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An ePub learning module and students' mathematical reasoning ability: A development study

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Abstract

The mathematical reasoning ability is one of the essential hard skills of a student, especially in solving everyday problems. In supporting the achievement of this mathematical reasoning ability, meaningful teaching materials are an essential part of keeping exciting and not dull a learning process. This study aimed to design and develop an e-module in the ePub format with the problem-based learning approach to improve students' mathematical reasoning ability on arithmetic sequences and series concepts. This study used the design research method of development research in two stages—preliminary design and formal evaluation design—with tryouts performed on 32 grade XI students as research subjects. The data collection techniques used were documentation, observation, interviews, and tryouts. Data analysis was carried out quantitatively and qualitatively. The results showed that the e-module developed was valid and practical to improve students' mathematical reasoning ability, especially in solving problems related to sequences and series. The indicators of mathematical reasoning ability better improved using this ePub module were proposing problem-solving assumptions and concluding solutions logically. The development of the e-module in the e-Pub format offers alternative solutions to improve students' mathematical reasoning ability.

Keywords: Design Research, e-Module, ePub, Mathematical Reasoning

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The reasoning ability is one of the higher-order thinking skills important to be carefully developed and mastered by students (Saleh et al., 2017; Thompson et al., 2017; Thuneberg et al., 2018). Numerous things related to the reasoning ability will later see many applications in the solving of everyday problems (Hendriana et al., 2019; Kurniawan et al., 2018; Pratiwi et al., 2019; Rawani et al., 2019; Yansen et al., 2019). One will need the ability to distinguish the good from the bad and the important from the unimportant when facing problems in life (Hidayat et al., 2018). Reasoning is the ability to estimate something based on the facts needed to solve the problems at hand. Thus, it is one of the essential competencies that must be mastered by students.

The Government of the Republic of Indonesia through the Ministry of Education and Culture (Kemendikbud) has adopted a policy setting out the elimination of the National Examination starting from 2020 and has implemented minimum competency assessment (MCA) and character survey for elementary and secondary school students in its place (Machromah et al., 2021; Nusantara et al., 2021).

This shows that, either on a personal, national, or global scale, learning processes in Indonesia are focused more on assessing the skills of text literacy reasoning and numerical (mathematical) literacy reasoning than on the contextual problems faced by students (Dasaprawira et al., 2019; Efriani et al., 2019; Hwang & Ham, 2021; Nusantara et al., 2021).

The policy of the Ministry of Education and Culture of the Republic of Indonesia that stipulates to abolish the National Examination assessment system and replace it with MCA is also based on the 2018 PISA report showing that Indonesia's rating was unsatisfactory, being ranked 73rd out of 79 countries (Schleicher, 2019). In addition, when compared to the 2015 PISA results, its ranking also appeared to have decreased with a score declining from 386 to 379. The study was also strengthened by the results of an internal survey by the Indonesian Government through the Indonesian National Assessment Program (INAP), whose name was later changed into the Indonesian Students Competency Assessment (ISCA), stating that Indonesian students' average acquisition of mathematical literacy competence was still low (Megawati & Sutarto, 2021).

The results of the 2018 PISA survey showed that most Indonesian students had low abilities in answering questions in the HOTS category (Dasaprawira et al., 2019; Schleicher, 2019). These results proved that Indonesia is one of the countries in which students are still at a low level in the aspect of mathematical reasoning skill (Zulkardi & Putri, 2020) although many have realized that this skill is essential for them to solve everyday problems.

Research on students' low mathematical reasoning skill (Hendriana et al., 2018; Kusmaryono et al., 2018; Kusmaryono et al., 2020; Rohaeti et al., 2020) showed that teachers still rarely train students to improve higher-order thinking skills, especially mathematical reasoning. There are many factors causing the teachers to rarely develop reasoning ability questions, among which is them lacking a sufficient competence necessary to make those questions to test the students' high-level reasoning ability on their own (de Castro, 2004; Hendriana et al., 2017; Hendriana & Fadhillah, 2019; Hidayat et al., 2018; Risnawati et al., 2019). In relation to the importance of developing digital independent teaching materials, Winters et al. (2008) state that the use of computer-based teaching materials can help students learn independently, so it is expected to increase the students' motivation and self-confidence. In addition, the use of independent learning modules has been proven to improve students' higher-order thinking skills (Benavides-Varela et al., 2020; Klingenberg et al., 2020; Li et al., 2021; Ramadhani et al., 2019), one of which is the mathematical reasoning ability.

