

A Study of Students' Science Experiences with Metacognitive Learning Strategies in Indonesian Elementary Schools

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ABSTRACT

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Students' lack of learning awareness influences science learning loss in elementary schools due to poor metacognitive skills. Therefore, teachers need to facilitate the development of students' metacognitive abilities, for example, by utilizing metacognition-based modules to provide an independent and engaging science education experience. The present study sought to develop a science module founded on metacognition principles, to facilitate autonomous and pleasurable learning for pupils in elementary school. We followed the research and development procedure to generate the module. A needs analysis was conducted to determine the demand for the metacognition-based module and identify student characteristics and learning challenges. The needs analysis data were collected via interviews and observation. The module was assessed by experts and tested for effectiveness through a one-group pretest-posttest experiment. The expert evaluation instrument and metacognition awareness inventory (MAI) were developed and validated. The expert validity score was determined using the Delphi technique. The qualitative data on expert judgment were analyzed descriptively, while the quantitative data on expert judgment were determined using the Aiken-V coefficient. Metacognition data were analyzed using the paired sample t-test. The expert validation score was high, indicating that the module was valid. The effectiveness test result using the t-test showed a significant difference in the study participants'

metacognitive skills before and after learning ($\text{sig} = 0.000$ or $\text{sig} < 0.05$). This study's findings suggested that a metacognition-integrated module could facilitate the development of elementary school students' metacognitive skills. Teachers as facilitators play a crucial role in providing instruction and assisting students in the classroom.

Keywords

Elementary School
Metacognitive Skills
Module
Science

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Introduction

Science learning, which is anticipated to facilitate the attainment of educational objectives, continues to encounter numerous challenges. In recent times, many issues have been identified in the domain of science education. These include the issue of learning loss [1], [2], [3], [4], [5], poor learning outcomes resulting from traditional teaching methods [6], limited creativity during the science learning process [7], inadequate scientific literacy [8], suboptimal problem-solving skills [9], insufficient motivation to engage with science [10]. All the issues that arose directly resulted from the implementation of distance education amidst the COVID-19 outbreak.

Distance learning problems in elementary schools need rapid recovery [11]. The educator should facilitate a swift and comprehensible assimilation of knowledge and foster a malleability of attitudes in instruction. It is imperative to provide students with the necessary training to develop an awareness of their learning process, tasks at hand, and comprehension of concepts. This awareness will enable them to effectively address learning difficulties by utilizing the most suitable strategies. Independent learning strategies, with the help of independent teaching materials, can be used as a guide and source of information to find knowledge [12]. Therefore, instructional resources are crucial in promoting elementary students' educational experiences.

The development of independent teaching materials, such as the Science module, must incorporate an effective learning strategy to address student learning difficulties. The ability of students to engage in metacognition, an essential component of self-regulation [13], is crucial to the success of the independent learning process. Students with solid metacognitive skills can develop domain-oriented metacognitive learning [14]. In science learning, metacognition encompasses processes such as self-awareness and self-regulation. Metacognition enables teachers to facilitate student learning and ruminate on their teaching in order for students to enhance or modify their learning [15], [16].

Several science teaching materials have been developed successfully in prior research, including an encyclopedia to develop student character, a STEM-based module to cultivate student problem-solving skills (Martaningsih et al., 2022), and even a science magazine to overcome learning difficulties (Maryani, Lestari, et al., 2019). However, there are no instructional materials that address metacognition issues. A metacognition-based Physics module has been developed, but its effect on students' metacognitive skills has not been evaluated (Maryani, Prasetyo, et al., 2021). The present study involved a retrospective analysis of the evolution of metacognition-based instructional resources within the timeframe of 2019 to 2023. The data were sourced from the <https://www.sciencedirect.com/> database, wherein a total of 838 articles were retrieved based on the search terms [metacognition], [resources], [learning], and [science]. The results showed that twenty studies were carried out in Indonesia, suggesting a dearth of comparable research endeavors in the Indonesian context—furthermore, none of the retrieved articles reported on research conducted in elementary school environments. Figure 1 displays the visualization of the keywords obtained from the VOS viewer analysis.

