginning with the preliminary design and continuing through teaching experiments to retrospective analysis.

2.1. Subject / Participants

The subjects in this study were seventh-grade students of a junior high school in Cimahi City, Indonesia. The total number of research subjects was 40 students. The researcher's reasons for determining the research sample subjects were generally based on several factors, namely the heterogeneous initial abilities of students consisting of high, medium, and low abilities, relevance to the research objectives, and the availability and proximity of the subjects to the learning context. Subjects were selected to represent the existing variation in abilities so that the research results were valid and generalizable. The research subject selection technique used purposive sampling by considering the stages of students' cognitive development according to Piaget's developmental theory. According to Piaget's theory, junior high school students have entered the formal operational stage, which means they are more capable of abstract thinking and solving complex mathematical problems. Junior high school students also have sufficient basic knowledge and relevant learning experiences so that researchers can measure abilities more reliably, and junior high school students are adaptive in using Scratch media. In addition, junior high school is a strategic middle level for intervening learning with inquiry-based.

2.2. Data Collection / Instrument

Data collection techniques in this study included 1) Interviews: Researchers conducted direct questions and answers with teachers and students to analyze needs and identify problems in the field. Data from interviews were recorded and analyzed in depth to design an e-miracle that suits students' needs. 2) Questionnaire: A questionnaire that has been validated by experts regarding structure, appearance, and content, which has 4 answer choices according to the question indicators. Each answer choice has a different score that indicates the level of e-miracle validation, and a student response questionnaire to measure the achievement of students' 6C competencies. 3) Observation and Documentation Sheet: directly observing the learning process in the classroom in implementing e-miracle. Researchers used observation guidelines in the form of sheets or checklists that had been prepared to systematically record the observed aspects. The data obtained were in the form of descriptive notes describing the observed conditions and documentation in the form of photos and videos of the research implementation. The results of the observations and direct observations allowed researchers to analyze how the 6C competencies (Critical Thinking, Communication, and Creativity) were implemented. Collaboration, Citizenship, and Character) students develop in learning.

The research instruments were validated by three experts selected based on their academic qualifications and professional experience in mathematics education, instructional media development, and curriculum design. Each expert holds a doctoral degree and has experience in developing or evaluating mathematics learning materials. The validation process was conducted through an expert review procedure in which the experts evaluated the instruments using a structured validation sheet covering content validity, construct validity, and visual or layout appropriateness, and provided qualitative feedback to improve the clarity, relevance, and suitability of each item.

2.3. Data Analysis

Interview

The interview guideline indicators consist of six aspects, namely curriculum, learning model, teaching materials, student difficulties, instructional media, and students' 6C competencies, as presented in Table 1.

Table 1. Interview guidelines indicators

No	Indicator	Question
1	Curriculum	What curriculum is currently used for mathematics learning?
2	Learning model	What model do you usually use in learning?
3	Teaching materials	What teaching materials do you use during learning?
		How is the availability of teaching materials during learning and is it effective for students to use?
4	Student Difficulties	What math material do you find most difficult to teach students?
5	Instructional Media	What media do you usually use in learning mathematics?
6	Student 6C competencies	How are the 6C competencies of the students in your class?
		What causes students' low 6C competency?

Table 1 presents the interview guideline indicators designed to explore the current conditions of mathematics learning comprehensively. The indicators are organized into six aspects, each representing an essential component that influences the implementation of instruction. This structured arrangement allows the researcher to obtain systematic information regarding curriculum implementation, instructional practices, learning resources, and students' competencies.

Questionnaire

To interpret the results of the validation process, this study employs the Aiken index as a basis for determining the level of feasibility of the developed instrument. The interpretation criteria used in this study are presented in Table 2. A validation questionnaire was designed based on the Aiken index interpretation criteria to analyze the feasibility of e-miracle in this study (Irawan et al., 2023).

Table 2. Interpretation of the Aiken index

Validity Index (V)	Interpretation
$0 \leq V \leq 0.4$	Not worthy
$0.4 < V \leq 0.8$	Worthy
$0.8 < V \leq 1.0$	Very worthy

The use of these criteria enables a more nuanced interpretation of expert judgments, not merely in terms of acceptance or rejection, but in identifying the extent to which the instrument meets the expected standards. In this sense, the Aiken index does not only function as a statistical measure, but also as an analytical tool to support decision-making in the refinement of the instrument. Through this approach, the validation process becomes more transparent and systematically grounded.

Observation and Documentation Sheet

This observation guide refers to several indicators related to the implementation of e-miracle in the classroom (see Table 3).

Table 3. Observation sheet indicators

No	Indicator	Observation
1	Critical Thinking	a. Students are able to analyze information logically
		b. Students are able to solve problems according to context
2	Creative	a. Students are able to create new ideas and concepts
		b. Students produce innovative solutions
3	Communication	a. Students are able to express ideas clearly
		b. Students can utilize scratch media well
4	Collaboration	a. Students work together fairly with groups
		b. Students can discuss actively in their groups
5	Character	a. Students are honest, disciplined and responsible for their duties
		b. Students show high empathy towards their friends
6	Citizen	a. Students comply with the norms and rules that apply in learning
		b. Students are fully aware of being active and contributing to learning.

Table 3 presents the indicators used to observe the development of students' 6C competencies during the implementation of the E-Miracle learning media. These indicators are not positioned as isolated behavioral checklists; rather, they function as interconnected dimensions that reflect students' engagement in meaningful learning activities. Through these indicators, the observation process captures both cognitive and socio-affective aspects that emerge during classroom interaction.

Taken together, the indicators in Table 3 provide a comprehensive framework for observing the development of students' 6C competencies. By integrating cognitive skills, communication abilities, collaborative behavior, and character-related attributes, the observation sheet enables the researcher to obtain a holistic picture of students' learning engagement during the implementation of E-Miracle.

To evaluate the level of students' 6C competencies, the achievement of each indicator was converted into percentage scores and interpreted using predefined criteria. These criteria were developed to provide a consistent basis for classifying the extent to which the competencies emerged during the learning process. The 6C competencies can be measured from the achievement of each indicator for each student with the following achievement criteria (see Table 4).

Table 4. Achievement criteria

No	Percentage (%)	Interpretation
1	0-20	Very weak
2	21-40	Weak
3	41-60	Currently
4	61-80	Strong
5	81-100	Very strong

Table 4 presents the classification of achievement levels based on percentage intervals. By applying these criteria, the analysis of students' 6C competencies becomes more systematic and interpretable. The percentage-based classification allows the researcher to identify variations in competency development across different learning activities. Furthermore, these categories support a more nuanced interpretation of students' progress, rather than relying solely on descriptive observations.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Preliminary Design

At this stage, the researcher analyzed the needs and identified the problems that occurred in the field by collecting empirical data, through a review of literature studies from various relevant articles, analyzing the curriculum, learning outcomes, and conducting interviews with junior high school mathematics teachers, with R: Researcher, T1: Teacher one, and T2: Teacher two. The following are the results of interviews with mathematics teachers in 2 different schools.