In addition to using appropriate teaching materials, we also need a proven learning approach to train and improve students' reasoning skill. An approach qualified to improve mathematical reasoning is Problem-Based Learning (PBL). This is an approach that provides problems at the beginning of learning activities to which students are then asked to make solutions. In learning, students are expected to form new knowledge based on the knowledge they already have guided and directed by the teacher as a facilitator (Firdaus et al., 2017; Kim et al., 2018; Mann et al., 2021; Masfingatin et al., 2020; Merritt et al., 2017; Mulyanto et al., 2018).

Mathematics is a science of patterns and order have the meaning that mathematics is a science that discusses patterns or regularities and levels. Like learning sequences and series, students are taught to learn regular patterns, think logically, carefully, creatively and to reasoning. Materials Sequences and series are mathematical topics that are closely related to everyday life. This material is introduced to elementary school students as number patterns, then proceeds to the topic of sequences and series at the junior and senior high school levels. So, students need to understand this topic completely because it is taught continuously at several school levels and the importance of this material in helping solve everyday problems that students can face. However, students in fact still have difficulty understanding concepts and then applying them in solving problems related to sequences and series in everyday life. From the explanation above, it is very important for students to learn and master the concept of sequence and series material (Maharani et al., 2020; Rachma & Rosjanuardi, 2021).

Research results showed that PBL could improve students' mathematical reasoning ability in terms of mathematical sequences and series (Eriksson & Sumpter, 2021; Leong et al., 2021; Merritt et al., 2017; Setiawan, 2020; Suprapto et al., 2017). However, their ability on mathematical sequences and series materials, influenced by the problem-based learning approach with the use of independent teaching materials in the digital form, has never been investigated. Thus, it is necessary to conduct research focused on developing self-reliant teaching materials or digital modules.

The self-reliant teaching materials that will be developed in this research are in the form of an ePub module. They are designed in the form of a module that is beneficial in making students more interested in learning and in improving self-reliant learning activities. Thus, this study aimed to develop an ePub-mathematics module with the problem-based learning approach and to determine its effect on students' mathematical reasoning ability.

METHODS

This study aimed to develop an electronic mathematics module with the PBL approach in the ePub (electronic publication) format. The research model used was the design method of development research (Purwitaningrum & Prahmana, 2021). It was conducted in two stages, namely preliminary design and formative evaluation design.

Preliminary Design

In this stage, the researcher arranged the place, subjects, and other preparations, including the schedule for conducting the research. The research was conducted at SMA Negeri 2 Padalarang, West Bandung Regency, West Java Province, on July 27, 2021. The subjects were 32 students of grade XI of SMA Negeri 2 Padalarang, two of whom were assigned in the individual tryout, six in the small-group tryout, and 24 in the field tryout.

Formative Evaluation Design

This stage was divided into three sub-stages, namely self-evaluation, designing the prototype, and field testing.

Self-evaluation

This sub-stage was comprised of two phases, namely analysis and design. In the analysis phase, the researcher analyzed the students, curriculum, and contents. The aspect analyzed in the students was their abilities in learning mathematics, the data of which were obtained from interviews with the teacher. The researcher also received information about their abilities which were then classified into high, medium, and low category. The curriculum analyzed was the K-13 Curriculum for the Mathematics subject, particularly the Core Competencies and Basic Competencies in the arithmetic sequences and series materials taught in grade XI of high school. In addition, the books commonly used to learn the materials in question were also analyzed.

At the design phase, the researcher designed the product to be developed in the form of an electronic module in the ePub format to improve mathematical reasoning skill on arithmetic sequences and series with the problem-based approach. The module design focused on five aspects of feasibility: (1) content; (2) presentation; (3) language; (4) conformity with the problem-based approach; and (5) conformity with the principles of module development (see Table 1).

