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INTEGRATION OF SRL AND PROBING PROMPTING IN MODULES TO IMPROVE STUDENTS' MATHEMATICAL REASONING SKILLS

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Abstract

The Indonesian government has continued to work toward improving the quality of learning by emphasizing the development of 21st century skills, particularly higher order thinking skills. However, students' mathematical reasoning skills remained relatively low, indicating a need for teaching materials capable of facilitating their development. This study aimed to develop a mathematics learning module based on self-regulated learning (SRL) and probing prompting that proved valid, practical, and effective in enhancing students' mathematical reasoning skills. The study used the R&D method with the ADDIE model, comprising the Analyze, Design, Develop, Implement, and Evaluate stages. The research subjects were 29 students of Class X E-9 at SMA Negeri 3 Purwokerto. The results of expert validation showed average scores of 3.76 for the media aspect and 3.80 for the content aspect, both of which fell within the valid category. Practicality testing showed an average score of 3.31 from student responses and 3.91 from teacher responses, both falling within the practical category. Effectiveness testing using N-Gain was dominated by the moderate category (79.3%), further supported by a paired t-test with a significance value of 0.00 (< 0.05), confirming a significant difference between pretest and posttest scores. These findings indicated that the module made a positive learning impact on the improvement of students' mathematical reasoning skills. It was therefore concluded that the developed module qualified as valid, practical, and effective, making it suitable for use as a teaching resource to improve students' mathematical reasoning skills.

Keywords: Learning Module, Mathematical Reasoning, Probing-Prompting, Self-Regulated Learning

Abstrak

Pemerintah Indonesia terus berupaya meningkatkan mutu pembelajaran dengan menekankan pengembangan keterampilan abad ke-21, khususnya kemampuan berpikir tingkat tinggi. Namun, kemampuan penalaran matematis peserta didik masih tergolong rendah, sehingga diperlukan bahan ajar yang mampu memfasilitasi pengembangannya. Penelitian ini bertujuan mengembangkan modul pembelajaran matematika berbasis self-regulated learning (SRL) dan probing prompting yang valid, praktis, dan efektif dalam meningkatkan kemampuan penalaran matematis peserta didik. Penelitian menggunakan metode Research and Development (R&D) dengan model ADDIE, meliputi tahap Analyze, Design, Develop, Implement, dan Evaluate. Subjek penelitian adalah 29 peserta didik kelas X E-9 SMA Negeri 3 Purwokerto. Hasil validasi ahli menunjukkan rata-rata skor 3,76 pada aspek media dan 3,80 pada aspek materi, keduanya berkategori valid. Hasil uji kepraktisan menunjukkan rata-rata skor 3,31 dari respon peserta didik dan 3,91 dari respon guru, keduanya berkategori praktis. Hasil uji keefektifan dengan N-Gain didominasi kategori sedang (79,3%), diperkuat uji t berpasangan dengan nilai signifikansi 0,00 (< 0,05), menunjukkan perbedaan signifikan antara skor pretest dan posttest. Temuan ini mengindikasikan modul memberikan kontribusi positif (positive learning impact) terhadap peningkatan kemampuan penalaran matematis peserta didik. Dapat disimpulkan bahwa modul yang dikembangkan telah memenuhi kriteria valid, praktis, dan efektif, sehingga layak digunakan sebagai bahan ajar untuk meningkatkan kemampuan penalaran matematis peserta didik.

Kata kunci: Modul Pembelajaran, Penalaran Matematis, *Probing Prompting, Self-regulated Learning*

INTRODUCTION

Through its current education policies, the Indonesian government continues to improve the quality of learning across all levels of education, emphasizing the development of 21st century skills, especially higher order thinking (Dewi, 2019). Mathematics plays a

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central role in helping students develop the ability to think logically, critically, systematically, analytically, and creatively (Rahmatika & Waluya, 2023). As a form of higher order thinking, mathematical reasoning underlies mathematics learning—helping students grasp abstract concepts, solve problems systematically, and apply mathematics across real life contexts (Syafa'atun, 2024)—and shapes how students understand concepts and arrive at conclusions Riswari et al. (2024) , mattering for both academic achievement and navigating real world problems (Rahmatika & Waluya, 2023).

