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DEVELOPMENT OF ANDROID-BASED MATHEMATICS E-MODULE WITH SCIENTIFIC APPROACH TO ENHANCE PROBLEM-SOLVING SKILLS

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Abstract

The research is designed to implement an Android mathematics e-module integrated with a scientific approach to uplift the students' skills in problem solving mathematically, especially in Grade XI. The basis of this research was for a more interactive and contextual learning media that could respond well to the novelty of digital native learners and the demands of 21st-century education. The Educational Design Research (EDR) method using the Plomp model was applied in this study. The study went through three major phases of the research process: preliminary research, prototyping, and assessment. The e-module was validated by experts as well as being practically and effectively tested through individual, small group, and large group evaluations and teacher responses. The findings showed that the e-module met validity criteria in terms of content, language, and design. Practicality was indicated from students and educators-to use it conveniently, and interesting from visual display, effective in arranging the contents systematically. Effectiveness testing also showed significant improvement in students' capabilities in solving mathematics problems through posttest scores and N-Gain results. The scientific phases of observing, questioning, experimenting, reasoning, and communicating were implemented within the Android platform, successfully fostering critical thinking as well as independence and meaningful learning. In conclusion, the e-module developed is a pedagogically sound and technologically accessible learning medium, geared towards developing higher-order thinking skills in mathematics, thus providing a valid alternative to classroom instruction.

Keywords: *Android Based E-Module; Mathematics Learning; Scientific Approach; Senior High School.*

Abstrak

Penelitian ini bertujuan untuk mengembangkan e-modul matematika berbasis Android yang terintegrasi dengan pendekatan saintifik guna meningkatkan kemampuan pemecahan masalah matematis siswa kelas XI. Penelitian ini dilatarbelakangi oleh kebutuhan akan media pembelajaran yang interaktif dan kontekstual, sesuai dengan karakteristik peserta didik era digital serta tuntutan pembelajaran abad ke-21. Metode yang digunakan adalah Educational Design Research (EDR) dengan model Plomp yang meliputi tiga tahap utama yaitu penelitian pendahuluan, pengembangan atau prototipe, dan penilaian. E-modul yang dikembangkan divalidasi oleh para ahli dan diuji keterpraktisan serta efektivitasnya melalui evaluasi individu, kelompok kecil, kelompok besar, dan tanggapan guru. Hasil penelitian menunjukkan bahwa e-modul memenuhi kriteria valid dari segi isi, bahasa, dan desain tampilan. Uji kepraktisan menunjukkan bahwa e-modul mudah digunakan, menarik secara visual, serta mampu menyajikan materi secara sistematis. Uji efektivitas menunjukkan peningkatan signifikan dalam kemampuan pemecahan masalah matematis siswa, tercermin dari skor posttest dan hasil N-Gain. Integrasi tahapan saintifik seperti mengamati, menanya, mencoba, menalar, dan mengomunikasikan dalam platform Android berhasil membentuk keterampilan berpikir kritis, kemandirian, dan pembelajaran yang bermakna. Dengan demikian, e-modul yang dikembangkan merupakan media pembelajaran yang layak, mudah diakses, dan mendukung penguatan keterampilan berpikir tingkat tinggi dalam matematika serta menjadi alternatif pembelajaran yang relevan dan inovatif.

***Kata kunci**: E-Modul Berbasis Android; Pembelajaran Matematika; Pemecahan Masalah; Pendekatan Saintifik; SMA*

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INTRODUCTION

In the present era of rapid technological development, the education sector is undergoing a major transformation to meet the demands of the 21st century(Alenezi et al., 2023). Students are now expected not only to master academic content, but also to develop problem-solving skills, creativity, critical thinking, and technological literacy. In this context, the integration of information and communication technology (ICT) into education has become a necessity rather than an option. Mathematics, often perceived as abstract and difficult by students, requires the support of innovative media that can facilitate more engaging and interactive learning experiences (Yuniarti et al., 2022).