Table 1. Development characteristics

No	Development Aspects	Indicators
1	Content feasibility	a. Conformity with the Basic Competences b. Accuracy of the teaching materials c. Up-to-date teaching materials
2	Presentation feasibility	a. Presentation technique b. Presentation supports c. Complete train of thought
3	Language feasibility	a. Straightforwardness b. Communicativeness and interactivity c. Suitability with students' development d. Conformity with language rules e. Accuracy of terms and symbols
4	Conformity with the PBL approach	a. Problem orientation b. Problem-solving c. Troubleshooting results
5	Conformity with the principles of module development	a. Self-Instructional on ePub Module b. Self-Contained (ePub contians various media) c. Stand alone (ePub doesn't need another separate media) d. Adaptive (ePub can be readjusted and costumized) e. User-friendly (ePub easy to use)

Designing the Prototype

This sub-stage consisted of three phases, namely expert review, individual tryout, and small-group tryout. At this sub-stage an evaluation of the product designed was carried out.

1. Expert Review

This is a phase in which practitioners considered expert at mathematics learning and IT evaluated and validated the module designed to analyze its strengths and weaknesses. They took a look at the aspects of module development presented in Table 1.

The experts assessed, evaluated, and validated the module resulted based on the prototype I design developed in the self-evaluation stage. The module was then revised according to the experts' suggestions and comments. Their validation statement of the module designed was available on the validation sheet as a consideration for the module revision; they would state whether the module was valid or in need of revision. The result of the revision of prototype I at this stage is called prototype II.

2. Individual Tryout

This is a phase in which prototype I, that was previously developed, was tried out on several students separately. This phase was parallel to the expert review, so that the results from this phase were used to revise prototype I to produce prototype II.

3. Small-group Tryout

This is a phase in which prototype II, that was developed based on the results of the expert review and individual tryout, was tried out on several students who had different levels of ability. At this phase, six students were asked to discuss and study the module designed and to provide comments or suggestions about the module. This tryout aimed to determine the practicality of the module developed. Based on the inputs and suggestions from the students in the small-group tryout, the module was then revised to produce prototype III.

Field Tryout

In this sub-stage, the product was tried out on a larger number of students than the number of students in the previous sub-stage. The product tried out at the field tryout was one that met the quality criteria—validation, according to the experts, and practicality, according to the students' responses—and that was considered feasible to use to improve students' mathematical reasoning abilities.

RESULTS AND DISCUSSION

Preliminary Design

The study was conducted at SMA Negeri 2 Padalarang, West Bandung Regency, West Java Province, on July 27, 2021. The subjects were 32 students of grade XI at SMA Negeri 2 Padalarang, comprising two students as subjects in the individual tryout, six students in the small-group tryout, and 24 students in the field tryout.

Formative Evaluation

This stage consisted of three sub-stages of development: evaluation, prototype designing (expert review, individual tryout, and small-group tryout), and field tryout and revision, from which the final product was resulted. Based on the development characteristics (see Table 1), an electronic module in the ePub format was designed using the application Sigil version 2.0. From the module designing, an output of the ePub display on a smartphone was obtained (see Figure 1).

Translate:

2. LEARNING ACTIVITIES

A. Introduction

In this meeting, we will discuss the pattern of numbers, rows and arithmetic series. You can find the concept of rows and series in everyday life, one of which is in the financial sector, namely the investment concept.

For example, you invest with an initial capital of IDR 10,000,000 with the same profit every month. If in the 4th month you get a profit of IDR 300,000 and in the 8th month you get a profit of IDR 1,720,000.

The benefits that you get by investing are also pretty good. The longer the period of time, the more profits will be obtained and multiplied. This concept in economics is also known as Compound Interest.

From the example above, how much profit will you get after 5 years of investing? The total profit you get, can be calculated with the concept of rows and series.

Figure 1. The ePub display on a smartphone (Prototype I)

The mathematics module that was designed (prototype I) was validated by material experts. After that the module was revised based on the comments or suggestions from the validators, which are presented in Table 2.

Table 2. Suggestions and comments from expert validators

No	Suggestions	Changes
1	PBL characteristics are not present, especially in phases 3 and 4.	An instructional description on the module in each problem-solving stage is provided.
2	The module should not stimulate students' curiosity to solve problems too much.	Conclusions of the concepts and principles presented are no longer provided. Students are given an opportunity to draw their own conclusions.
3	The file size is too big for students to download.	Files that are large in size (videos and images) were compressed.