However, Indonesian students' mathematical achievement remains low, as reflected in the declining 2022 PISA score of 366 (OECD, 2023). This is consistent with Asdarina & Ridha (2020) and Isnaeni et al. (2018), who both reported weak mathematical reasoning—particularly in forming conjectures, carrying out mathematical manipulation, constructing proofs, justifying reasoning, and drawing logical conclusions.

An unstructured interview with a teacher at SMA Negeri 3 Purwokerto confirmed this, attributing it largely to teacher-centered, lecture-based instruction that leaves little room for students to construct their own understanding—compounded by printed textbooks that emphasize information delivery over reasoning development (Haryonik & Bhakti, 2018).

One way to make mathematics learning more meaningful and strengthen mathematical reasoning is by developing a learning module (Husniah & Azka, 2022)—instructional material that is systematically designed with usage instructions, organizing content into a structured learning experience students can work through independently or with guidance (Famulaqih & Lukman, 2024).

Self-regulated learning (SRL) is an individual's ability to organize and control their own learning process—planning strategies, implementing them, and evaluating achievement. Zimmerman (2000) describes SRL as occurring in three phases—forethought, performance, and self-reflection—requiring students to continuously monitor their own thinking. These phases align with mathematical reasoning, which likewise requires formulating conjectures, examining solution steps, and drawing valid conclusions—essentially forms of cognitive regulation (Napitupulu et al., 2016; Rudtin et al., 2017). Probing-prompting is similarly effective for developing reasoning, relying on a sequence of questions that draw out and guide students' understanding (Natsir et al., 2024).

Although conceptually related, prior research has examined SRL and probing prompting separately. Rizqia et al. (2022) found a strong positive influence of SRL on mathematical reasoning in the SPLDV topic, but the study was correlational and produced no learning product. Widayat & Murniati (2015) found significant differences in reasoning between students taught with probing prompting versus conventional methods, but did not address independent learning. Husna & Hasibuan (2018) developed a practical and effective probing-prompting-based Calculus 2 module, but measured effectiveness through general outcomes rather than reasoning. Natsir et al. (2024) showed probing prompting significantly improved junior high students' reasoning, but it was teacher-applied within an experimental design—not embedded in materials for independent use.

No study, then, has integrated SRL and probing prompting into teaching materials aimed at enhancing mathematical reasoning—existing work tests single variables or targets general outcomes, not all three aspects together. This study offers that novel combination: probing-prompting-based teaching materials deliberately designed to facilitate SRL phases as a means of improving mathematical reasoning. Accordingly, the study aims to produce a probing-prompting and SRL-based learning module that is valid, practical, and effective in enhancing students' mathematical reasoning skills.

METHODS

This study was conducted at SMA Negeri 3 Purwokerto with students from class X E-9, using the Research and Development (R&D) method—an approach that follows a defined process to create a new product or refine an existing one, while validating its effectiveness through measurable testing (Judijanto et al., 2024). The development model used was ADDIE, comprising five stages: Analyze, Design, Develop, Implement, and Evaluate.

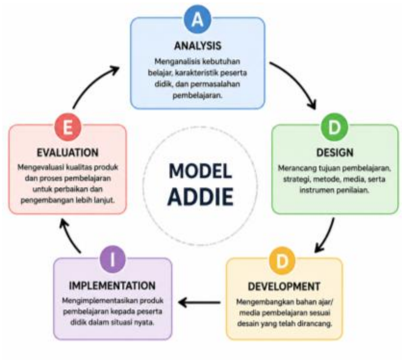


Figure 1. Skema ADDIE

Data were collected using two techniques—test and non-test. The non-test technique involved interviews, validation sheets, and student and teacher response questionnaires, all designed with reference to the study's three main foci: SRL, probing-prompting, and mathematical reasoning. The test technique used a set of five open-ended questions designed based on the mathematical reasoning indicators applied in this study, which included formulating conjectures, carrying out mathematical manipulations, constructing proofs and justifying their correctness, evaluating the validity of arguments, and drawing conclusions.