Android-based e-modules, as a form of mobile learning, have emerged as a promising solution to support these goals. These digital resources allow students to access instructional content independently and flexibly, beyond the constraints of classroom time and teacher availability (Firdayati et al., 2021). Their interactivity and mobility promote autonomous learning and, when designed effectively, have been shown to enhance learning motivation (Nasrulloh et al., 2024). This is especially relevant for senior high school students, who are already familiar with smartphone usage and digital environments (Widodo et al., 2024).

Mathematics education aims not only to help students master mathematical concepts but also to develop problem-solving skills that can be applied in real life (Chau et al., 2025; Cotič et al., 2024). These skills are recognized as core competencies essential for cultivating higher-order thinking abilities required in both academic and professional contexts.

Despite its importance, problem-solving remains a skill that many students struggle to master. According to PISA 2022, the average mathematical literacy score for Indonesian students was 366 significantly below the OECD average of 489. Although Indonesia improved its ranking slightly from 73rd to 69th among 81 participating countries, persistent challenges in mathematical modeling and reasoning remain. Indonesian students frequently encounter difficulties in translating real-world problems into mathematical models, applying appropriate concepts and procedures, and interpreting results in context (Putri et al., 2024).

Several studies have highlighted that digital learning tools are more effective when integrated with pedagogical strategies such as the scientific approach. This approach which involves observing, questioning, collecting data, reasoning, and communicating is consistent with constructivist learning theory and has been shown to significantly enhance critical thinking and problem-solving abilities (Atika et al., 2020; Handayani et al., 2022).

For example, Taufiqurrahman and Hidayat (2023) demonstrated that a problem-based learning (PBL) model integrated with a scientific approach improved both students' problem-solving skills and self-efficacy in junior high school. Students in the experimental group scored substantially higher than those in the control group, with a gain of 0.57 compared to 0.40, highlighting the effectiveness of inquiry-based learning environments.

In higher education, Arifin et al. (2021) introduced the Interactive Mobile Mathematics Inquiry (IMMI) platform, based on scientific inquiry learning. Their findings showed that the platform enhanced students' ability to

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plan and implement mathematical problem-solving strategies. IMMI integrates phases such as orientation, conceptualization, investigation, and discussion, creating a learning environment that emphasizes reasoning, evaluation, and student agency in solving real-world mathematical problems.

Previous research by Asmianto et al. (2022) developed an interactive Android-based e-module for teaching trigonometry. The results of the trial indicated that the e-module had excellent validity and was effective in enhancing student motivation and understanding of trigonometric concepts.. These findings further confirm the potential of mobile, constructivist-based learning tools to support meaningful engagement and cognitive transfer in mathematics learning.

Despite these promising developments, many existing e-modules remain limited. Most emphasize procedural learning and offer minimal opportunities for students to explore alternative strategies, connect concepts, or engage in metacognitive reflection (Firda et al., 2023). Additionally, the majority of studies have targeted elementary or junior high school populations, leaving a notable gap in research addressing the specific needs of senior high school students particularly concerning higher-order cognitive demands such as non-routine problem solving (Wahyuni et al., 2025).

Field observations further reveal a paradox: although most senior high school students own smartphones, their problem-solving performance remains weak. National classroom assessments indicate that many students are unable to apply structured steps effectively when confronted with unfamiliar mathematical problems. This highlights the urgent need for digital learning tools that are not only technologically sophisticated but also pedagogically sound.

In response to this need, the present study aims to develop an Android-based mathematics e-module embedded with the scientific approach, specifically designed for Grade XI learners. The module will be developed using a systematic research and development (R&D) framework to ensure its content validity, pedagogical alignment, and feasibility for classroom integration. Unlike traditional instructional materials, this e-module will guide students through the stages of scientific reasoning while allowing them to interact with digital content in ways that promote exploration, reflection, and deeper conceptual understanding.