Based on the suggestions and inputs from the reviewers, the researcher made some revisions, an example of one of which is presented in Figure 2.

A number sequence is a sequence of a set of numbers with certain rules.
Example:

a) 1, 2, 3, 4, 5, …
b) 2, 4, 6, 8, 10, …
c) 14, 11, 8, 5, 2, …
d) 2, -2, 2, -2, 2, …
e) 1, ½, ¼, …
f) 8, 4, 3, 1, -2, -5, …
g) 1, 5, 3, 7, 9, …

In the example above, the numbers in **a**, **b**, **c**, **d**, **e** have certain rules so they are called number sequences, while **f** and **g** have no rules.

> Each number in the number sequence is called a term (U).
> The first term is denoted by U_1 or a
> The second and third terms are denoted by U_2 and U_3
> The n^{th} term is denoted by U_n, where $n \in N$

Figure 2. An example of a summary of the concepts and principles provided

After the expert review was performed, the module developed was given to several students at SMA Negeri 2 Padalarang for the individual tryout. After that the module was revised based on the comments or suggestions for improvement from the students combined with the suggestions from the expert review that was conducted in parallel.

After being revised, the PBL-based module (now prototype II) was tried out on six students (a small group) from a different class than the students involved in the individual tryout. The students were given the module developed, and the students studied and solved the questions contained in the module. The students then provided some comments/suggestions about the developed module. Each student was asked to provide feedback about the readability of the module, which included the easiness or difficulty in understanding the materials contained in the module and how they could perform the instructions given with the problem-based approach (see Figure 3).