Data were analyzed to assess the validity, practicality, and effectiveness of the developed module. Two experts—a mathematics education lecturer from Universitas Muhammadiyah Purwokerto (UMP) and a mathematics teacher—validated the module, deemed valid if the average expert validation score met the validity criteria, and practical if the average teacher and student response scores met the practicality criteria. Effectiveness was assessed by comparing pretest and posttest results, with improvement calculated using the normalized gain score. A paired-sample t-test at a 0.05 significance level was also used to examine whether the improvement in students' mathematical reasoning was statistically significant, with a p-value below 0.05 taken as evidence of a significant difference (Sugiyono, 2013).

Table 1. Classification N-gain values (Hake, 1999)

Average	Criteria
$0,7 \leq g$	High
$0,3 \leq g < 0,7$	Medium
$0 \leq g < 0,3$	Low

RESULTS AND DISCUSSION

This study focused on developing a mathematics module oriented toward self-regulated learning and probing-prompting for class X students at SMA Negeri 3 Purwokerto, following the ADDIE model (Analyze, Design, Develop, Implement, Evaluate). The results of each stage are presented below.

Analyze Stage

a. Needs Analysis

This analysis aims to identify the gaps forming the basis of this research, conducted through interviews with a class X mathematics teachers at SMA Negeri 3 Purwokerto. Results indicate that students' mathematical reasoning remains low—they still struggle to prove statements, justify their answers, and draw conclusions from their problem-solving processes. Teaching materials consist largely of textbooks, and although teachers occasionally use learning modules, these merely contain explanations, formulas, and example questions—doing little to develop students' reasoning skills.

b. Curriculum Analysis

Curriculum analysis was carried out to ensure the module content aligned with applicable educational standards—reviewing the Phase E learning outcomes set out in the curriculum to identify the competencies students must master. These outcomes were then broken down into more specific learning objectives, which formed the basis for the module's instructional design.

Table 2. Learning Outcomes

Element	Learning Outcomes
Geometry	By the end of Phase E, students are expected to understand the concept of basic trigonometric ratios in right triangles and to solve problems related to everyday life.

c. Learner Characteristics Analysis

In this analysis, the researcher identified students' characteristics by examining their mathematical reasoning abilities. Pretest results showed that most students still struggled to construct proofs, justify their problem-solving results, and draw accurate, logical conclusions—findings consistent with the teacher interviews at SMA Negeri 3 Purwokerto.

d. Content Analysis

This analysis aimed to determine the content and concepts for the module, identifying key subject matter relevant to the learning outcomes and students' needs, then organizing it systematically—from basic to applied and contextual concepts. The resulting material is divided into three parts: angle concepts, covering units of measurement (degrees and radians), positive and negative angles, and angles in the Cartesian coordinate system; trigonometric ratios in right-angled triangles—determining sine, cosine, and tangent values, forming the core learning outcome; and angles of elevation and depression, demonstrating trigonometry's application in everyday life.

Design Stage

During the design phase, the researcher developed the module based on the analysis findings, dividing it into three learning activities sequenced by topic difficulty. The module's learning outcomes align with the curriculum analysis—students should understand trigonometric ratios in right-angled triangles and solve related real-life problems—with difficulty level adapted to student characteristics.

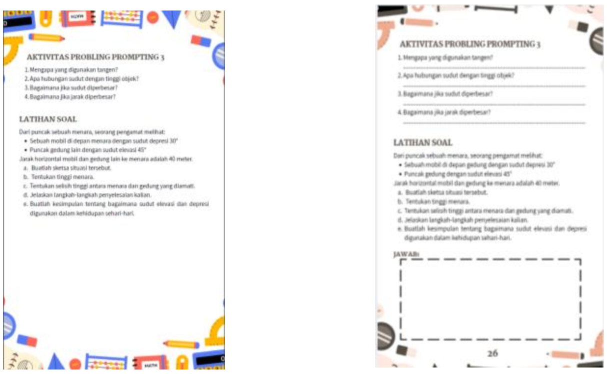
SRL and probing prompting were integrated according to (Zimmerman, 2000) three phases—forethought, performance, and self-reflection—applied to every learning activity. In the forethought phase, students set learning targets before engaging with the material. In the performance phase, material is presented systematically alongside activities designed to enhance students' thinking, including probing prompts tailored to the mathematical reasoning indicators. This phase ends with a monitoring activity—a table of statements assessing students' understanding. The self-reflection phase involves reflection activities at the end of each unit, where students compare their outcomes against the targets set earlier—completing the SRL cycle rather than stopping at planning or implementation. The module concludes with an assessment based on the mathematical reasoning indicators, serving as a final measure of the combined impact of SRL and probing prompting on students' reasoning skills.