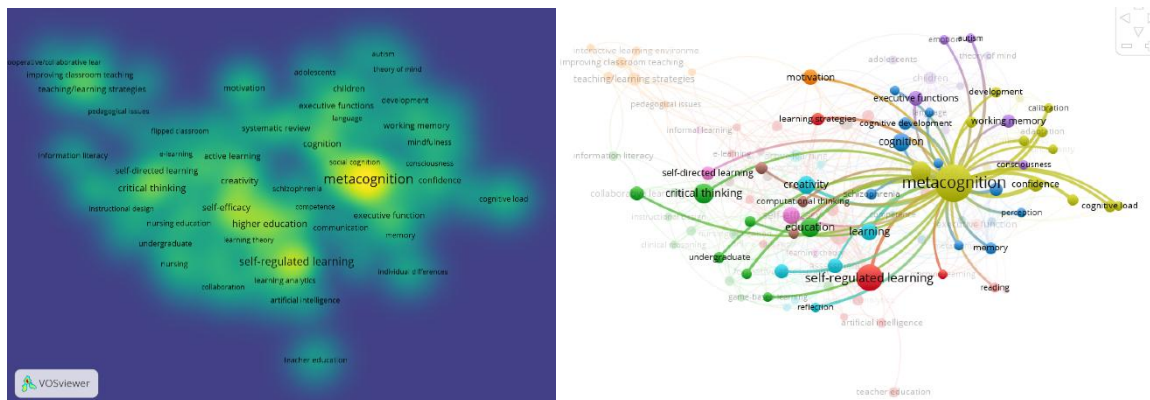


Fig. 1. Visualization of the keywords

Fig. 1 illustrates the proximity of the concept of metacognition to significant factors that influence the process of learning, including but not limited to self-regulated learning, critical thinking, cognition, confidence, memory, perception, cognitive load, motivation, creativity, computational thinking, learning strategies, reflection, and self-directed learning. The aforementioned results suggest that metacognition holds significant value as a variable that can contribute positively to the achievement of successful learning outcomes. Hence, employing metacognition as a foundation for crafting instructional resources is a thoughtful decision.

Metacognitive thinking plays a pivotal role in education. Metacognition is crucial in determining student academic performance [17]. The integration of metacognition into science education can be achieved through the cultivation of awareness, the formulation of essential

inquiries, the process of planning, the practice of monitoring, the act of evaluating, and the act of reflecting. [18] have created lesson plans, teaching materials, and instructional activities to enhance students' metacognitive abilities using this syntax. The syntax above has the potential to serve as a fundamental framework for the incorporation of metacognitive strategies within an educational module. The incorporation of metacognition strategies into instructional materials offers metacognitive learning opportunities that can enhance students' metacognitive abilities.

The development of modules as independent pedagogical resources necessitates the integration of learning strategies' benefits. Incorporating modules in the educational setting can enhance student engagement with the learning material and increase physical and cognitive participation in the learning process [19]. Modules have been demonstrated to enhance students' motivation to learn, resulting in a more seamless learning experience [20]. Utilizing modules within educational settings could promote increased academic performance among students [21], [22]. Modules can also boost students' motivation and academic performance by facilitating their comprehension of course material [23], [24]. The present study makes a valuable contribution to advancing science education resources for primary school pupils, which purportedly incorporate metacognitive strategies. This module serves as a self-contained educational resource that offers a significant opportunity for scientific learning.

Material and Methods

The present study used the ADDIE research and development procedures suggested by Dick and Carry. The ADDIE procedures were carried out in five stages: Analysis, Design, Development or Production, Implementation or Delivery, and Evaluations [25]. Fig. 2 illustrates the ADDIE procedures used in this study.

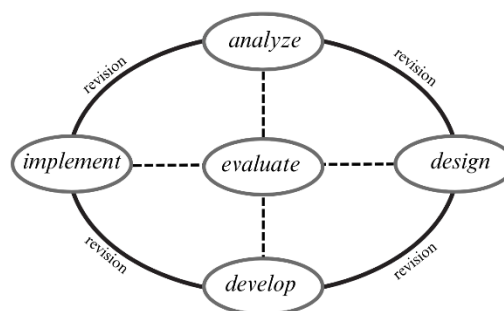


Fig. 2. The ADDIE Procedures

The Analyze phase was conducted to assess students' metacognitive abilities, identify the necessity for creating the instructional resources, scrutinize the material or content, and evaluate the attributes of the students or users of the module under development. During the

Design phase, the initial product was conceptualized and developed. The Develop phase aimed to enhance the product's calibre through expert evaluation and field experiments. The product was deployed to a broader user base during the Implement stage. An evaluation was conducted at every phase of the product development cycle (including analysis, design, development, and implementation) to gauge the process's efficacy and outcomes [26].