P : What curriculum is currently used for mathematics learning?
T1 : Independent Curriculum

T2 : Independent Curriculum
P : What model do you usually use in learning?
T1 : Contextual
T2 : Lecture
P : What teaching materials do you use during learning?
T1 : Internet and Textbooks
T2 : Textbooks from the government, videos from YouTube, and PowerPoint presentations made from Canva.
P : How is the availability of teaching materials during learning? Are they effective for students to use?
T1 : There is no student handbook; the book is only for teacher reference.
T2 : For textbooks, all students borrow from the library
P : Are there any shortcomings or suggestions for the teaching materials that have been used?
T1 : There are several languages that are not well understood by junior high school students in the textbooks.
T2 : Yes, students only focus on government textbooks, the content of which tends to be textbook and normative.
P : What math material do you find most difficult to teach students?
T1 : Geometry Material
T2 : Material on flat and spatial shapes.
P : What media do you usually use in learning mathematics?
T1 : Powerpoint only
T2 : None
P : How are the 6C competencies of the students in your class?
T1 : Students' 6C competencies still tend to be low.
T2 : Still low
P : In your opinion, what is the cause of students' low 6C competency?
T1 : Lack of facilities/teaching materials that support the creation of interactive and adaptive learning for students.
T2 : The availability of textbooks is still minimal, and the learning flow does not support the development of students' 6C competencies.

Based on the results of interviews and identification of problems that occur in the field, the low competency of 6C students is due to learning that still tends to be teacher-centered with lecture/contextual methods, and also the lack of learning facilities, such as media and teaching materials used. The textbooks used tend to be textbooks and do not support the creation of student-centered learning. The existing teaching materials tend to focus on the final result or memorization of formulas without paying attention to the meaningfulness of the concept and minimal student involvement in the process of concept discovery. The material that teachers find difficult to teach to students is the geometric elements of flat and solid shapes (Ayuningtyas et al., 2019; Iskrenovic-Momcilovic, 2020; Kokeb et al., 2025; Mulenga et al., 2025; Stevani et al., 2025; Zhengtao & Hidayat, 2025). Based on observations of students, several problems were identified in the mathematics learning process. Data shows that geometry material is difficult for as many as 75% of students find it difficult to learn geometry. In addition, students feel bored and less motivated to read mathematics textbooks that are full of notations and symbols (Hidayat & Aripin, 2023; Yumiati et al., 2024). Therefore, a solution is needed in the form of interactive teaching materials to improve students' 6C competencies that can guide students to discover concepts meaningfully, not just memorize formulas. This was also stated by Latorre-Cosculluela et al. (2021). The 6C competencies are very relevant to preparing students to face the challenges of the 21st century. To support the achievement of these competencies, the learning process needs to be supported by adequate learning facilities.

Based on these problems, researchers designed and developed an interactive e-miracle that can support the creation of meaningful and in-depth learning with an inquiry-realistic learning flow on the area of a quadrilateral. So that students can find concepts independently and easily understand the material with guidance and assistance from teachers through digital modules that can be accessed flexibly with an attractive display, and can improve students' 6C. The following is the e-miracle design (an interactive e-module based on inquiry-realistic learning in deep learning) by referring to the achievement of students' 6C competencies at each step of their learning.

The initial e-miracle design was validated by three experts: a content expert, a learning expert, and a media expert. The experts' input served as the initial reference for revisions and improvements to the e-miracle. Table 5 shows the expert validation results.

Table 5. Results of expert assessment of learning design aspects

No	Indicator	V-Aiken	Conclusion
1	Clarity of learning objectives (formulation, realistic)	0.85	Very worthy
2	Relevance of learning objectives to the curriculum	0.85	Very worthy
3	Scope and depth of learning objectives	0.9	Very worthy
4	Accuracy of using learning strategies	0.9	Very worthy
5	Interactivity	0.85	Very worthy
6	Providing learning motivation	0.8	Worthy
7	Contextuality and actuality	0.9	Very worthy
8	Completeness and quality of learning aid materials	0.9	Very worthy
9	Suitability of material to learning objectives	0.9	Very worthy
10	Depth of material	0.8	Worthy
11	Ease of understanding	0.85	Very worthy
12	Systematic, coherent, clear logical flow	0.9	Very worthy
13	Clarity of description, discussion, examples, simulations, exercises	0.75	Worthy
14	Consistency of evaluation with learning objectives	0.95	Very worthy
15	Accuracy and precision of evaluation tools	0.95	Very worthy
16	Providing feedback on evaluation results	0.9	Very worthy
17	Accuracy of the material presented	0.95	Very worthy
18	Examples of questions presented	0.75	Worthy
	Average	**0.87**	**Very worthy**

The validation results showed a score of 0.87, indicating that the e-miracle design was highly suitable for implementation in learning. After revising the design based on expert input, the researchers implemented the e-module with 40 seventh-grade students.

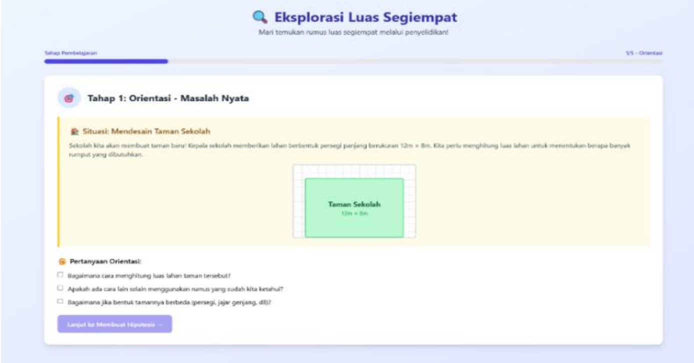
3.1.2. Teaching Experiment

The e-miracle design was revised during the preliminary trial phase and based on input from experts. The researchers then implemented the e-miracle with students and analyzed student responses through observation sheets/field notes, documentation, and student work during the teaching and learning process. Figure 2 shows the results of the e-miracle implementation in the field.

