Al-Jabar: Jurnal Pendidikan Matematika
Volume 13, Number 1, 2022, Pages 211 – 220
http://ejournal.radenintan.ac.id/index.php/al-jabar/index

# Self-regulated learning-based digital module development to improve students' critical thinking skills

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**Article Information**
Submitted May 26, 2022
Revised June 26, 2022
Accepted June 31, 2022

**Keywords**
Critical thinking;
Digital Module;
Self-Regulated Learning.

**Abstract**
Learning technology needs to support improving critical thinking skills in the 21st century. Self-regulated learning-based digital module can be used to support students' independent learning. The aims of this study are (1) to describe a valid digital module based on self-regulated learning; (2) to evaluate and describe the practicality of the digital module based on self-regulated learning; (3) to determine the effectiveness of the digital module based on self-regulated learning on students' critical thinking skills. The method used is Research and Development with the ADDIE development model. The results of the study are (1) the developed digital module based on self-regulated learning is declared valid; (2) the digital module based on self-regulated learning is stated to be practical as indicated by the response and implementation in the good category; (3) students' critical thinking skills in the experimental class are better than the control class. Generally, the self-regulated learning-based digital modules are valid, practical, and effective.

## INTRODUCTION

Learning continues to develop both in the implementation process and in increasing understanding abilities. In the 21st century, learning is not only focused on cognitive abilities. Students are expected to master various personal and social skills. Critical thinking, creative, collaborative, and communication are skills that students must master. Developing one of the four abilities, namely critical thinking skills, is very important. Given that the amount of information is growing rapidly every day, it is difficult to have a general picture for its analysis and understanding (Osorio et al., 2022). Critical thinking skills have been widely discussed in various studies, such as improving critical thinking skills through problem-solving concepts (Alfayez et al., 2022), concept mapping pedagogy in strengthening critical thinking skills (O'Halloran, 2022), critical thinking skills assessment strategies (Arce-Trigatti et al., 2022), identifying problems with APOS theory (Umam & Susandi, 2022), and identifying barriers to critical thinking skills (List, 2022).

The number of studies that raise the issue of critical thinking skills does not guarantee that most people have mastered this ability. Even so, critical thinking skills are still relatively low. Weiyuan's research reveals that critical thinking skills in indicators of learning new things and understanding and analyzing information in critical thinking skills are only 37% and 33% (Li, 2022). The main cause of low critical thinking skills is a lack of direction in problem-solving. Critical thinking skills consolidate students' ability to solve problems. But the fact is that learning tends not to be taught problem-solving. So that students are not accustomed to critical thinking. Therefore, it is very important to improve students' critical thinking skills.

So far, the improvement of critical thinking skills has been carried out in various ways such as learning models, such as the Flipped Classroom (Nugraheni et al., 2022), the Discovery-Based

How to cite Kusmaharti. D., & Yustitia, V. (2022). Self-regulated learning-based digital module development to improve students' critical thinking skills. *Al-Jabar: Pendidikan Matematika*, *13*(1), 211-220.
E-ISSN 2540-7562
Published by Mathematics Education Department, UIN Raden Intan Lampung

Multiple Representations Model (Chusni et al., 2022), the problem-based learning model (Angraeni, 2021), and the RANDAI model (Arsih et al., 2021). Also, the use of learning strategies can improve critical thinking skills, such as mind mapping strategies (Hazaymeh, & Alomery, 2022) and metacognitive knowledge strategies (Nusantari et al., 2021). In terms of learning media, critical thinking skills can also be improved. Video-based learning media (Hsu et al., 2022), LKPD (Putra et al., 2019; Sayekti & Suparman, 2020) and modules (Koth et al., 2021; Muhdhar et al., 2021) have been shown to improve critical thinking skills.

The module is one learning media that can improve critical thinking skills. The module serves as independent teaching material and an evaluation media for students (Serevina et al., 2022). In addition, the module can increase student motivation in learning (Marnah, 2022). Modules have various forms, namely print and digital. A digital module is a module in the form of an application on a smartphone. Most modules are combined with various bases in module development to improve their quality. Starting from the basics, inquiry (Hairida, 2016), Literacy and HOTS (Feriyanto & Putri, 2020) to discovery (Ellizar et al., 2019). In this study, a self-regulated basis was selected in the module.