Development Stage

Once the module was designed, the initial product was validated by two experts—a mathematics education lecturer and a mathematics teacher—to assess its validity before trialing, in line with Nieveen (1999) view that an educational product is high quality if it meets three criteria: validity, practicality, and effectiveness. Validation covered two aspects: media and content suitability.

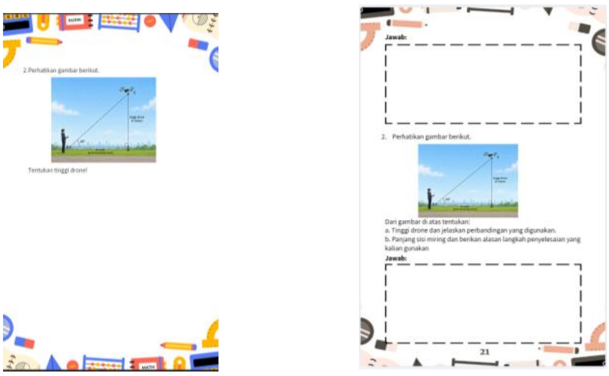
The average score was 3.76 for media and 3.80 for content, both meeting the validity criteria. These results indicate the module has systematically integrated SRL and probing prompting into its structure and activities, and supports students' development of mathematical reasoning skills—confirming it was ready for trial testing following revision based on the validators' recommendations.

Based on the first validator's suggestions, the researchers added answer space to each activity and question, along with more explicit instructions to improve clarity for students. The revised material is shown in the following figure.



(a) (b)

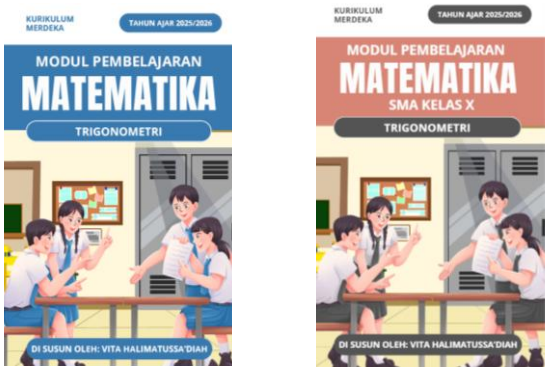
Figure 1. The module before (a) and after (b) answer spaces were added



(a) (b)

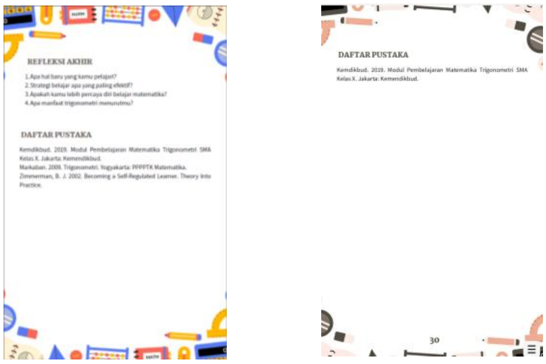
Gambar 2. Figure 2. Questions before (a) and after (b) explicit instructions were added

Based on the second validator's suggestions, the researchers also added the class name to the module cover to clarify the target audience, revised the colors and reduced the background size at the top and bottom of the module content to avoid distracting students, and separated the final reflection section from the bibliography for a more systematic structure.



(a) (b)

Figure 3. The module covers before (a) and after (b) class identity was added



(a) (b)

Figure 4. The background and reference list before (a) and after (b) revision

Implementation Stage

This trial was conducted at SMA N 3 Purwokerto with 29 Class X E-9 students. During implementation, observations were made to gather practicality data—important as a form of field validation complementing the earlier expert validation, in line with Nieveen (1999) view that validity and practicality are complementary criteria for determining product quality. The implementation phase also assessed the module's effectiveness in enhancing students' mathematical reasoning, measured through a posttest administered after the module was used in class. Posttest data were then analyzed to determine students' attainment of mathematical reasoning skills following instruction with the module, forming the basis for assessing the product's effectiveness.