Figure 2. Stage of introducing E-Miracle to students

Figure 2 illustrates the stage in which the E-Miracle interactive e-module was introduced to students during the classroom learning process. At this stage, the teacher first explained the objectives of the learning activities and demonstrated how students could access and navigate the E-Miracle module through their digital devices. The module was projected on the classroom screen to guide students through each stage of the inquiry–realistic learning process. During this activity, students were encouraged to explore the contextual problems presented in the module and discuss their ideas collaboratively. The teacher acted as a facilitator by providing guidance and prompting questions to support students' exploration and reasoning processes. Through this guided exploration, students gradually constructed their understanding of the concepts of quadrilaterals and were able to identify the area formulas for each type of quadrilateral based on their investigation results. This stage illustrates how the E-Miracle module supports inquiry-based and contextual learning, where students actively participate in exploring mathematical ideas rather than receiving formulas directly from the teacher. As a result, the learning process becomes more interactive, meaningful, and supportive of students' conceptual understanding.

Researchers introduced and guided the learning flow of the interactive, inquiry-realistic e-module and its stages. Students could access the e-miracle from their devices and computers. With teacher guidance, they were able to complete each stage successfully and find the area formula for each quadrilateral through clear exploration and construction, making the learning process more meaningful. Figure 3 shows the students' answers for each stage.



Activities at the orientation stage with the reality principle in inquiry-realistic learning for the material on the area of a quadrilateral in the context of calculating the need for grass in a yard by involving the provision of real and relevant contextual problems for students.

Figure 3. Orientation stage with reality principle

The initial stage of the learning process involved introducing students to a contextual problem related to everyday situations. As illustrated in Figure 3, students were asked to estimate the amount of grass needed to cover a rectangular yard by examining the number of square units represented in the diagram. This activity encouraged students to interpret the contextual situation and formulate an initial hypothesis regarding how the area of the yard could be determined. Students identify problems related to everyday life by calculating the amount of grass, using the square units shown in the picture as an example. Once they have calculated the number and provided a tentative hypothesis/guess regarding the amount of grass in the yard, they can proceed to the next stage.

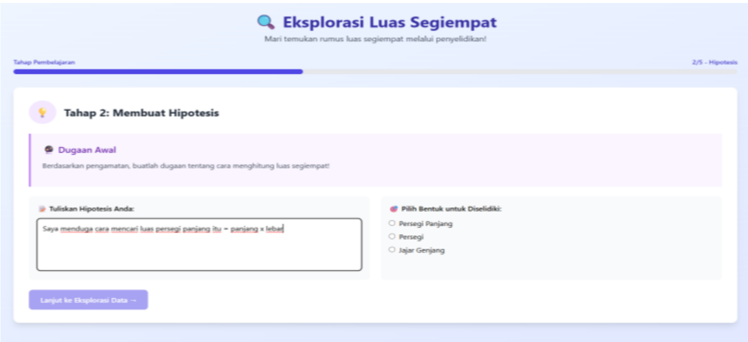
Figure 4. Students identify problems presented in the orientation stage

As shown in Figure 4, students actively observe and analyze the contextual problem presented in the E-Miracle module during the orientation stage. In this stage, students work collaboratively in small groups while accessing the digital module through their laptops. They carefully read the problem situation and discuss the information provided in order to identify what is known and what needs to be determined. Through this discussion process, students begin to formulate an initial hypothesis based on their prior mathematical knowledge. In the example presented in the module, students attempt to determine the number of square units required to cover a rectangular yard. Based on their observations and reasoning, students propose that the area can be obtained by multiplying the length and the width of the rectangle.

This hypothesis represents an early stage of conceptual construction before the formal mathematical formula is introduced.

At the orientation stage, students' initial responses indicated that their understanding of area was still procedural and limited to memorization. Several students initially assumed that the area of a quadrilateral could be determined only by counting visible squares without recognizing the multiplicative relationship between dimensions. This reflects an early conceptual stage in which students rely on counting strategies rather than structural reasoning. However, through guided discussion and contextual problem analysis, students began to shift from counting individual units toward recognizing patterns in rectangular arrangements. This transition illustrates the development of students' understanding from informal reasoning to more structured mathematical thinking.

The learning activity illustrated in Figure 4 demonstrates how the orientation stage of the inquiry–realistic learning process encourages students to actively explore problems, exchange ideas, and develop initial mathematical reasoning before moving to the subsequent stages of investigation and formalization. Students observe the problem presented in e-Miracle. At this stage, students discuss with their groups to identify what is known and what is asked in the problem orientation. Then, they make an initial hypothesis and guess the temporary answer to the problem based on what they know. Students provide an initial guess that finding the number of square units of grass in a rectangular yard is done by counting the number of square units in the rectangle. This can be formulated by multiplying the *length x width* of the rectangle. So, the students' initial hypothesis regarding the formula *Area of a Rectangle = length x width*. Students present this formula in the hypothesis-making column stage.



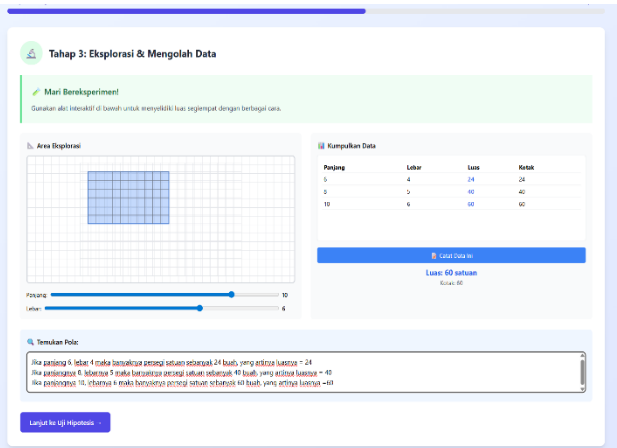
The teacher gives provocative questions so that students can develop rational and logical hypotheses through their initial knowledge of the area of a quadrilateral and write it in the answer column.

Figure 5. Stages of hypothesis submission through the activity principle

The illustration in Figure 5 depicts the stage of hypothesis submission within the activity principle. As shown in the Figure 5, students are encouraged to formulate an initial conjecture about the area of a quadrilateral based on their prior knowledge. The interface provides a space for students to write their hypotheses and select the geometric form they consider relevant. At this stage, the teacher's role is to pose provocative questions that stimulate students' reasoning, prompting them to construct rational and logical assumptions. Through this process, students articulate their preliminary ideas in the answer column before proceeding to the verification phase. This activity supports the development of mathematical reasoning by guiding students to connect intuitive understanding with formal exploration.

During the hypothesis formulation stage, several misconceptions were observed. Some students initially believed that changing the orientation of a shape would alter its area, indicating a misunderstanding of area invariance. Others assumed that irregular quadrilaterals required entirely different formulas rather than decomposition into familiar shapes. Through experimentation using the Scratch-based environment, students tested multiple configurations and gradually recognized that area depends on dimensional relationships rather than visual orientation. This process helped students revise their misconceptions and refine their mathematical reasoning.

After students provide a temporary estimate regarding the amount of grass needed, which is equivalent to the number of unit squares in the picture, students then test the hypothesis by experimenting by entering several experiments by entering data for different lengths and widths and finally get a pattern for the formula for the area of a rectangle based on the following activity (see Figure 6).