Self-regulation is widely discussed and in demand in learning (Zhou & Hiver, 2022). Self-regulation can encourage the development of students' metacognition, motivation, and strategic action (Brenner, 2022). Self-regulated abilities can make students actively involved with learning, such as goal setting, planning, use of task strategies and time management, reflecting on the effectiveness of past learning strategies and adapting future learning as needed (Russell et al., 2022). This self-regulated concept refers to self-regulation that can result in achievement and is an orderly stage. Regularity in this learning process can improve critical thinking skills. In line with this, the results of interviews and documentation studies that have been carried out on lecturers in Basic Mathematics courses are needed to create teaching materials that can improve learning to be more innovative and modern and support independent student learning. So it is appropriate to develop a self-regulated-based digital module.

Many studies on the use of modules in improving critical thinking have been carried out (Andriani & Suparman, 2019; Haryanto et al., 2021; Lestari et al., 2020; Syahrial et al., 2021). However, the basic self-regulated module to improve critical thinking skills has never been studied. Therefore, the objectives of this study are (1) to describe a valid digital module based on self-regulated learning; (2) to describe a practical digital module based on self-regulated learning; and (3) to determine the effectiveness of a digital module based on self-regulated learning on students' critical thinking skills.

## METHODS

This research is a Research and Development (R&D) research which produces a product in the form of a digital module based on self-regulated learning in Basic Mathematics Courses. The development uses the ADDIE model, which consists of five stages (Dick & Carey, 1996), namely: (1) analysis; (2) designs; (3) development; (4) implementation; (5) evaluation. The stages of the research can be seen in Figure 1.

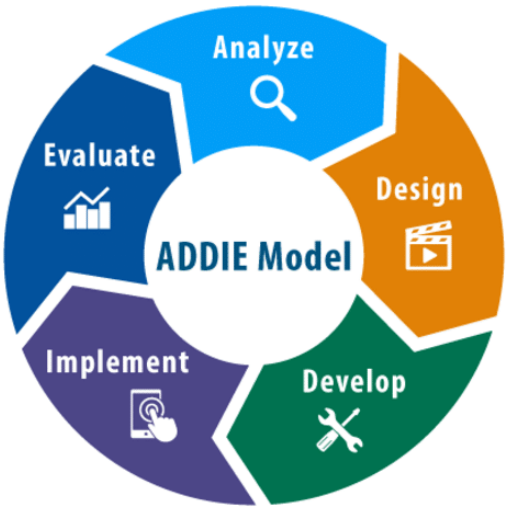



**Figure 1.** The ADDIE Development Model

In the analysis stage, the researchers analyzed the urgency, feasibility, and requirements for developing a digital module based on self-regulated learning in basic mathematics courses. Needs analysis includes student characteristics, background and conditions, subject matter, and relevant sources to be used as the basis for developing a digital module. At the design stage, the researcher prepares a plan for doing a digital module that begins with developing a framework for making the digital module. This conceptual framework is used as a reference in preparing the digital module. In the development stage, the researcher develops a digital module based on the framework made in the previous stage. At the implementation stage, the researchers carried out validation and feasibility testing of the digital module that had been developed. The trial was carried out on 239 students. In the final stage, the researchers analyzed the trial's results to determine its effectiveness on students taking basic mathematics courses.

The research instruments used consisted of test and non-test instruments. Non-test instruments include validation sheets and practicality questionnaires. While the test instrument includes a critical thinking skills test, the validation sheet aims to verify the validity of the developed product. The validation sheet was filled out by two experts, each of whom assessed the design and content of the developed digital module. The validation sheet contains several aspects of the assessment: material substance, visual communication display, learning design, and software utilization. The practicality questionnaire aims to measure digital module products' practicality level. This questionnaire was filled out by test subject students who have used digital modules developed in their learning. The variables assessed in the practicality questionnaire were student interest, the process of use, increased student activity, and the adequacy of the available time. The critical thinking skills test instrument used is in the form of an essay question consisting of five questions. The test instrument is valid and reliable.