Theoretically, this study contributes to the advancement of constructivist instructional media by embedding the scientific approach into mobile learning environments. Practically, the resulting e-module is intended to serve as an engaging, accessible, and curriculum-aligned learning resource for senior high school students. This innovation seeks to bridge the gap between technology and pedagogy, addressing both cognitive and affective learning outcomes in mathematics.

METHODS

This study employed a research and development (R&D) approach, aiming to produce a scientific approach-based mathematics e-module that enhances students' mathematical problem-solving abilities. The research was conducted using the Educational Design Research (EDR) framework developed by Plomp & Nieveen (2013), which consists of three iterative and interconnected stages: preliminary

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investigation, prototyping (design and development), and assessment. In the preliminary phase, a series of literature reviews, curriculum analyses, teacher interviews, and classroom observations were conducted to identify the needs and problems encountered in mathematics learning, particularly in the topic of sequences and series. These findings informed the instructional design specification of the e-module.

In the design and development phase, the module was developed according to the five learning steps of the scientific approach observing, questioning, experimenting, associating, and communicating integrated with interactive digital components. The initial product was validated by experts in mathematics education, revised accordingly, and tested in a limited classroom environment for formative feedback and refinement. In the assessment phase, the final version of the module was implemented with students to evaluate its practicality and effectiveness in improving problem-solving performance.

The research was conducted at SMAN 5 Sijunjung, West Sumatra, Indonesia, from March to July 2025, involving 32 students of Grade XI. The sample was selected purposively based on academic performance levels and teacher recommendations to ensure representativeness. The topic developed in the module "Matrix" was chosen due to its abstract nature and strong relevance to mathematical reasoning and higher-order thinking.

Data were collected using several instruments: expert validation sheets, classroom observation sheets, teacher and student questionnaires, and mathematical problem-solving tests administered as pretest and posttest. The expert validation sheets measured content, construct, and language validity using a five-point Likert scale. Observation sheets were used to monitor the fidelity of module implementation and classroom interaction patterns. Questionnaires captured responses on practicality aspects such as clarity, usability, and engagement. The mathematical problem-solving test consisted of five open-ended questions developed according to Polya's problem-solving stages and reviewed by experts. The test was piloted on 30 students outside the sample to estimate reliability, resulting in Cronbach's Alpha = 0.82.

Students' responses to the problem-solving test were scored using a detailed rubric consisting of four aspects: understanding the problem, devising a plan, carrying out the plan, and looking back. Each aspect had criteria with score levels ranging from 0 to 3 (except carrying out the plan, scored 0–5), with a total maximum score of 13 . The complete rubric is presented in Table 1.

Table 1. Rubric for mathematical problem-solving ability test

Aspect	Criteria	Score
Understanding the Problem	Clearly states the known and asked information, or represents it correctly in a sketch	3
	States all known information with one minor error and correctly identifies the question	2
	Only identifies the question correctly without stating known information	1
	Incorrectly states or omits both known and asked information	0

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Aspect	Criteria	Score
Devising the Plan	Accurately and completely outlines the steps to solve the problem	3
	Outlines the steps with one error in the final step	2
	Provides only one correct step in the plan	1
	All steps are incorrect or no steps are written	0
Carrying Out the Plan	Solves the problem systematically and correctly	5
	Solves the problem systematically and completely, but with an incorrect final result	3
	Solution is incomplete and final result is incorrect	1
Looking Back	Reviews the solution and provides justification	2
	Reviews the solution without providing justification	1
	Does not review the solution or the review is incorrect	0
Maximum Score		**13**

To analyze the content validity of the instruments, using the formula 1:

$$V = \frac{\sum s}{n(c-1)} \qquad (1)$$

Information:
V : Validity Score
S : $\sum s\,(s = r - lo)$
lo : The lowest validity rating score
r : The number given by an appraiser
c : The highest validity rating score
n: Number of items

To interpret the results of expert validation, a classification scale is needed to determine the level of content validity achieved. This classification enables researchers to decide whether an instrument or product is suitable for further use, revision, or rejection. Table 2 provides the classification criteria used to interpret the Aiken's V coefficient, indicating whether the module is categorized as valid or not based on expert agreement scores (Kania et al., 2024).