The study conducted product trials on a science learning specialist, a fundamental education specialist, and a language specialist. The study employed research instruments in the form of an expert assessment guide and a metacognition awareness inventory (MAI), which underwent development and validation by experts, as well as empirical validation. The evaluation tool for the product employed a Likert scale ranging from 1 to 5. Professionals used the guide to evaluate the product utilizing a range of responses that include excellent (5), good (4), satisfactory (3), substandard (2), and highly inadequate (1). The MAI tool was constructed utilizing the Guttman scale due to the study participants' age, who could not discern the nuances of response options. Once the instrument's validity was established, it was disseminated to specialists to assess the module. The Delphi technique was utilized to derive the product validity score. Upon validation, the abovementioned instrument was used to measure metacognitive awareness among research participants.

During the product trial, the participants were subjected to observations. The study was carried out to investigate the process of learning facilitated by the product. Following the trial's conclusion, the instructional materials' efficacy was evaluated via an experimental investigation utilizing the pretest-posttest design with a single group. The present study employed the Metacognition Awareness Inventory (MAI) in the pretest and posttest to assess participants' metacognitive skills across three domains: planning, monitoring, and evaluating and reflecting [27], [28], [29]. The product trial was done in three sessions. The learning steps outlined in the lesson plan were followed, and teaching materials that were developed as part of the study were utilized. The study employed both qualitative and quantitative analyses. Descriptive methods were utilized in the qualitative analysis. In contrast, descriptive statistics such as mean, categorization and inferential statistics (paired sample t-test) were employed for the quantitative analysis to validate the hypothesis. Figure 2 depicts the flowchart of the research methodology.

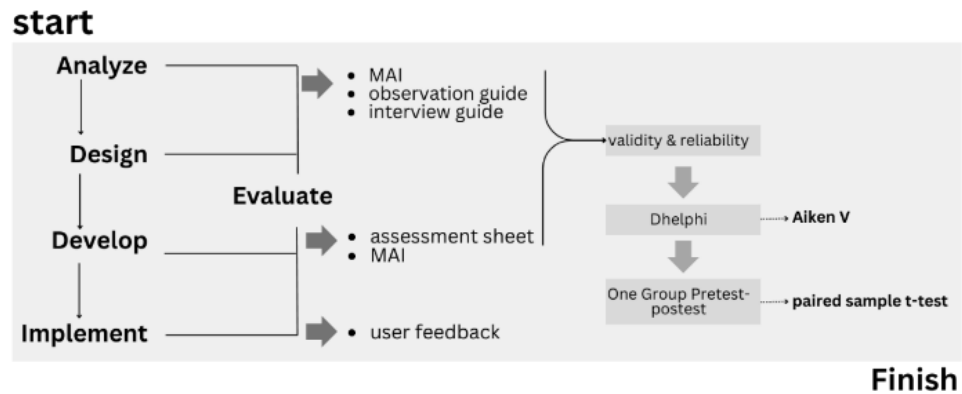


Fig. 3. The Research Methodology Flowchart

Results

The study's findings are presented utilizing the ADDIE framework, encompassing the following phases: analysis, design, development, implementation, and evaluation.

A. Analyze

At this stage, we analyzed the current school curriculum, teaching materials, and student needs for the module. The study revealed that a significant proportion of students, precisely 68%, exhibited low metacognitive skills. Meanwhile, 27% of the participants demonstrated moderate metacognitive skills, while only 5% exhibited high metacognitive skills. A contributing factor to students' poor metacognitive skills is the restricted availability of educational materials that can effectively cultivate these competencies [30].

A learning module based on metacognition was developed as a potential solution to address the issue above. The educational module comprises information on the circulatory system of the human body. This material was selected based on the observation that many students encountered challenges in comprehending it. The biological concept of blood circulation is characterized by a high degree of complexity and encompasses abstract concepts that pose challenges to comprehension. The module exhibits several distinctive features that render it suitable for autonomous pedagogical purposes: self-instruction, self-contained, stand-alone, adaptive, and user-friendly [31].

B. Design

We formulated a module design at this stage and advanced it into a prototype module encompassing all necessary components. The module's structure comprises three distinct sections: the preliminary segment (encompassing the cover page, table of contents, introduction, and user instructions), the central segment consisting of learning activities (comprising learning objectives and materials), and the concluding segment (encompassing

evaluation, answer keys, and bibliography). Metacognitive practices were tailored into the module by incorporating the three key metacognition stages: planning, monitoring, and evaluation. The central segment of the module employs these three phases as pedagogical increments. This particular module comprises six different learning activities. The curriculum was structured to include components such as *Let's Find Out*, *Let's Observe*, *Let's Read*, *Let's Do It*, *Summary*, *Let's Reflect*, and *Evaluation* activities in each lesson.