At this stage, students conduct experiments to calculate the area of a quadrilateral in an interactive way, with the help of scratch and carry out tests with different length and width measurements for each shape so that students can find patterns and formulas for the area of a quadrilateral.

Figure 6. Data processing through the interactivity principle

Figure 6 illustrates the data processing stage implemented through the interactivity principle. As shown in the Figure 6, students conduct experiments using an interactive exploration board to manipulate different values of length and width. The visual grid enables students to observe the formation of rectangular shapes and count the number of unit squares generated for each configuration. In addition, the system provides a data table where the results of each experiment are recorded, allowing students to organize their findings systematically. Through repeated trials, students compare the number of unit squares obtained from various combinations of dimensions. This interactive process helps them identify regularities between length, width, and area. The experimentation supported by the Scratch-based interface encourages students to actively construct mathematical understanding by analyzing patterns emerging from the collected data. Consequently, students are guided to formulate the general rule for determining the area of a rectangle, namely by multiplying the length by the width, based on empirical observations derived from the interactive activity.

At this stage, students process data through experiments on the exploration board by selecting data for different lengths and widths, resulting in various rectangular shapes according to the length and width determined by the students. So that students can count the number of unit squares in each image according to their length and width, and form a pattern as listed in the data collection column. Based on this, students can determine the area of a rectangle with a length of 6, a width of 4, resulting in the number of unit squares needed as many as 24. If the length is 8 and the width is 5, then the number of unit squares contained is 40 unit squares, and so on. Through this activity, students can find patterns and formulas to determine the formula for the area of a rectangle by multiplying its length and width.

E-Miracle features a scratch link for visualizing and manipulating images, which can encourage students to construct the concept of area for various quadrilaterals. It is hoped that students will gradually discover patterns and formulas for the area of each quadrilateral.

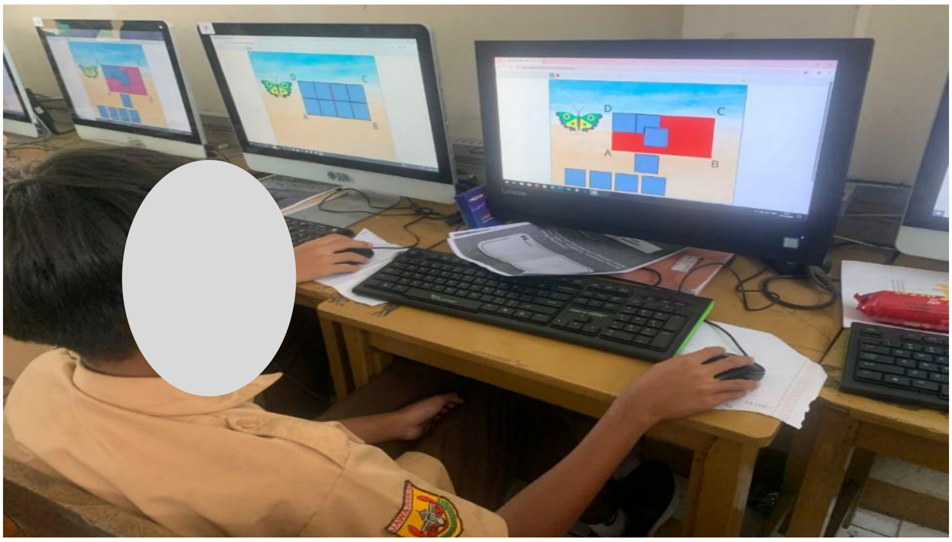
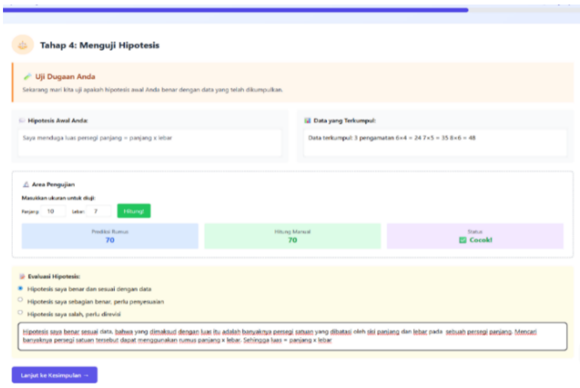


Figure 7. Concept discovery process in E-Miracle through the guidance principle

Figure 7 presents the concept discovery process in E-Miracle implemented through the guidance principle. As illustrated in the figure, a student interacts directly with the computer-based learning environment to explore the area of quadrilateral shapes. The screen displays an interactive Scratch-based activity that allows the student to manipulate shapes and observe how rectangular units are arranged to form a composite figure. This guided activity encourages students to experiment independently while still following structured instructions embedded in the system. Through this guided exploration, students analyze how the arrangement of unit squares corresponds to the dimensions of the rectangle. By observing the visual representation on the screen, students recognize that the total number of unit squares is determined by multiplying the length and width. Students' mathematical representations also evolved during the learning process. Initially, students represented area visually by counting unit squares. As they interacted with the Scratch-based visualization, they began expressing relationships numerically using multiplication.

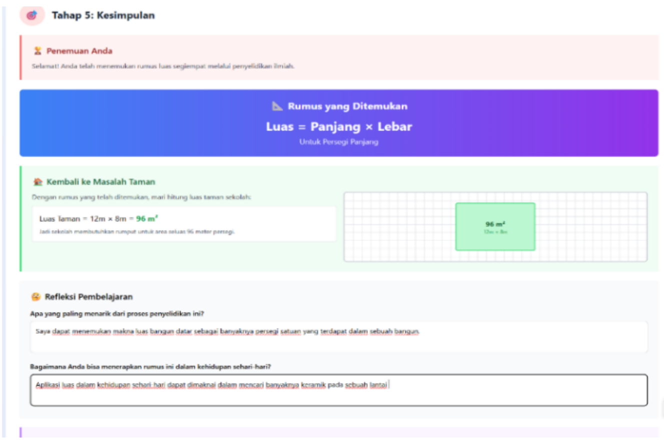
The teacher's guidance is implicitly embedded in the task design, directing students to verify their reasoning through repeated trials. Consequently, students are able to construct the concept that the area of a quadrilateral can be determined by decomposing it into rectangular units and identifying the relationship between dimensions and the number of unit squares forming the plane figure. Students experiment to find the formula for the area of a quadrilateral using the area of a rectangle approach. Through scratch media, students can prove that the number of unit squares that fit into a rectangle is the product of the length and width of the rectangle. So, students can conclude that area is the number of unit squares that can form a plane shape.