Table 2. Aiken's V validity classification

Achievement Level	Category
$\geq$ 0,6	Valid
$<$ 0.6	Invalid

Based on this classification, any Aiken's V value equal to or greater than 0.60 indicates acceptable content validity, suggesting that the item or instrument is suitable for implementation with minimal revision.

To determine the level of practicality of the developed module, data from teacher and student questionnaires were analyzed using a percentage formula (Riduwan, 2022). This calculation is based on the proportion of favorable responses specifically the number of "agree" or "strongly agree" responses to each item. The practicality percentage (P) was computed using the formula 2:

$$P = \frac{f}{N} \times 100\% \qquad (2)$$

where (f) is the number of respondents giving favorable responses and (N) is the total number of respondents.

The interpretation of the practicality percentage requires reference to a standardized set of criteria to determine the degree to which the developed module is considered usable in classroom settings. These criteria help categorize the module as highly practical, practical, fairly practical, or otherwise, based on user feedback. Table 3 presents the classification thresholds used to interpret the practicality scores derived from the questionnaire responses.

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Table 3. Practicality criteria

Score Range	Criteria
80% < x ≤ 100%	Highly Practical
60% < x ≤ 80%	Practical
40% < x ≤ 60%	Fairly Practical
20% < x ≤ 40%	Less Practical
0% < x ≤ 20%	Not Practical

Based on this classification, a practicality score exceeding 80% indicates that the module is considered highly practical and suitable for classroom use without major revisions.

To evaluate the effectiveness of the developed e-module, students' learning outcomes were compared using their pretest and posttest scores. The analysis employed the normalized gain (N-Gain) formula, which measures the relative improvement in performance by accounting for students' initial understanding. This approach is suitable for determining the extent of learning gain as a proportion of the maximum achievable score. The formula 3 used is as follows:

$$g = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Max possible score} - \text{Pretest score}} \quad (3)$$

As shown in Table 4, the normalized gain index (g) is used to interpret the effectiveness of student learning outcomes. The classification scale categorizes gain values into levels such as low, medium, and high, providing a clear benchmark for evaluating the impact of the developed e-module.

Table 4. Categories of normalized gain index values

Gain Index (g)	Category
(g) ≥ 0.70	High
0.30 ≤ (g) ≥ 0.70	Medium
(g) < 0.30	Low

In addition to measuring individual learning gains, the effectiveness of the module was also evaluated at the classroom level through a classical completeness criterion. This approach assesses the proportion of students who successfully reach the minimum mastery threshold, allowing for evaluation of the module's collective instructional impact. The percentage of students achieving mastery was calculated using the formula 4:

$$KK = \frac{JT}{JS} \times 100\% \quad (4)$$

where (JT) is the number of students who achieved the minimum score (9 or more), and (JS) is the total number of students. A module is considered instructionally effective at the class level if at least 75% of the students reach this threshold, as suggested by Rohmawati (2017). This measure ensures that the learning product not only benefits individuals but also performs well across a group setting.

RESULTS AND DISCUSSION

Developing a mathematics e-module based on a scientific approach and supported by Android technology for Grade XI senior high school students should take a systematic procedure consisting of the preliminary investigation, design and prototyping, and assessment phases adapted according to the needs of this research, based on the Plomp model. This development is expected to produce an e-module for enhancing students' mathematical problem-solving skills in accordance with the demands of 21st-century education and the characteristics of scientific learning. Based on the defined objectives and development stages, the following research data were obtained.