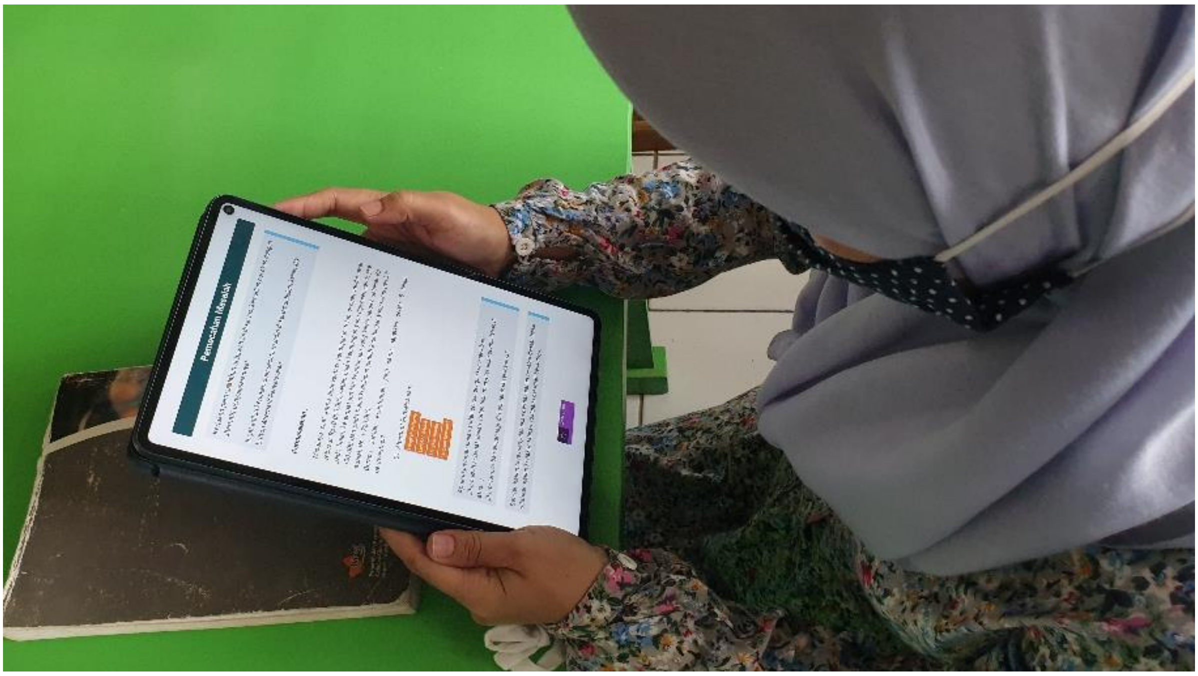

Figure 3. A student studied the module (prototype II) in the small-group tryout

The responses and inputs from the students from the small-group tryout were used as considerations for the improvement of the module, which at this time entered the prototype III or final design phase, before the module was tried out in mathematics learning activities to determine its impact on students' mathematical reasoning ability. Some of the responses and inputs given by the students in the small-group tryout phase included the following: 1) there was a lack of legibility in the formulation of concepts and mathematical symbols in some parts of the module; 2) it was considered that there were too many questions in the final evaluation exercise section and there was not enough time for students to work on all the questions; and 3) the instructions for using the module were not very clear, so more explanation from the teacher was needed.

Prototype II was revised based on the inputs from the small-group tryout to produce prototype III, which was then given at the time of product testing on students. The module used was tried out on students to find out whether the module could improve the students' mathematical reasoning ability on arithmetic sequences and series.

The module implementation in the learning process lasted for two meetings. In the first meeting pre-test and learning process were carried out. The second meeting was for the learning process and working on the post-test questions. Students were given a pre-test before the module was tried out during the learning process. Finally, the students were given a post-test after the learning process using prototype III on arithmetic sequences and series (see Figure 4).

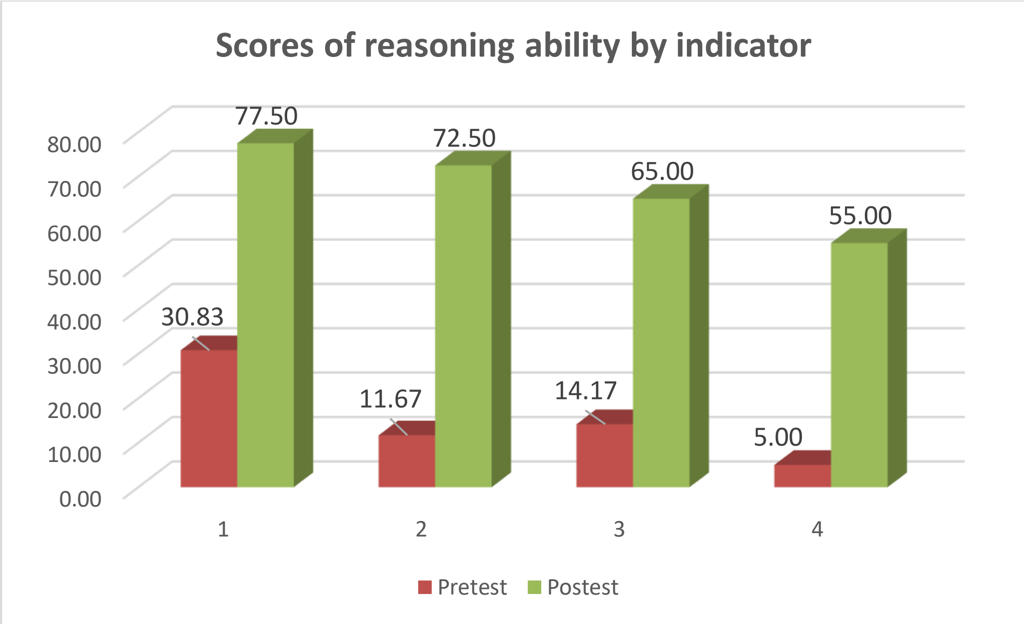

Figure 4. Students' pretest and posttest scores at the field tryout sub-stage

Figure 4 shows that the scores of students' mathematical reasoning ability during the posttest increased after the implementation of the learning process using the ePub module with the PBL approach. Based on the comparison of scores for the 2nd and 3rd indicators, there was a difference in the students' reasoning ability: in the 2nd indicator, the students seemed to find it easier to make logical conclusions based on the visualization of the ePub learning module. This means that, if students learn to understand a problem using an interactive learning medium, it will be easier for them to solve and draw conclusions from the problems they have faced (Benavides-Varela et al., 2020; Hendriana et al., 2018; Hidayat et al., 2018; Li et al., 2021; Rohaeti et al., 2020; Thuneberg et al., 2018).