Let's Find Out presents fundamental inquiries that serve as a catalyst for students to engage in the process of acquiring knowledge. This section contains a series of questions that assess students' comprehension of the material covered in the chapter, including their grasp of established concepts and their awareness of areas where further knowledge is needed. This educational exercise constitutes a component of the strategic planning phase in metacognitive-oriented instruction. The initial stage of the educational process involves the planning phase, which entails identifying students' existing knowledge and utilizing it as a benchmark for establishing individualized learning objectives and strategies.

The *Let's Observe* feature presents questions about material that students have not yet understood. After answering the questions in the previous activity, students can identify the material they have mastered and have not mastered. Then answer the questions to lead students to be able to understand the material that was previously not understood.

Let's Observe provides learning materials corresponding to each learning outcome. Students can use the materials as a source of information to study independently. The learning activity in this section aids students in comprehending the material they have not yet mastered. After completing the reading activity, students can play a digital barcode-based game to access the Wordwall game on smartphones online. This exercise assesses students' comprehension and is part of the metacognitive-based controlling or monitoring process.

Let's Do It includes a list of queries for students to complete as assignments. Exercises in this section reinforce students' comprehension of previously covered material. Creating a concept map is the first activity in this section. The module contains a vacant concept map that students can attempt to complete. After completing the concept map, students must answer questions, create a work, or experiment on the discussed topic.

Summary is the module's component that contains the essence of the chapter's content from beginning to end. This feature functions to reinforce students' comprehension of previously learned material. In the *Let's Reflect* section, students evaluate the metacognition-based learning process by responding to five reflection questions. Students can also assess themselves while participating in these learning activities. Self-evaluation begins with evaluating learning material comprehension, learning strategies, and learning constraints. Students can use the reflection results to improve the quality of their future learning activities.

The *Evaluation* section comprises of five multiple choice statements that aim to evaluate the independent learning outcomes of students, as well as the changes that transpire in students' knowledge and skills after being exposed to this module. The provided answer sheet can be utilized by students to engage in the evaluation process. Furthermore, students can engage with evaluation inquiries via the Quizizz platform, which can be conveniently accessed by scanning the provided barcodes.

C. Develop

This phase involved the assessment of module quality through expert validation and empirical effectiveness testing. Expert validation was performed by experts in learning media, materials, language, and learning. Table 3 presents the feedback and suggestions on the module resulting from expert judgment. The Aiken V coefficient was utilized to determine the validation expert score.

Table 1. Expert feedback on the metacognition-based module

No	Validator	comments/suggestions/feedback
1.	Media Expert	The module needs an interior cover. The learning activity's title should be modified to be distinct but consistent. The language needs to be replaced by instrumental language. The module's image font size should be increased to be more legible. It is necessary to illustrate how to create a concept map so students can understand how to do concept mapping. The authors' names and photos must be attached to the module.
2.	Material Expert	A tensimeter image should be included in the materials for learning activity 1. Activity 1 should include a discussion of the factors affecting the human pulse. The material references should be written. Each table should be named.
3.	Language Expert	There is a need for improvement in placing a period after the brackets. There is a need for improvement in the proper application of punctuation marks in conjunction with the preceding word. There is a need to enhance the proper utilization of word concatenation and separation in writing. There is a need to enhance the written expression of words that require the application of italics.
4.	Learning Expert	It is imperative to incorporate core competencies, establish clear learning outcomes, and provide unambiguous instructions on how to use the module.

Suggestions, comments and input from the experts were used as a reference in revising the module. Furthermore, the module was assessed quantitatively based on its material, language, pedagogical approach, and appearance. The average Aiken V index analysis produced $V = 0.931$, indicating that the module was highly valid.

Besides expert judgement, we also measured the module's effectiveness on students' metacognitive awareness. Prior to conducting the pretest and post-test, the data normality was tested using the Kolmogorov-Smirnov analysis and the data homogeneity was examined using the Levene's Statistics. The normality test showed a significance value of 0.164 (> 0.05) for the pretest data and a significance value of 0.052 (> 0.05) for the post-test data. Therefore, we concluded that the data were distributed normally. In addition, the homogeneity test showed a significance value of 0.063 ($\text{sig} > 0.05$), suggesting that the data had homogeneous variance.

The paired sample t-test was done to examine the difference in participants' metacognitive awareness before and after using the module for learning. Table 1 summarizes the t-test results.