In the hypothesis testing stage, students test their hypotheses by entering several different numbers and generalizing them into the formula for the area of a quadrilateral.

Figure 8. Testing the hypothesis

Figure 8 illustrates the hypothesis testing stage of the learning process. As shown in the Figure 8, students examine the validity of their initial conjectures by entering several numerical values into the provided fields. The interactive interface allows students to manipulate different combinations of measurements and observe the resulting calculations. Through this activity, students compare outcomes obtained from various inputs and evaluate whether their previously formulated hypotheses remain consistent. This testing phase encourages students to verify their reasoning empirically. By experimenting with multiple numerical examples, students identify regular patterns in the relationship between the dimensions of a quadrilateral and its area. The process of substituting values and observing the results supports students in refining their conjectures and generalizing them into a mathematical rule. Consequently, students are guided to confirm that the area of a quadrilateral, particularly in rectangular form, can be determined systematically by applying the relationship between length and width. Based on the hypothesis testing, students found a pattern and were able to conclude that the number of unit squares in a rectangle is the area of a rectangle, and can be obtained by multiplying the length and width of the rectangle, and likewise for other quadrilaterals. Students verified the correctness of their initial answers at the hypothesis submission stage through this hypothesis testing stage.



At the conclusion stage, students conclude and write down the formulas found for each area of a quadrilateral.

Figure 9. Conclusion stage through principle level

Figure 9 illustrates the conclusion stage as a point where students' understanding becomes more structured after progressing through a sequence of exploratory activities. At earlier stages, students tended to rely on intuitive counting of unit squares, reflecting a concrete and still fragmented grasp of the area concept. As they engaged in hypothesis formulation and experimentation with varying length and width values, their reasoning began to shift toward recognizing relationships between dimensions and the number of units, although some initially maintained the misconception that area must always be determined through counting. Through repeated comparisons and guided reflection, these misconceptions gradually diminished, and students started to generalize patterns by expressing area as a multiplicative relationship. The conclusion stage therefore functions as a consolidation of this evolving understanding, where students synthesize empirical observations into a formal representation. The interface supports this transition by explicitly displaying the derived formula while prompting students to articulate their reasoning, allowing them to move beyond procedural recall toward conceptual justification. This progression from concrete manipulation, through relational visualization, to symbolic generalization indicates a gradual development of mathematical thinking, in which students reorganize their ideas into a coherent structure that can be communicated and applied more flexibly, thereby reflecting deeper conceptual understanding.

3.1.3. Retrospective Analysis

At this stage, researchers comprehensively analyze how 6C competencies can develop with the application of E-miracle. Students' 6C competencies, namely indicators: 1) Critical thinking (the ability to analyze information logically & the ability to solve problems according to context 2) Creativity (the ability to create new ideas and concepts, and can produce innovative solutions, 3) Communication (the ability to express ideas and information clearly and be able to utilize scratch media well), 4) Collaboration (the ability to work together and discuss in groups, and do assignments well in their groups), 5) Character (showing honesty, discipline, responsibility, and empathy 6) Citizenship (Complying with applicable norms, values, and rules and being aware and active in learning and contributing to their groups) students based on the learning process that has been carried out. Table 6 shows the recapitulation of the percentage of achievement based on students' 6C indicators.

Table 6. Achievement of competency 6C

No	Indicator	Frequency	Achievement (%)	Criteria
1	Critical Thinking	29	72.5 %	Strong
2	Creative	25	65.0 %	Strong
3	Communication	30	75.0 %	Strong
4	Collaboration	32	80.0 %	Very Strong
5	Character	31	77.5 %	Strong
6	Citizen	26	65.0 %	Strong
	Average	**28.83**	**72.5 %**	**Strong**

Qualitative evidence from classroom observations and students' work supports the interpretation of these findings. For instance, students who initially relied on trial-and-error strategies were later able to justify their solutions using general mathematical relationships. Similarly, group discussions revealed increasing levels of participation and shared reasoning, indicating the emergence of collaborative and communicative competencies during the learning process.

After implementing e-miracle, 72.5 % of students showed improvement in analyzing and breaking down math problems into smaller, more understandable parts, thereby developing their logical analysis skills. This suggests that e-miracle impacts students' critical thinking. It was evident in its implementation that students' reasoning skills improved with the guided discovery process. Students were able to analyze the orientation of the given real-world problems and discover patterns from the hypothetical answers they designed. This enabled them to effectively discover the concept of the area formula for a quadrilateral.

As many as 65% of students felt challenged to solve mathematical problems and problems that require in-depth thinking, and students were more creative in finding solutions to the problems presented. Students' creative abilities were further developed by the application of this e-miracle. By manipulating the shape of various quadrilaterals through the rectangular approach presented in the Scratch application, it can improve students' creative thinking skills can be improved in finding other shapes for each shape. In addition, students can also connect concepts between shapes in quadrilaterals. Thus, this e-miracle has an impact on increasing student creativity.

As many as 75 % of students can visualize and describe mathematical concepts well, and can explain mathematical concepts using their own language. Students can interpret images into mathematical language. This indicates a significant improvement in students' mathematical communication skills. Therefore, this e-miracle appears to have significantly impacted students' communication skills. Furthermore, Collaboration or the ability to work together in a team of students is strengthened by group discussions and interactivity. Students can respect each other's opinions and can solve problems together. This is shown by the achievement of 80 % of students showing activeness in group discussions during learning. Likewise, the attitude of Character is 77.5 %, which shows strong criteria. This can be seen from the attitude of honesty, responsibility, and discipline. Students can complete each stage in e-miracle with enthusiasm and enthusiasm in learning, which shows that students' character can develop with the application of this e-miracle. Likewise with Citizenship, which is in the strong category, this is shown from awareness, responsibility and showing empathy, students help each other when other friends have difficulty in the process of using scratch or group discussions in working on each stage and filling out the e-module.

The observed achievement of 72.5% in the strong category should be interpreted in relation to the baseline findings from the preliminary phase, which indicated limited student engagement and low perceived 6C competencies. The improvement observed during the implementation suggests that students demonstrated more active participation, collaborative interaction, and conceptual reasoning compared to the initial learning conditions. The implementation of e-miracle makes learning more interactive. Students are actively involved in discovering the concept of the area of a quadrilateral. Through the reality principle, learning is very meaningful and can be applied by students in everyday life, and through the integration of scratch-assisted technology, learning is very interesting and fun for students. Based on this analysis, this e-miracle strongly supports the creation of deep learning implementation that is mindful learning, meaningful, and joyful learning and is effective in strengthening students' 6C competencies. This can be seen from the student answers (see Figure 10).

Student questionnaire assessing e-miracle. Does this media help my learning process be more effective and enjoyable? Questionnaire options are strongly agree, agree, somewhat agree, disagree.