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Findings of Preliminary Research

The initial analysis of challenges faced in learning mathematics subject, especially in the grade XI level of senior high school, is in relation to the quality of instructional media in supporting student's autonomy as well as higher-order thinking. The learning process is still teacher-centered and has not enabled to involve students actively in most cases. It was reported by the teachers that learning outcomes of students were mostly poor and many of them did not meet the minimum mastery criterion predetermined. Worst of all, such was worsened by the fact that learning media have been quite limited in addressing the need for flexible and contextual experience in learning.

Most students, already having their own android phones, are eager for more digital learning materials. Unfortunately, until now there hasn't been a structured and readily assessable e-module with a scientific approach that can be used in combination with mobile media. Furthermore, the implementation of scientific methods in teaching mathematics has not been fully realized either, mainly because of time constrain into the lesson, not many students were actively involved in stages of scientific learning, and also because the absence of media leading them in this process in independent and systematic ways impacted the failure of such condition.

These arrangements specify that matrices form part of the learning objectives for the Grade XI content, with a focus on conceptual understanding and real-world problem-solving skills. Such a topic is best designed as an e-module because of needing a gradual and coherent conceptual understanding process through scientific learning observing, questioning, reasoning, experimenting, and communicating systematically organized within concepts into four lessons. Such a seamless flow would help students connect the lessons within intersubtopics and know how to apply them effectively in problem-solving.

According to Piaget's theory, the students are currently at the formal operational stage. They think abstractly, reason logically, and solve problems systematically. There is a consistent urgency, based on the analysis of the need, curriculum and content analysis, and also learner characteristics, about developing mathematics e-modules based on scientific approaches and supported by Android technology: improving quality for mathematics education-as-applicable, meaningful context and efficacious means-for-enhancing mathematical problem solving by students.

Development or Prototyping Phase Results

The product designed in this study is a mathematics e-module based on the scientific approach and supported by Android technology.

1) Cover page

As shown in Figure 1,the e-module cover is designed to be informative, featuring the title, target users (Grade XI Science students, matrix topic), and a “Start” button leading to the main menu. The dominant use of blue and white colors aims to create a harmonious and visually appealing appearance.

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Figure 1. Cover Page

2) Main Menu

As shown in Figure 2, the main menu of the e-module consists of navigation buttons, each serving a specific function, including usage instructions, profile, introduction, materials, and evaluation. The main menu page is presented with a white background, complemented by blue and pink accent colors.

Figure 2. Main menu display

3) User Guide

As shown in Figure 3, the user guide section of the e-module aims to provide students with information on how to use the e-module effectively, including explanations of the functions of each navigation button within the module.

Figure 3. User guide display

4) Developer Profile

As shown in Figure 4, the developer profile display in the scientific approach-based mathematics e-module presents the developer's identity. This page includes a photo of the developer and a home button that redirects users back to the main menu.

Figure 4. Developer Profile Display

5) Learning Objectives

As shown in Figure 5, the learning objectives display is designed to inform students about the expected learning outcomes to be achieved throughout the instructional process.

Figure 5. Learning objectives display

6) Material Menu

As shown in Figure 6, the material menu display in the e-module contains navigation buttons that provide access to lesson content organized across four instructional meetings.

Figure 6. Material menu display

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7) Learning Activities

As shown in Figure 7, the learning activities are designed using a scientific approach, incorporating content explanations, example problems, and practice exercises. The display of the learning activity on matrix material features the first stage of the scientific approach, namely the observing phase, applied to the topic "Definition of Matrix".

Figure 7. Learning activity display

8) Instructional Videos

As shown in Figure 8, this section contains instructional videos related to the lesson content, aimed at helping students better understand complex concepts. The video button is available within the scientific approach stage, specifically under the collecting information phase.