Table 2. Paired Sample T-test on participants' metacognitive awareness

Pair	Comparison	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference (Lower)	95% Confidence Interval of the Difference (Upper)	t	df	Sig. (2-tailed)
Pair 1	Pretest - Posttest	-29.559	5.679	0.974	-31.540	-27.577	-30.348	33	0.000

Based on Table 2, the significance value was smaller than 0.05 ($< \alpha (0.05)$), indicating a difference in students' metacognitive awareness before and after learning science using the metacognition-based module.

D. Implement

This phase involved executing some educational procedures in an alternative classroom and gathering student feedback on their learning experience. The reflection questionnaire was utilized to gather feedback. Some students faced constraints in accessing the digital functionalities of the module. Some others encountered challenges with the metacognitive processes outlined in the module, particularly in the lesson planning section. Therefore, the teacher's assistance was required.

E. Evaluation

The *Evaluation* stage was carried out at the end of the *analysis*, *design*, *develop*, and *implement* stages. The evaluation stages yielded information about the congruity between the module and its design, the compatibility of the schedule with the predetermined timeline, modifications in student conduct during the learning process, the integration of metacognitive techniques within the module, and the assessment of the metacognitive awareness of the research subjects. The findings of the evaluation stage have been expounded upon in the preceding section.

Discussion

A metacognition-based science module for fifth graders in elementary schools has been successfully developed. The module effectively incorporates metacognitive strategies pertaining to metacognitive knowledge, including conditional and procedural declarations, as well as metacognitive regulations such as planning, monitoring, and evaluation [32]. The present integration considered the notion that metacognition plays a significant role in

problem-solving [33], goal attainment [34], and the regulation of actions to achieve goals [35]. The possession of metacognitive knowledge has been found effective in facilitating students' execution of learning tasks. Figure 3 illustrates the integration of metacognition in the module.