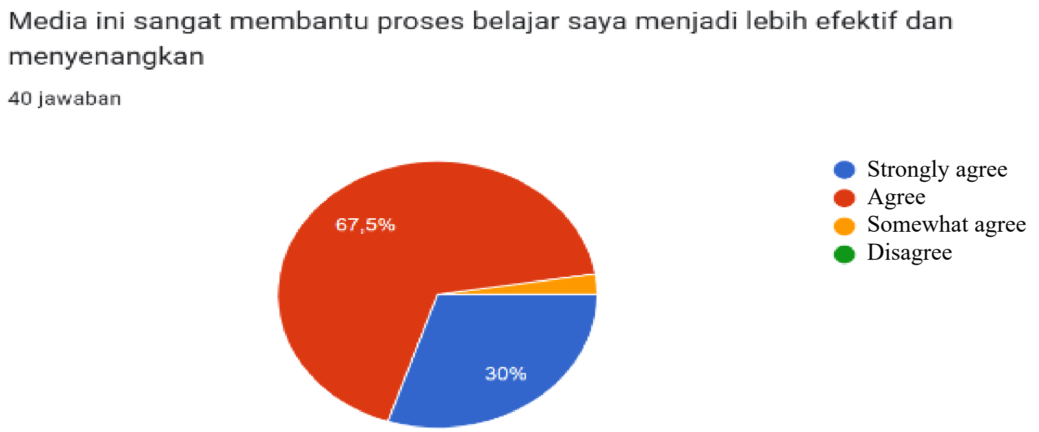


Figure 10. Student questionnaire results

Figure 10 presents the results of the student questionnaire evaluating the use of the E-Miracle learning media. As shown in the figure, the responses are displayed in a pie chart summarizing students' perceptions of whether the media helps make learning more effective and enjoyable. The chart indicates that the majority of students responded positively to the statement.

Specifically, 67.5% of students selected "agree," while 30% chose "strongly agree." Only a very small proportion of students indicated less agreement, and no responses fell into the "disagree" category. These results demonstrate that most students perceived the E-Miracle media as beneficial in supporting their learning process. The dominance of positive responses suggests that the interactive features and structured activities provided by the media contribute to increased engagement, improved understanding, and a more enjoyable learning experience. Consequently, the questionnaire findings support the effectiveness of the developed learning media in facilitating meaningful mathematics learning.

3.2. Discussion

The findings of this study indicate that the implementation of E-Miracle within an inquiry-realistic learning framework supports deep learning by facilitating conceptual understanding and meaningful knowledge construction. Rather than focusing solely on procedural mastery, students engaged in contextual problem solving, discussion, and reflection, which encouraged them to reorganize prior knowledge and build new mathematical meaning. This outcome aligns with the principles of realistic mathematics education, which emphasize guided reinvention and the progressive mathematization of contextual problems into formal mathematical ideas (Gravemeijer & Cobb, 2006; van den Akker, 2013). The inquiry structure embedded in the learning design further strengthens this process by promoting questioning, hypothesis formation, and collaborative reasoning. Such learning conditions are known to support conceptual depth and higher-order thinking, particularly when students actively construct knowledge through inquiry-based exploration (Ceballos et al., 2026; Hmelo-Silver et al., 2007).

From a theoretical perspective, these findings suggest that the integration of inquiry learning with RME principles creates a complementary pedagogical structure. While RME provides contextual grounding and progressive formalization, inquiry learning contributes investigative processes that support students' reasoning and metacognitive development. The E-Miracle design demonstrates how these two approaches can be operationalized within a digital environment, thereby extending previous studies that examined RME or inquiry learning separately. This integration contributes to the literature by illustrating how technology-supported inquiry-realistic learning can enhance deep learning and promote meaningful conceptual understanding.

The observed improvements in students' competencies appear to be influenced by several instructional features embedded in the E-Miracle design. First, contextual problems allowed students to connect mathematical ideas with familiar situations, increasing cognitive engagement. Second, the iterative inquiry cycle encouraged students to test ideas, revise reasoning, and collaboratively refine solutions. Third, the Scratch-based environment provided visual and interactive representations that supported exploration and immediate feedback. These elements collectively created a learning environment consistent with constructivist principles, where knowledge is actively constructed through interaction and reflection (Fan & Ye, 2022; Irdalisa et al., 2020). Consequently, the development of students' competencies can be interpreted as the result of sustained engagement in meaningful inquiry supported by contextual and technological scaffolding.

The achievement of students' 6C competencies was evident across multiple data sources, including observation results, reflective questionnaires, and interview findings. Critical thinking emerged when students analyzed contextual problems and justified their reasoning during group discussions. Creativity was observed in students' ability to propose alternative solution strategies and construct new representations using Scratch. Communication skills developed as students explained their ideas and responded to peer feedback. Collaboration appeared through shared decision-making and task distribution within groups. Meanwhile, character and citizenship competencies were reflected in students' responsibility, respect for differing opinions, and adherence to agreed learning norms. These findings are consistent with studies showing that inquiry-based collaborative environments foster both cognitive and socio-emotional competencies (Barron & Darling-Hammond, 2010; Thornhill-Miller et al., 2023). Quantitative observation data further indicated that most students reached the "strong" category across the 6C indicators. This suggests that the competencies were not only observed qualitatively but also consistently demonstrated during the learning process. The convergence of qualitative and quantitative evidence strengthens the claim that E-Miracle effectively supports the development of 6C competencies.

These findings contribute to both inquiry learning and RME literature in several ways. First, the study demonstrates how inquiry processes can be embedded within the RME framework to support deep conceptual understanding. Second, it provides empirical evidence that digital tools such as Scratch can operationalize progressive mathematization by enabling students to explore and visualize mathematical relationships. Third, the integration of 6C competencies into the learning design expands previous research by linking mathematical understanding with broader 21st-century competencies. This contribution aligns with recent calls for integrating cognitive and socio-emotional skills within mathematics education (Thornhill-Miller et al., 2023).

Despite these positive findings, several limitations should be acknowledged. First, the study was conducted within a limited sample and specific classroom context, which may restrict the generalizability of the results. Second, the duration of implementation was relatively short, making it difficult to examine long-term impacts on students' competency development. Third, the measurement of 6C competencies relied partly on observational data, which may be influenced by subjective interpretation despite the use of structured indicators. These limitations suggest that the findings should be interpreted cautiously and considered as exploratory evidence of the effectiveness of the E-Miracle design.

Future research may expand this study by involving larger samples and diverse educational settings to enhance generalizability. Longitudinal studies are also needed to examine the sustainability of competency development over time. In addition, further investigation could explore how different technological platforms or learning contexts influence the effectiveness of inquiry-realistic learning. Such studies would deepen understanding of how digital inquiry-based RME approaches can support 21st-century competencies in mathematics education.