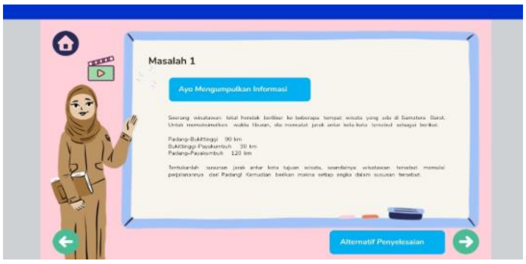

Figure 8. Instructional video display

9) Evaluation

As shown in Figure 9, the evaluation display in the e-module features navigation buttons related to matrix material. The evaluation section includes multiple-choice (objective) questions for meetings 1 to 3 and essay questions for meeting 4, which must be completed by the students

Figure 9. Evaluation display

Validity test

Validity testing becomes an important step in making an instructional material to match a product with the standards of content accuracy, the effectiveness of visual presentations, and the appropriateness of language. This study assesses the validity of the Android-based mathematics e-module developed through scientific approa to enhance problem-solving skills of Grade XI students using three experts: one a mathematics education expert, an educational technology expert, and a linguistics expert. As shown in Table 5, the expert validation results cover three critical aspects: mathematical content, graphical design, and language use. These aspects are assessed to ensure that the developed e-module meets academic standards in accuracy, visual appeal, and clarity of communication. The table presents the average scores given by expert reviewers for each aspect, reflecting the overall validity level of the instructional material.

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Table 5. Results of the e-module validity assessment by experts

No	Assessed Aspect	Validity Score	Category
1	Mathematical Content Validity	0.85	Valid
2	Graphical Design Validity	0.81	Valid
3	Language Validity	0.92	Valid
	Average Validity Score	**0.89**	**Valid**

Practicality test

1) Results of the One-to-One Practicality Evaluation

The one-to-one practicality evaluation was intended to determine the extent to which the developed Android-based mathematics e-module could be effectively and efficiently used in the individual learning route of students. It included such dimensions as user instruction, attractiveness, easy use, time efficiency, and content equivalence. The results showed that

The scientific approach-built e-module is categorized as very practical with an average indicator score of 84%. In particular, user instruction, attractiveness, ease of use, and content equivalence scored above 80% with a classification 'very practical' while time efficiency scored 78% under 'practical'. These results mean that the e-module is not only attractive and easy to navigate, but it has also been equivalently effective in delivering content and supporting students' individual learning pathways.

2) Results of the Small Group Practicality Evaluation

To evaluate small group practicum, further investigation was undertaken into the effectiveness and usability of the Android-based mathematics e-module within a tightly controlled environment. The assessment focused on five criteria: user instructions, attractiveness, ease of use, time efficiency, and content equivalence. The e-module was rated as highly practicable with an overall mean indicator achievement of 82.6%. With regard to user instructions (87%), attractiveness (88%), ease of use (82%), and content equivalence (80%), these aspects were classified as highly practicable, while time efficiency received a 76% rating and was categorized as practicable. Altogether these findings suggest that students received the e-module well in small group settings, which provided instructional guidance, was visually appealing, and was easy to navigate and content delivered. Nonetheless, time efficiency leaves room for improvement, which could further increase the quality of the learning experience.

3) Results of the Practicality Evaluation Based on Educator Responses

It is an evaluation of practicality based on educators' responses to try to assess how practical an Android-based e-module for mathematics is according to teaching professionals. The evaluation is measured under five main aspects, which are user instruction, attractiveness, ease of use, time saving, and content equivalancy. The averages show that the indicators achieved an average of 79.4%, thus making the e-module practical as a whole. Among the aspects evaluated: user instruction (80%) and attractiveness (85%) are very practical, which makes them refer to the clear guidance provided by the module and its appealing visual designs; ease of use (79%), time efficiency (75%), and content equivalent (78%) are considered

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practical. These reflect that practically educators must consider it feasible and functional. It is accessible and visually enticing; further refinements in other dimensions, especially regarding efficiency of operation and learning content delivery, would improve classroom functionality in this delivery mode.