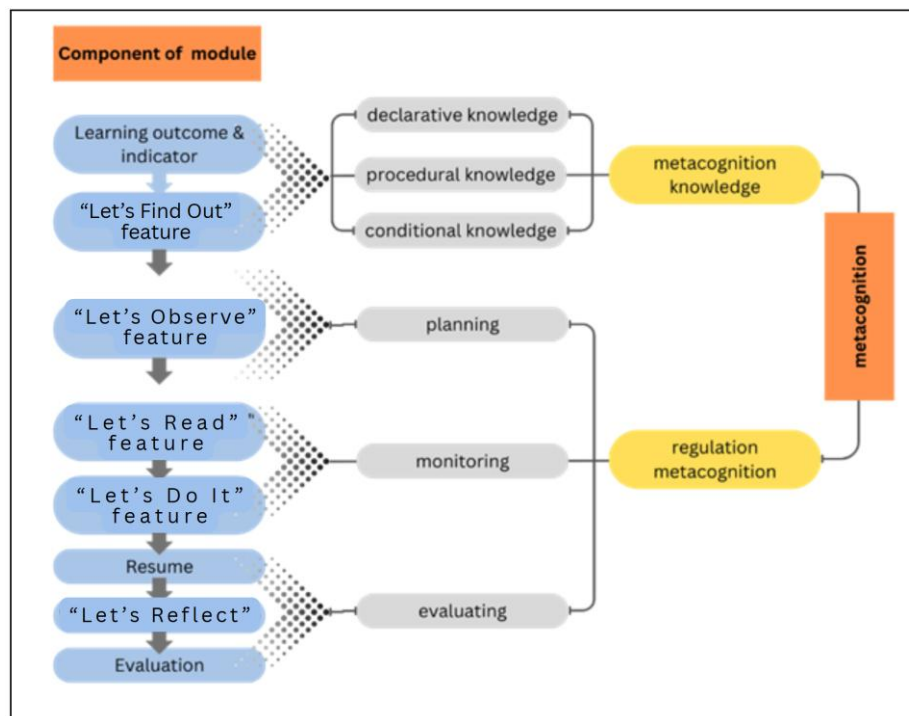


Fig. 4. The Integration of Metacognition into a Science Module

Metacognition comprises two distinct components, specifically metacognitive knowledge and metacognitive activity. Metacognitive knowledge consists of declarative, procedural, and conditional knowledge [36]. The module's *Let's Find Out* feature facilitates the realization of metacognitive knowledge aspects. This section outlines a series of inquiries that pertain to the context in which the student finds themselves and are pertinent to the subject matter at hand. Metacognitive regulation is a cognitive process whereby students deliberately employ cognitive strategies to solve problems and attain objectives. The assertion is corroborated by the research conducted by [37], which suggests that the metacognitive learning approach facilitates student engagement throughout the learning process. Planning, monitoring, and evaluating are parts of a syntax that can help students achieve these objectives through a pedagogical framework. *Planning* is executed via the *Let's Observe* segment, which encompasses a series of inquiries and directives aimed at facilitating the creation of a mind map. The process of *monitoring* is facilitated by the utilization of the *Learning Materials* and *Let's Do It* functionalities, which encompass comprehensive descriptions of educational materials and interactive quizzes. The *evaluating* aspect is operationalized via the *Material Summary*, *Let's Reflect*, and *Evaluation* functionalities, which incorporate appraisal exercises for both processes and learning achievements.

This module presents a distinct advantage over previously developed modules, offering segmented sections that can serve as incremental learning stages. Furthermore, the design of this module aims to offer users educational prospects both offline and online. The aesthetically pleasing design of this product elicits a sense of enthusiasm among students towards reading. The present study makes a valuable contribution to enhancing metacognitive skills simultaneously. The integration of diverse strategies and activities that foster self-reflection, self-monitoring, and self-regulation can significantly contribute to the enhancement of students' metacognitive skills. The employment of this module in the classroom offers various advantages, such as delivering explicit guidance on metacognitive strategies [38], enabling students to engage in self-reflection [39], motivating them to establish learning objectives [40], scaffolding the learning process [41], fostering self-assessment [42], promoting classroom discussion and collaboration [43], and providing timely feedback [44].

The implementation of the metacognition-based module can commence through the explicit instruction of metacognition and diverse metacognitive strategies to students. The instructions provided may encompass a range of activities, including but not limited to the establishment of learning objectives, the formulation of learning plans, self-assessment, introspection, and the identification and implementation of efficacious learning strategies [38]. By implementing these strategies, students understand their cognitive processes and acquire techniques to regulate their learning proficiently. Modules can present avenues for students to engage in reflective practices regarding their learning experiences [39]. Self-reflection can be done through reflective writing, discussion forums, or journaling. By reflecting on what they have learned, how they learned it, and what strategies were or were not effective, students could gain insight into their learning process and make adjustments accordingly.

Modules can encourage students to set specific, achievable, and measurable learning goals [40]. By establishing learning objectives, students gain a sense of direction and purpose, heightening their awareness of the specific targets they must attain. Regularly reviewing these objectives and monitoring progress can aid students in cultivating self-regulation abilities and maintaining their concentration on their educational objectives. Modules can provide scaffolding to support students' metacognitive development [41]. Scaffolding entails furnishing explicit directives, prompting inquiries, and offering checklists to aid students in manoeuvring through intricate tasks. Scaffolding helps students understand the thought processes required for a task and allows them to internalize these processes, gradually leading to self-directed metacognitive skills.

Modules can encourage students to assess their own learning progress and understanding [42] through self-assessment quizzes, reflection prompts, or peer feedback activities. By engaging in self-assessment, students become more aware of their strengths and

limitations, enabling them to make decisions regarding their learning strategies and problem areas.

Modules can incorporate collaborative activities and discussions that encourage students to share their thoughts, ideas, and perspectives [43]. Participating in peer discussions allows students to acquire diverse perspectives, introspect on their thought processes, and cultivate metacognitive proficiencies such as analytical reasoning, conflict resolution, and perspective-taking. Modules can provide constructive and timely feedback to students, focusing on their task performance and metacognitive processes [44]. Providing feedback that identifies areas for improvement, proposes alternative approaches and fosters introspection can enhance students' metacognitive abilities and promote a more profound comprehension of their cognitive processes.

Conclusion

The current study successfully developed a metacognition-based module following the ADDIE procedures. The expert validation using Aiken V Coefficient yielded a high validity score. The module's effect on students' metacognitive awareness was determined through an experimental study. The study results showed differences in students' metacognitive awareness before and after learning using the module. This research contributes to the concurrent development of students' metacognitive skills using a metacognition-based module. The metacognition-based module can significantly foster students' metacognitive skills by incorporating strategies and activities that promote self-reflection, self-monitoring, and self-regulation. This module explicitly teaches metacognition strategies, provides students with opportunities for self-reflection, encourages students to set learning objectives, scaffolds the learning process, fosters self-assessment, encourages classroom discussion and collaboration, and provides timely feedback.

Conflict of Interest

The authors declare that there is no conflict of interest.

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