4. CONCLUSION

This study culminates in the development of E-Miracle as a learning design that does not merely integrate technology into instruction but situates it within an inquiry-realistic pedagogical framework to support deep learning and the strengthening of students' 6C competencies. The findings suggest that the observed development of these competencies is closely related to how learning activities were structured, beginning from contextual problems, moving through cycles of inquiry, and supported by interactive representations that enabled students to test ideas, negotiate meaning, and gradually formalize their understanding. In this configuration, technology, particularly through the Scratch-based environment, functions as a cognitive and social mediator, rather than as an auxiliary tool, by making abstract relationships visible and enabling iterative exploration. From a theoretical standpoint, the study offers a nuanced contribution by showing that the convergence of inquiry processes and realistic mathematics principles can be effectively operationalized in a digital setting to foster both conceptual understanding and broader competencies associated with 21st-century learning. Nevertheless, the scope of implementation and the nature of the data warrant a cautious interpretation of the results, particularly in relation to their generalizability and long-term impact. These considerations point to the need for further studies that extend the context, duration, and methodological variation in order to more fully understand the potential and limitations of technology-supported inquiry realistic learning in mathematics education.

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Declarations

Author Contribution	: RA: Conceptualization, Resources, Visualization, Writing - original draft, and Writing - review & editing; TH: Methodology, Supervision, Validation, and Writing - review & editing; DD: Supervision, Validation, and Writing - review & editing; AJ: Supervision, Validation, and Writing - review & editing.
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REFERENCES

Alnasyan, B., Basheri, M., & Alassafi, M. (2024). The power of deep learning techniques for predicting student performance in virtual learning environments: A systematic literature review. *Computers and Education: Artificial Intelligence*, *6*, 100231. https://doi.org/10.1016/j.caeai.2024.100231

Anggraeni, P., Puspita, R. D., Sopandi, W., Maftuh, B., & Sunendar, D. (2022). Why 6 cs? The urgency of learning at elementary school. In *Proceedings of the 4th International Conference on Educational Development and Quality Assurance (ICED-QA 2021)*, (Vol. 650, pp. 35–41). https://doi.org/10.2991/assehr.k.220303.008

Ayuningtyas, W., Mardiyana, M., & Pramudya, I. (2019). Analysis of student's geometry reasoning ability at senior high school. *Journal of Physics: Conference Series*, *1188*(1), 012016. https://doi.org/10.1088/1742-6596/1188/1/012016

Barron, B., & Darling-Hammond, L. (2010). Prospects and challenges for inquiry-based approaches to learning. In H. Dumont, D. Istance, & F. Benavides (Eds.), *The nature of learning: Using research to inspire practice* (pp. 199–226). OECD.

Ceballos, H., Bogaart, T. v. d., van Ginkel, S., Spandaw, J., & Drijvers, P. (2026). How collaborative problem solving promotes higher-order thinking skills: A systematic review of design features and processes. *Thinking Skills and Creativity*, *59*, 102001. https://doi.org/10.1016/j.tsc.2025.102001

Fan, J.-Y., & Ye, J.-H. (2022). The effectiveness of inquiry and practice during project design courses at a technology university. *Frontiers in psychology*, *13*, 859164. https://doi.org/10.3389/fpsyg.2022.859164

Fauzan, A., Harisman, Y., Yerizon, Y., Suherman, S., Tasman, F., Nisa, S., Sumarwati, S., Hafizatunnisa, H., & Syaputra, H. (2024). Realistic mathematics education (RME) to improve literacy and numeracy skills of elementary school students based on teachers' experience. *Infinity Journal*, *13*(2), 301–316. https://doi.org/10.22460/infinity.v13i2.p301-316

Gravemeijer, K., & Cobb, P. (2006). Design research from a learning design perspective. In J. Van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 29–63). Routledge. https://doi.org/10.4324/9780203088364-12

Hakim, A. R., Asikin, M., & Nurcahyono, A. (2021). The development of learning module with mobile augmented reality based on 9E learning cycle to improve problem solving skills. *Unnes Journal of Mathematics Education Research*, *10*(1), 1–9.

Hidayat, W., & Aripin, U. (2023). How to develop an E-LKPD with a scientific approach to achieving students' mathematical communication abilities? *Infinity Journal*, *12*(1), 85–100. https://doi.org/10.22460/infinity.v12i1.p85-100

Hidayat, W., Aripin, U., & Widodo, S. A. (2025). Integration of ethno-modelling and 3N: An innovative digital worksheet framework to enhance students' mathematical critical thinking skills. *Infinity Journal*, *14*(4), 1019–1042. https://doi.org/10.22460/infinity.v14i4.p1019-1042

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 99–107. https://doi.org/10.1080/00461520701263368

Irawan, E., Kusumah, Y. S., & Saputri, V. (2023). Pengembangan multimedia interaktif menggunakan Scratch: Solusi pembelajaran di era society 5.0 [Interactive multimedia development using Scratch: Learning solutions in the era of society 5.0]. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *12*(1), 36–50. https://doi.org/10.24127/ajpm.v12i1.6226

Irdalisa, I., Paidi, P., & Djukri, D. (2020). Implementation of technology-based guided inquiry to improve TPACK among prospective biology teachers. *International Journal of Instruction*, *13*(2), 33–44. https://doi.org/10.29333/iji.2020.1323a

Iskrenovic-Momcilovic, O. (2020). Improving geometry teaching with Scratch. *International Electronic Journal of Mathematics Education*, *15*(2), em0582. https://doi.org/10.29333/iejme/7807

Johar, R., Annisa, D., Mailizar, M., Zubainur, C. M., Zubaidah, T., Usman, U., Indriyani, L., & Musa, M. (2025). Development of algebraic expressions e-modules through realistic mathematics education approach. *Infinity Journal*, *14*(4), 973–994. https://doi.org/10.22460/infinity.v14i4.p973-994

Kembara, M. D., Rozak, R. W. A., Maftuh, B., & Hadian, V. A. (2022). Research based learning to improve students 6C skills during the pandemic. In *Proceedings of the 4th Social and Humanities Research Symposium (SoRes 2021)*, (pp. 107–111). https://doi.org/10.2991/assehr.k.220407.020

Kokeb, A., Atnafu, M., & Mohammed, A. (2025). The effects of visually assisted guided discovery learning strategy on tenth grade students' problem solving skill of plane geometry. *Mathematics Teaching Research Journal*, *17*(2), 193–225.

Kumazah, V., & Agyei, D. D. (2025). Uncovering the power of inquiry-based teaching; Enhancing geometric thinking skills in students. *International Journal for Multidisciplinary Research (IJFMR)*, *7*(1), 1–18.