Evaluation Stage

After the module was trialed with class X E-9 students at SMA Negeri 3 Purwokerto, the researchers collected student response questionnaires and teacher feedback forms to evaluate the module's practicality. The average student response was 3.31, falling within the "practical" category. The highest score—3.50—was for language, indicating the module's language was communicative and easily understood. The lowest score—3.16—was for probing-prompting integration, suggesting some students still needed to adapt to the tiered questioning pattern requiring them to explain their reasoning and check their own answers. The average teacher response was 3.91, also "practical." Teachers assessed the module as aligned with the established learning outcomes, noting that its application of self-regulated learning (SRL) helped students learn independently—consistent with SRL's emphasis on active planning, monitoring and evaluation of one's own learning (Tarumasely, 2024). The probing-prompting questions were seen as effective in developing students' thinking, echoing Natsir et al. (2024), who found such questions help students think systematically and purposefully when solving problems. The module was further assessed as easy to use, clearly written, and suitable for classroom implementation to support mathematical reasoning development.

Beyond practicality, this stage's evaluation also examined the module's effectiveness in improving mathematical reasoning. Effectiveness was analyzed by comparing students' achievement before and after using the module. Pretest results showed low mathematical reasoning—students struggled to prove statements, justify their problem-solving results, and draw accurate, logical conclusions. Posttest results showed improvement instead—students could formulate conjectures about problem-solving outcomes and perform mathematical manipulations, with most also showing gains in proving statements, justifying each problem-solving step, checking the validity of arguments, and drawing conclusions. This improvement reinforces Natsir et al. (2024), who similarly found that probing prompts drove significant gains in lower secondary students' mathematical reasoning, following a comparable pattern.

Using the N-Gain calculation developed by (Hake, 1999), The results showed that 2 students (6.9%) fell into the low category, 23 students (79.3%) into the medium category, and 4 students (13.8%) into the high category. These medium N-Gain scores align with Husna & Hasibuan (2018), who similarly reported medium-to-high improvements following implementation of a probing-prompting-based module—indicating the developed module has a positive learning impact on students' mathematical reasoning. A paired t-test was also conducted to determine whether pretest and posttest scores differed significantly, yielding a significance value (2-tailed) of 0.00—below 0.05—confirming a significant difference. This is consistent with Rizqia et al. (2022), who likewise found a significant effect of SRL strategies on mathematical reasoning. Together, the N-Gain and paired t-test results reinforce the conclusion that the module is effective in improving students' mathematical reasoning, both in magnitude and statistical significance.

This improvement is likely driven by the integration of probing prompts, consistently engage students in practicing the formulation of conjectures, providing justifications, performing mathematical manipulations, evaluating the validity of arguments, and drawing conclusions. The forethought, performance and self-reflection phases of SRL further accustom students to setting learning targets and systematically monitoring and evaluating their progress. These findings can guide teachers in designing materials oriented not only toward conceptual mastery but also toward sustained independent learning—suggesting the module's potential for independent use outside lesson time, given its integrated SRL components. Teachers adapting similar modules should ensure students are adequately prepared, both in prerequisite understanding and independent learning habits, so that the integration of probing prompting and SRL can function optimally and yield more consistent gains in mathematical reasoning.

CONCLUSION

This research indicates that the module, which integrates SRL and probing prompting qualifies as valid, practical, and effective. Validity is demonstrated by expert assessments falling within the "valid" category, while practicality is evident from student (3.31) and teacher (3.91) responses, both "practical." Effectiveness is shown by improved mathematical reasoning skills—N-Gain results predominantly "medium" (79.3%), supported by a paired t-test with a two-tailed p-value of 0.00 (<0.05). The developed module is therefore suitable for use and capable of enhancing students' mathematical reasoning.

These findings offer an alternative teaching resource for fostering independent learning alongside reasoning development—its probing-prompting pattern adaptable to everyday classroom question-and-answer sessions. For developers of learning materials, a module structure combining the forethought, performance, and self-reflection phases can guide the design of similar materials on other mathematical topics, particularly those requiring higher-order thinking. For future researchers, the predominantly "medium" N-Gain results open opportunities to test the module's effectiveness over longer implementation periods, at different levels, or with different content—assessing the consistency of its impact more comprehensively.

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