4) Results of the Practicality Evaluation Based on Learner Responses in the Large Group

A large group setting practical evaluation was carried out through student responses to determine how far the Android-based mathematics e-module can be put to practical use by a much larger population of students. The evaluation encompasses five assessed aspects: user instructions, attractiveness, ease of use, time efficiency, and content equivalence. The results reflected an overall high average indicator achievement of 88.6% across all aspects rated as extremely practical. Specifically, user instructions scored 90%, attractiveness 93%, ease of use 88%, time efficiency 85%, and content equivalence 87% were rated as very practical. These findings suggest that students perceived the e-module positively in terms of clarity, visual appeal, usability, time efficiency, and content consistency- all factors which augur well for its implementation on a large scale in classrooms.

Effectiveness test

The use of the Android-based mathematics e-module constructed under the scientific approach was found to be effective in introducing improvement in students' abilities to solve mathematical problems. This effectiveness is seen in score improvement from the pretest to the posttest. The highest score possible for this test was 13, and the lowest score for minimum mastery (KKM) was designated at 9. As shown in Table 6, the results of the mathematical problem-solving test are summarized based on the normalized gain (N-gain) scores. The table displays pretest and posttest values, along with gain classifications, which illustrate the level of improvement in students' problem-solving skills after using the developed e-module.

Table 6. Mathematical Problem-Solving Skills Results Based on N-Gain Score

Test	Lowest Score	Highest Score	Average Score	<g>	Criteria
Pretest	3	11	6.4	0.61	Medium
Posttest	8	13	11.1		

As shown in Table 6, the gain score (<g>) of 0.61 indicates a moderate improvement in students' mathematical problem-solving skills. Students who obtained a posttest score of 9 or above were categorized as having achieved mastery. The analysis revealed that 26 out of 30 students (86.67%) met or exceeded the mastery level, while 4 students were still below the threshold. This corresponds to a classical mastery level of 86.67%, which surpasses the 75% criterion suggested by Rohmawati (2017) for declaring the learning intervention effective. Therefore, the Android-based scientific approach e-module is considered effective in enhancing students' mathematical problem-solving abilities.

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Of crucial importance in modern mathematics education is improving students' mathematical problem solving at the secondary school level. This study has shown that the Android-based e-module development with a scientific approach effectively serves this goal, integrating the convenience of digital technology into a structured, systematic thinking framework (Heryana et al., 2022. Active learning is transferred from passive habits to providing both downloadable material and independent learning space.

By offering a medium for the e-module distribution, the Android platform derives its strategic advantage by embeddment in every part of the students' lives. The digital-native generation is naturally familiar with mobile devices, as makes learning more practical and available any time and anywhere. Such students can go back to the concepts and practice independent problem-solving after classroom hours, which gives them many times to sharpen their analytical thinking patterns (Aladin et al., 2024).

Thus, one strength of the e-modules would probably lie within the scientific approach applied when designing the e-modules. The five scientific stages of observing, questioning, experimenting, reasoning, and communicating serve as a scaffold that qualifies students in breaking down problems logically and verifiably into various steps. This habit of thinking step by step is crucial in mathematics, where deeply-founded concepts and proofs of ideas are the major concern (Hamidah et al., 2022).

As reflected in understanding scientific learning with digital media, Gunawan et al. (2024) state that this helps students learn independently. Through the Android-based e-module, students have been taught not just to acquire information passively; instead, they learn to engage actively in applying the scientific stages through context-oriented exercises. Therefore, such technical skills would be developed not only competency but with sustained reasoning over time and patterns.

Constructed educational materials may not be presented in a manner that impairs critical thinking. According to Kusuma and Mujiono (2019), an Android-based e-module with a scientific approach fulfills this need by including both theoretical content and a sequence of organized practice problems necessitating students to construct logical, sound solutions. Thus, exercises are solved through clear reasoning rather than pure memory exercises.