Larsen, S., & Lockwood, E. (2013). A local instructional theory for the guided reinvention of the quotient group concept. *The Journal of Mathematical Behavior*, *32*(4), 726–742. https://doi.org/10.1016/j.jmathb.2013.02.010

Latorre-Cosculluela, C., Suárez, C., Quiroga, S., Sobradiel-Sierra, N., Lozano-Blasco, R., & Rodríguez-Martínez, A. (2021). Flipped classroom model before and during COVID-19: using technology to develop 21st century skills. *Interactive Technology and Smart Education*, *18*(2), 189–204. https://doi.org/10.1108/itse-08-2020-0137

Listiawati, N., Sabon, S. S., Siswantari, S., Subijanto, S., Wibowo, S., Zulkardi, Z., & Riyanto, B. (2023). Analysis of implementing Realistic Mathematics Education principles to enhance mathematics competence of slow learner students. *Journal on Mathematics Education*, *14*(4), 683–700. https://doi.org/10.22342/jme.v14i4.pp683-700

Mulenga, E. M., Folokwe, K., & Hamankolo, M. (2025). Exploring indigenous teaching approaches for geometry instruction in three secondary schools within Zambia. *Mathematics Teaching Research Journal*, *17*(1), 153–192.

Palinussa, A. L., Tupamahu, P. Z., Sabandar, V. P., Makaruku, Y. H., & Sabandar, J. (2025). Realistic mathematics education: Mathematics e-modules in improving student learning outcomes. *Infinity Journal*, *14*(1), 45–64. https://doi.org/10.22460/infinity.v14i1.p45-64

Prananta, Y. R. (2021). Pengembangan model pembelajaran abad 21 berbasis media penanaman karakter bertema nilai-nilai Pancasila dan sadar konstitusi [Development of a 21st century learning model based on character building media with the theme of Pancasila values and constitutional awareness.]. *Jurnal Didaktika Pendidikan Dasar*, *5*(2), 375–398. https://doi.org/10.26811/didaktika.v5i2.213

Pratiwi, M. D., Putri, R. I. I., & Zulkardi, Z. (2022). Mathematics critical thinking ability materials social arrithmatic class VII assisted video animation in the era of COVID-19. *Infinity Journal*, *11*(2), 297–310. https://doi.org/10.22460/infinity.v11i2.p297-310

Prayogi, R. D., & Estetika, R. (2019). Kecakapan abad 21: Kompetensi digital pendidik masa depan [21st century skills: Digital competencies of future educators]. *Manajemen Pendidikan*, *14*(2), 144–151. https://doi.org/10.23917/jmp.v14i2.9486

Purnomo, Y. W., Nabillah, R., Aziz, T. A., & Widodo, S. A. (2024). Fostering mathematical connections and habits of mind: A problem-based learning module for elementary education. *Infinity Journal*, *13*(2), 333–348. https://doi.org/10.22460/infinity.v13i2.p333-348

Rosidin, U., Widyastuti, W., Kadaritna, N., & Handoko, H. (2024). The implementation of dynamic society oriented 6c skills assessment instruments in case method and team based project learning. *JISAE: Journal of Indonesian Student Assessment and Evaluation*, *10*(1), 22–31. https://doi.org/10.21009/jisae.v10i1.43879

Sahrudin, A., Pamungkas, A. S., Pagiling, S. L., & Rosdianwinata, E. (2025). Integration of abstraction theory and TPACK framework in geometry learning to optimize prospective mathematics teachers' spatial abilities. *Infinity Journal*, *14*(4), 899–918. https://doi.org/10.22460/infinity.v14i4.p899-918

Saryadi, W., & Sulisworo, D. (2023). Development of e-module based on the discovery learning to improve the student creative thinking skills. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, *7*(1), 11–22. https://doi.org/10.31764/jtam.v7i1.10185

Stevani, A. L., Tanujaya, B., & Widodo, S. A. (2025). Android-based mathematics learning media on geometry using the context of tourist destinations. *Mathematics Teaching Research Journal*, *17*(2), 60–79.

Suharta, I. G. P., Suparta, I. N., & Setiawan, K. A. (2025). Development of a 2D shape e-module based on project-based learning with Scratch to improve computational thinking skills. *International Journal of Education, Management, and Technology*, *3*(1), 242–262. https://doi.org/10.58578/ijemt.v3i1.4918

Sutarni, S., Sutama, S., Prayitno, H. J., Sutopo, A., & Laksmiwati, P. A. (2024). The development of realistic mathematics education-based student worksheets to enhance higher-order thinking skills and mathematical ability. *Infinity Journal*, *13*(2), 285–300. https://doi.org/10.22460/infinity.v13i2.p285-300

Swidan, O., & Arzarello, F. (2022). Adaptive instruction in an inquiry-based mathematics and digitally rich classroom – multiple perspectives. *The Journal of Mathematical Behavior*, *66*, 100962. https://doi.org/10.1016/j.jmathb.2022.100962

Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J.-M., Morisseau, T., Bourgeois-Bougrine, S., Vinchon, F., El Hayek, S., Augereau-Landais, M., Mourey, F., Feybesse, C., Sundquist, D., & Lubart, T. (2023). Creativity, critical thinking, communication, and collaboration: Assessment, certification, and promotion of 21st century skills for the future of work and education. *Journal of Intelligence*, *11*(3), 54. https://doi.org/10.3390/jintelligence11030054

van den Akker, J. (2013). Curricular development research as a specimen of educational design research. In T. Plomp & N. Nieveen (Eds.), *Educational design research part A: An introduction* (pp. 52–71). Netherlands Institute for Curriculum Development (SLO).

Wijaya, T. T., Hidayat, W., Hermita, N., Alim, J. A., & Talib, C. A. (2024). Exploring contributing factors to PISA 2022 mathematics achievement: Insights from Indonesian teachers. *Infinity Journal*, *13*(1), 139–156. https://doi.org/10.22460/infinity.v13i1.p139-156

Yumiati, Y., Putra, H. D., & Haji, S. (2024). Blended online learning: Students' perception and its effect on learning outcomes abstract algebra. *Infinity Journal*, *14*(1), 65–84. https://doi.org/10.22460/infinity.v14i1.p65-84

Zafrullah, Z., Arriza, L., Rashid, S., Mwakapemba, J. L., Santos, M. D., & Rasheed, U. (2025). Research trends on deep learning for mathematics learning in scopus database: Concept map & emerging themes using scopus AI. *Elementaria: Journal of Educational Research*, *3*(1), 132–142. https://doi.org/10.61166/elm.v3i1.93

Zhengtao, Z., & Hidayat, R. (2025). The effects of augmented reality (AR) toward achievement on the graphs and geometry topic among third-grade students. *Mathematics Teaching Research Journal*, *17*(1), 82–98.