From the comparison of students' answers when working on pretest and posttest questions about mathematical reasoning ability on sequences dan series topics, it can be seen that before students study the material for that topics through the ePub module with a problem-based approach (see Figure 5), students cannot solve the problem completely, this shows students are not really have the ability to understand and to analyze the problems given, so that students do not have an idea how to solve or find answers to these problems given. Even though, we can see on student answer (see Figure 5), students already know what concepts are needed to solve problems, they are just confused about how to apply these concepts to help solve the problems given.

Then if we look carefully at the students' answers when working on the posttest questions on right side of Figure 5, students have been able to master and understand thoroughly the problems given and then they know how the procedures for solving these problems are. This can be used as an indicator that learning with a problem-based approach using the ePub module is able to train students' mathematical reasoning skills, especially on sequences and series topics, so that students can solve everyday problems related to the topic of sequences and series.

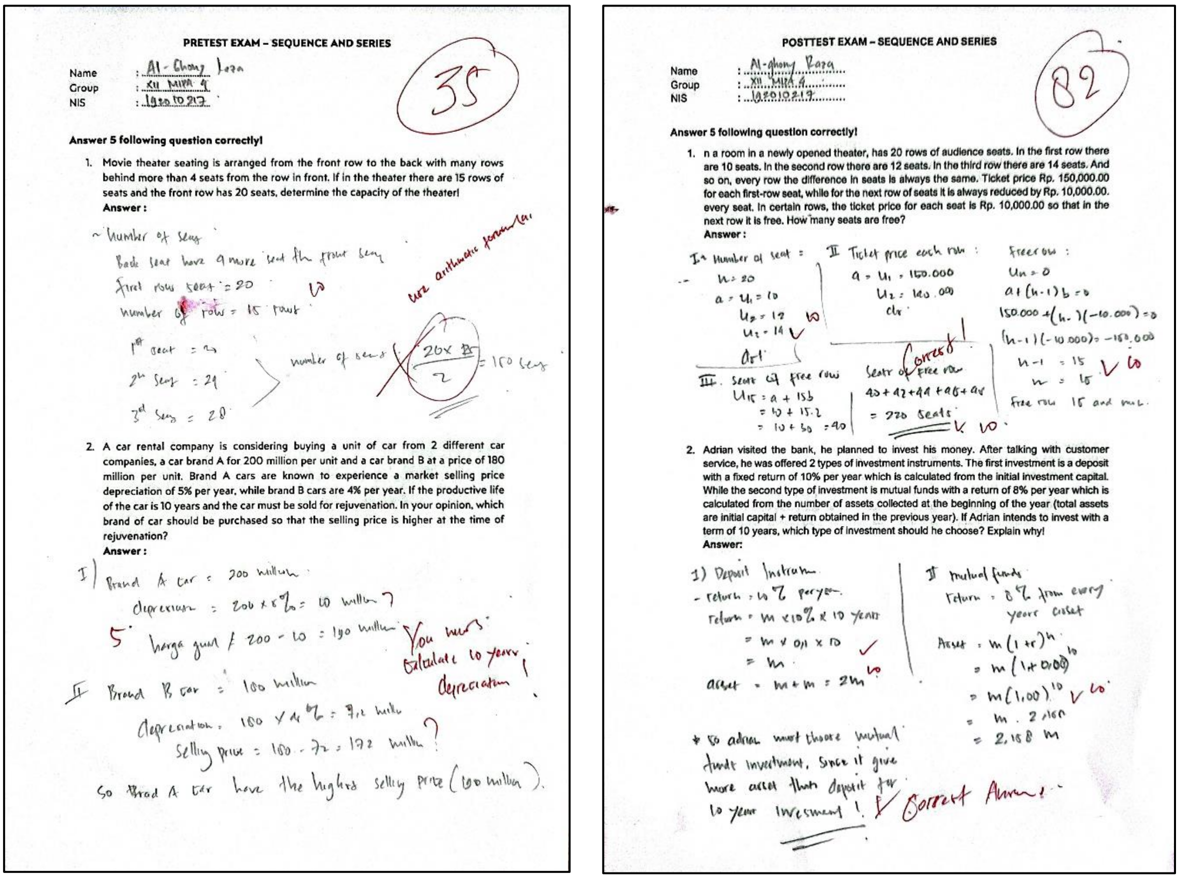

Figure 5. Sample of Student Paperwork of Pretest and Posttest

The achievements of indicators of the students' mathematical reasoning ability were categorized into three, namely high, medium, and low levels of ability. The indicators making problem-solving assumptions and making logical conclusions fell into the high level of ability category. Meanwhile, the indicators compiling evidence against the correctness of the solution and finding patterns and relationships (generalizations) fell into the medium level of ability category (see Table 3).

Table 3. Posttest achievements based on mathematical reasoning indicators

No	Indicators of Mathematical Reasoning Ability	Posttest Score Average	Category	Total Students (N = 24)	
				$X_i \geq 70.00$	$X_i < 70.00$
1	Proposing a conjecture or assumption of a solution to the problem	77.50	High	16 (66.67%)	8 (33.33%)
2	Constructing logical conclusions	72.50	High	13 (54.17%)	11 (45.83%)
3	Compiling evidence and giving reasons or evidence for the correctness of the solution	65.00	Medium	7 (29.17%)	17 (70.83%)
4	Finding patterns and relationships to generalize	55.00	Medium	1 (4.17%)	23 (95.83%)

Regarding the students' achievements of mathematical reasoning ability, Table 3 shows that only 16 of 24 students (66.67%) were able to propose conjectures or assumptions of solutions to the problems given, while the remaining 8 (33.33%) were less good. Likewise, in the indicator making logical conclusions, the students' achievements of mathematical reasoning ability were good in 13 of 24 students (54.17%) and less good in the remaining 11 (45.83%). This shows that the students tended to be able to solve problems based on basic assumptions and make conclusions of the work logically (Dasaprawira et al., 2019; Fitriani et al., 2018; Gorev et al., 2018; Kadarisma et al., 2020; Morsanyi et al., 2018; Norqvist, 2018; Powell & Fuchs, 2018; Saleh et al., 2017).