Another strength of the e-module would be flexibility for the enrichment of content. The Android platform provides teachers with the opportunity to easily update materials, add new variations of questions, or include interactive explanations. According to Juniarti et al. (2019), learning resources based on scientific approaches significantly encourage students' participation because students have to collect and analyze the data before arriving at a conclusion. This complements developing skills dealing with solving problems by exposure rather than rote memorization.

Gozali et al. (2022)show empirical evidence that well-structured exercises help students understand problem patterns, deconstruct questions, and test solutions. The Android-based e-module provides such an exercise by leading students through gradual practice that builds their ability to plan and carry out their problem-solving strategies step by step.

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Besides that, Retnowati et al. (2018)realize the importance of developing problem-posing habits in students as one of the higher-order thinking skills. The scientific approach-oriented e-module is relevant in giving students an opportunity to solve questions as well as understanding how to design problems and how to make them manageable systematically.

The tiered exercises supporting HOTS (Higher Order Thinking Skills) showed to be beneficial in helping students break down complex problems into more achievable parts from multiple perspectives in the work of Tobing et al. (2022). However, the Android platform enables learners to try all of these outside school hours, extending their periods of learning and hence again developing their critical thinking.

An Android-based e-module overcomes the time constraints of conventional mathematics, face-to-face instruction. Hence students can, using structured exercises associated with the scientific approach, consolidate those independent understandings. General explanations happen within the classroom; however, their detailed practice occurs with their mobile devices outside the classroom.

Different views result in analyzing questions through the scientific method instead of employing logical steps that only rely on single-answer shortcuts, states Gunawan and Setyaningrum (2024). This means that rather than automatically being formed through habit, mathematical problem-solving faculties are built according to a consistent habit of reasoning step by step.

Hamidah et al. (2022) assert that the scientific approach is not a mere theoretical framework; it is a practical approach with which students are trained to reason logically in going from observations to conclusions. Android technology adds a benefit in providing access to learning stages at any time that students may need reinforcement of what they have previously learned.

Heryana et al. (2022) further contend that the Android solves the problem of limitations in printed materials. Digital distribution of practicum enhances students' practice opportunities to strengthen their skills in problem-solving, while teachers can monitor student engagement without physical barriers.

In summary, the synergy of Android, the e-module, and the scientific approach has indeed proven to be mutually reinforcing. All three conditions match the demands in mathematics learning as they are now, ensuring that students do not just memorize formulas but develop in-depth reasoned structures for the purposes behind responsibility and systematic problem solving when approaching mathematical problems.

CONCLUSION AND SUGGESTION

This study aimed to develop an Android-based mathematics e-module integrated with a scientific approach to enhance problem-solving skills in Grade XI students. Based on the findings, the developed e-module met the validity criteria in terms of content, graphic design, and language, and demonstrated a high level of practicality based on feedback from students and teachers. The implementation of the scientific approach within the module successfully improved students' problem-solving abilities, as evidenced by the significant improvement in posttest scores. The effectiveness analysis showed that the e-module

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effectively enhanced students' problem-solving skills, with a success rate of 86.67%, surpassing the minimum mastery threshold of 75%. These findings confirm that the Android-based e-module with the scientific approach is an effective alternative for enhancing critical thinking and mathematical problem-solving skills among students.

Based on the findings, the development of the Android-based e-module with the scientific approach should be expanded to include other relevant mathematical topics aligned with the curriculum to diversify the learning experience. Additionally, while the e-module has been rated as practical and effective, improvements in time efficiency and user convenience should be a key focus for enhancing the overall user experience, particularly in terms of navigation speed and ease of use. Further research should be conducted to implement this e-module on a larger scale, involving more schools and students, to test the sustainability and generalizability of these findings in various educational contexts. Future studies could also explore the integration of other technologies, such as augmented reality (AR) or virtual reality (VR), to enrich student interaction and engagement in mathematics learning.

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