The data analysis technique to determine the valid and practical criteria used is descriptive analysis, namely by describing the level of validity and practicality of the developed product. In this development research, two data analysis techniques were used: quantitative and qualitative descriptive. Qualitative data was analyzed by collecting comments and suggestions from expert validators and students as consideration for revising the product. Quantitative data was analyzed

by calculating the percentage score from filling out the validation questionnaire sheet. Data analysis techniques to determine the effective criteria were inferential statistical analysis. Researchers experimented with digital module based on self-regulated learning on students' critical thinking skills. The analysis uses the t-test. The prerequisites are the normality test and the homogeneity test.

## RESULTS AND DISCUSSION

This study reports the results of developing a digital module based on self-regulated learning in basic mathematics courses. The feasibility level of this digital module is known through validation by media experts, validation by material, validation by course lecturers and trial use by students.

### Analyze Stage

At the analysis stage, the activities carried out include (1) analyzing graduate learning outcomes that students must master; In real terms, this textbook is realized by determining graduate learning outcomes (CPL), course learning outcomes (CPMK), and sub-course learning outcomes (Sub-CPMK), (2) analyzing student characteristics concerning knowledge, attitudes, and skills that students have owned, and (3) analyzing relevant material for the achievement of the desired competencies possessed by students. The analysis results at this stage are self-evaluated and followed by a joint evaluation with colleagues to refine the analysis results.

### The Design Stage

The design stage focuses on three activities: the selection of materials according to the characteristics of students and the demands of the competencies to be achieved; learning strategies; forms, and methods of assessment and evaluation. At this stage, the structure of the textbook and the framework of the contents of the textbook are designed. You and your friends evaluate the results obtained at this stage to refine the design results.

### The Development Stage

At the development stage, several activities were carried out, such as searching and gathering relevant sources to enrich the material, making illustrations, charts, and graphs needed, typing, editing, setting the layout of textbooks, and digitizing modules. The following activities in the development stage are activities to validate the draft product development and revision after expert input.

### Implementation Stage

At this stage, the development results are applied in learning to determine the effect on the quality of learning, including effectiveness, attractiveness, and learning efficiency. Implementation is carried out in small groups to get input from students as material for improving product drafts.

### The Evaluation Stage

The last stage is to conduct an evaluation, which includes formative evaluation. Formative evaluation is carried out to collect data in each phase used for improvement. It is carried out at the end of the program to determine its effect on students' critical thinking skills. This type of evaluation relates to the research development stage to improve the resulting product development. Evaluation of the ADDIE model has been carried out step by step. After the digital module based on self-regulated learning has been developed, the next step is to carry out

validation activities for the resulting product. The following describes the results of product development trials, starting with the validation of material experts, linguists, and learning media experts, to small group trials with second-semester students as the subject.

## Self-regulated Learning-Based Digital Module Validation

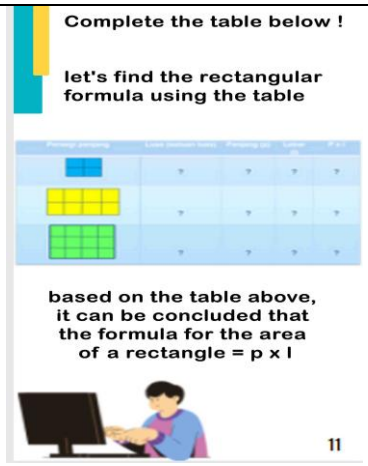
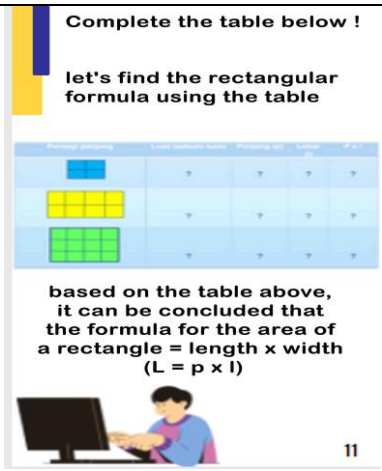
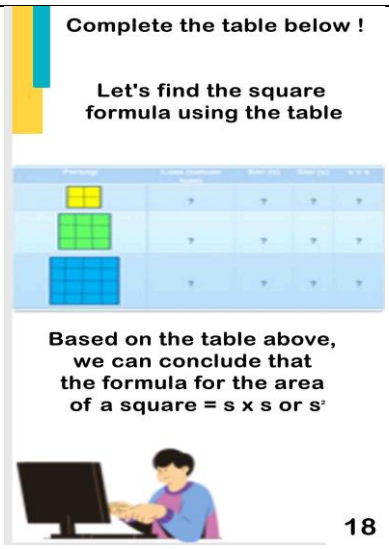
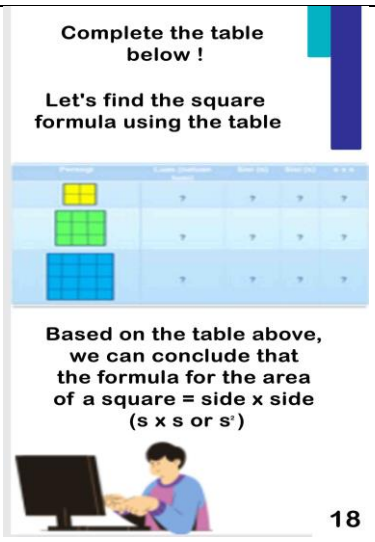
The results validating the digital module based on expert self-regulated learning were published. It was found that digital modules based on self-regulated learning were valid with good categories, meaning that digital modules based on self-regulated learning could be used with revisions. In general, the results of validation by experts are shown in Table 1 below.