In the indicators compiling evidence and finding patterns and relationships to generalize, all students were considered to have a medium level of ability. This shows that they were still doing problem-solving procedurally (Bergqvist & Lithner, 2012; Bergqvist et al., 2008; de Castro, 2004; Eriksson & Sumpter, 2021; Hidayat et al., 2018; Lithner, 2014). In addition, the problem-solving procedures carried out by the students were based on the examples taught by the teacher, which constituted an imitative reasoning thoughtful process (Granberg & Olsson, 2015; Hendriana et al., 2018; Jonsson et al., 2014; Lithner, 2008, 2017; Mac an Bhaird et al., 2017).

CONCLUSION

This study attempted to design and develop a product in the form of a self-reliant electronic module in the ePub format with the PBL approach to improve students' mathematical reasoning ability, especially on sequences and series materials. The module design went through a formative evaluation design stage, which included self-evaluation, designing prototype (expert review, individual tryout, and small-group tryout), and field tryout sub-stages.

The ePub module with the qualitative PBL approach developed was declared valid based on the results of the assessment by some validators, who later contributed suggestions and comments for the improvement of the module in terms of content, flow, and language. The validators declared the module to be good based on the content (the materials and necessary competencies, following the steps in PBL learning) and construction (developing mathematical reasoning skills, building good concepts), with the use of a simple language the students could understand easily. In addition, the module developed was categorized as qualitatively practical.

Based on the observation during the small-group tryout, all students could use the ePub module well and independently. This shows that the module developed was in accordance with the students' characteristics and levels of ability. Finally, the researcher had successfully developed an ePub module with the PBL approach that could improve students' mathematical reasoning ability, especially in the indicators proposing predictions for problem-solving and making logical conclusions.

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Declarations

Author Contribution : WH: Conceptualization, Writing – Original Draft, Editing and Visualization.
EER: Validation, Review Formal Analysis and Language Proofreading.
AG: Visualization, Review Formal Analysis and Templating.
RIIP: Validation and Review Formal Analysis.

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