**Table 1.** The Results of Validation.

| Self-Regulated Learning-Based Digital Module | Score from Validator | | | | | Average Score | Criteria |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | | |
| Media expert | 3,25 | 3,46 | 3,25 | 3,32 | 3,32 | 3,32 | Good |
| Material expert | 3,11 | 3,44 | 3,67 | 3,44 | 3,44 | 3,42 | Good |
| Linguist | 3,44 | 3,33 | 3,56 | 3,33 | 3,56 | 3,44 | Good |

Based on comments and suggestions from the validator, an evaluation is carried out and followed up by making revision to the parts that need to be improved. One example of a suggestion from a media expert and research validator to make improvements can be seen in Table 2.

**Table 2.** Product Revision

| No. | Revision | Before | After |
|---|---|---|---|
| 1. | Emphasizing each material's conclusion |  |  |
| | |  |  |

The developed digital module based on self-regulated learning has the following characteristics: (1) a digital module based on self-regulated learning includes core competencies, basic competencies and clear indicators of competency achievement; (2) the preparation of a digital module based on self-regulated learning refers to the demands of the Independent Curriculum; (3) contains components of self-regulated learning; (4) provides students with learning experiences to construct their knowledge through digital module based on self-regulated learning; (6) the presentation of the material begins with phenomena and problems in the real world context; (7) directing students to think critically.

Based on the validation results of five experts, it was found that the mathematics learning media developed were in the valid category. Several things caused the achievement of the valid criteria, including: (1) the components of a digital module based on self-regulated learning have been developed according to the theoretical basis and indicators contained in the instrument validity of learning media; (2) the preparation of digital module based on self-regulated learning refers to the demands of an independent curriculum process standard to improve critical thinking skills; (3) a digital module based on self-regulated learning was developed to accommodate students to think critically in solving problems.

### The Trial of Self-Regulated Learning-Based Digital Module

The test results of learning media show that the learning media developed are practical, with the following indicators: (1) observers argue that the implementation of learning with digital module based on self-regulated learning is in a good category; (2) student responses to digital module based on self-regulated learning are positive; (3) the response of lecturers (research colleagues) to learning media is good. This is following the opinion of Rochmad (2012) that practicality refers to the level that users (or other experts) consider an intervention to be used and preferred under normal conditions. Practical learning media because the implementation of learning is good and student-teacher responses are good.

### Self-regulated Learning-Based Digital Module Effectiveness Test on Critical Thinking Skills

Researchers collected initial data from UTS scores in the Advanced Mathematics Concept Course. UTS data is used to ensure that the initial conditions of the experimental class are homogeneous. The initial population data (the value in the form of the UTS value) was analyzed using a two-party t-test. Normality and homogeneity tests are used to perform prerequisite tests. Based on the initial data, it was obtained that the data came from normally distributed and homogeneous (see tables 4 and 5).

Furthermore, two classes were selected through random cluster sampling, with the first class as the experimental class and the second as the control class. After selecting two classes, the researchers conducted learning with a digital module based on self-regulated learning in the experimental class and learning without a digital module based on self-regulated learning in the control class. The researcher gave a critical thinking skills test after being given treatment three times.

The researcher developed the test. The test is in the form of multiple-choice questions and grids adapted to critical thinking indicators. The critical thinking test results showed that the experimental class's average score was better than the control class. The description is shown in Table 3 below.

**Table 3.** Description of Test Results

| | Experiment Class | Control Class |
|---|---|---|
| **Average** | 76,24 | 72,81 |
| **Max Value** | 96 | 93 |
| **Min Value** | 50 | 37 |

Based on Table 3 above, it is known that the average value of the experimental class is better than the control class. The following are the results of the normality test of critical thinking test data.

**Table 4.** Normality Test Results

| | Experiment Class | Kelas C |
|---|---|---|
| **$X^2$ count** | 5,26 | 2,27 |
| **$X^2$ table** | 7,81 | 7,81 |
| **Criteria** | Normal distribution | Normal distribution |

Based on Table 4 above, the results of the normality test of the data show that the $X^2$ count is smaller than the $X^2$ table, so it can be concluded that the data comes from a normally distributed population. The following are the results of the critical thinking test data homogeneity test.

**Table 5.** Homogeneity Test Results

| | Experimental and control homogeneity test results |
|---|---|
| **$F_{count}$** | 1,44 |
| **$F_{table}$** | 1,92 |
| **Criteria** | Both classes have the same variance |

Based on Table 5 above, the results of the data normality test show that the calculated F is smaller than the F table, so it can be concluded that the two classes have the same variance. The results of the similarity test of the two mean critical thinking skills test data are shown in table 6.

**Table 6.** Results of the Similarity Test of Two Means

| | Average | N | $T_{count}$ | $T_{table}$ | Conclusion |
|---|---|---|---|---|---|
| Experiment Class | 76,24 | 36 | 2,86 | 1,993 | There are differences between the experimental and control classes. |
| Control Class | 72,81 | 40 | | | |

Based on Table 6 above, the average critical thinking of the experimental class is 76.24, while the average critical thinking of the control class is 72.81. This shows that the experimental class's critical thinking is better than the control classes. These results are in line with the results of research (Morin & Saadé, 2012; Retnowati et al,. 2020; Desnita et al.,, 2022), which states that the use of digital modules can have a positive effect on students' critical thinking skills. Through the use of the digital module, students are given the responsibility to solve the problems given so that their self-regulated learning becomes better.

The test results of the digital module based on self-regulated learning have shown the following results: Student activity in the experimental class is high; (2) students' critical thinking skills in the digital module trial class based on self-regulated learning are superior to students' critical thinking skills in the learning class without a digital module based on self-regulated learning. Based on these two things, the trial of digital modules based on self-regulated learning has resulted in an effective learning process.

The success of the experimental class learning is because the digital module has succeeded in increasing student self-regulated learning in a positive direction, especially critical thinking skills individually and discussion until a solution is found. Students are better trained to solve critical thinking questions to improve their critical thinking skills. This is in line with research

by Broadbent et al. (2020) that the use of digital technology affects students' self-regulated learning. Students with moderate or low mathematical abilities find the method used to solve problems tends to give long and sometimes inaccurate answers. Even many students with low mathematical abilities have difficulty finding ways to solve mathematical problems. Therefore, teachers and educators must be creative in developing digital-based teaching modules.

## CONCLUSIONS

The results of the study are as follows: (1) the developed self-regulated learning-based digital module is declared valid; (2) the digital module based on self-regulated learning is stated to be practical as indicated by the response and implementation of learning with the digital module based on self-regulated learning in the good category; and (3) students' critical thinking skills in the experimental class are better than the control class. Generally, the self-regulated learning-based digital modules are valid, practical, and effective.

## AUTHOR CONTRIBUTIONS STATEMENT

The lead researcher, DK, is in charge of analyzing, designing, and developing modules based on Self-Regulated Learning. Research member VY is in charge of designing teaching modules in digital form, preparing trials, and conducting data analysis.

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