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Development of Mathematical Module Based on Guided Discovery to Develop Critical Thinking Ability and Learning Independence

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***Abstract**: In mathematics learning the ability to think critically and the independence of learning is essential to be trained and developed. Therefore, it is necessary to design or compile materials or teaching materials that support the realization of critical thinking and student learning independence. The purpose of this study was to produce guided discovery-based mathematics modules to help develop critical thinking skills and learning independence of grade VII students of SMP/MTs. The research method used is a design research type formative evaluation. The research was conducted in two stages: the preliminary stage and the formative evaluation stage. The formative evaluation phase includes self-evaluation, prototyping (expert reviews and one-to-one, and small groups), as well as field tests. This study produced teaching materials in the form of mathematics modules on valid and practical social arithmetic materials. Then based on the process of development and analysis, the prototype of mathematics modules based on guided discovery has potential effects on critical thinking skills and learning independence.*

***Keywords**: Guided Discovery, Critical Thinking Ability, Learning Independence, Mathematics Module*

INTRODUCTION

Critical thinking is the ability of reflective thinking so students can assess skillfully to decide information that can be relied upon in problem-solving (Kong, 2015; Fung, 2014). The ability to think critically is one person's ability to solve problems and draw conclusions by providing logical reasons or solutions. Palinnusa (2013) says the ability to think critically is one's ability to identify problems, connect, analyze and solve mathematical problems. In the learning process, critical thinking is needed to achieve optimal results. *The Partnership for 21st Century Skills* confirms that one of the abilities students must possess in *21st-century* learning is critical thinking. Empowering critical thinking in students can help them in solving various problems in everyday life. Critical thinking can improve creative problem solving by encouraging students to find new strategies when solving problems (Aizikovitsh-Udi, 2015; Huang, 2016).

Syahbana (2012), research shows that there is still a low average of critical thinking skills in mathematics in junior high school students. This is also evident from the low performance of Indonesian students in the international world. The results of the latest TIMSS study in 2015, the achievement of Indonesian students in mathematics ranked 46 out of 51 countries. Conditions that are not much different can be seen from the 2015 PISA results, Indonesia ranked 62 of the 70 participating countries. The low ability of students to think critically in mathematics learning needs to get serious attention from all circles, especially mathematics teachers. For that reason, students' critical thinking skills are very important to be trained and developed.

In addition to critical thinking skills, learning independence is one of the effective aspects that are also important for students. Independence is a form of self-confidence to organize, develop, and be able to solve problems without intervention from others. (Abubakar, 2015; Sumantri, 2016). Independent people are easier to develop themselves than people who are less independent or even not independent. Agree with Kanan (2015), independent people will be more responsible and confident than people who are not independent. Metallidou (2010) says that independent learning is learning that allows students to determine their own learning goals,

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plan, make decisions, and conduct activities that contribute to the achievement of learning goals.

The need to develop learning independence for students who study mathematics is also supported by several findings. Independent learning has a positive effect on students' academic achievement (Banarjee, 2014). The greater the independence of student learning, the higher the learning outcomes of mathematics and vice versa (Vargas, 2012; Çiftçi, 2015). However, at present the reality that learning independence has not been socialized and developed among students. Students consider the teacher to be the only source of knowledge so that students have dependencies with others, especially to the teacher. Based on observations at SMP N 3 Pajangan and MTs Muhammadiyah Karangkajen that students often experience doubts and difficulties in solving problems, this happens because students do not believe in their own abilities so that the learning independence of students is still low.

Based on the description above, critical thinking skills and student learning independence are needed. Therefore, it is necessary to design learning that supports the realization of critical thinking and student learning independence. One of the mathematical learning models that can be used to help develop student independence and critical thinking is guided discovery learning models. Guided discovery learning is more effective than conventional learning because guided discovery learning can help students learn actively and motivate students to learn (Alex, 2013; Makoolati, 2015; Achera, 2015; Lasisi, 2016). Guided discovery learning is a teaching method that uses exploration, manipulation, and experimentation to enable students to discover new knowledge or new concepts (Lasisi, 2016; Shieh, 2016). Some studies show guided discovery learning can improve student learning independence (Akanbi, 2014) and guided discovery learning can improve students' critical thinking skills (Yuliani, 2015).

Apart from the learning model, the right teaching materials will help students in the learning process. Designing or compiling material or teaching material becomes one of the things that are very instrumental in determining the success of the learning and learning process. In the source of the 2013 Curriculum socialization document (Kemdikbud, 2012) explained that the current condition, the nature of learning is still oriented to textbooks, while ideally, the nature of learning must be contextual. Therefore, there needs to be a teaching material other than a textbook as a companion material that can help students to learn more maximally. One learning resource that can be used to understand the concept of material and help students to learn independently, namely by using modules. Agreeing with Daryanto (2013) module is a form of teaching material that is systematically packaged and designed to help students master learning goals. Based on the results of interviews with mathematics teachers in SMP N 3 Pajangan and MTs Muhammadiyah Karangkajen, there are no teaching materials in the form of mathematics modules that support guided discovery learning models. Therefore, the researchers intend to develop a mathematics teaching material in the form of guided discovery-based mathematics modules.

This article aims to analyze the material to be developed in teaching materials in the form of guided discovery-based mathematics modules, design and produce guided discovery-based mathematics modules that can help the development of critical thinking skills and student learning independence.The article is written in a systematic manner as follows: the first section presents the introduction, the second part describes the research method, the third part outlines the results and discussion, and the fourth section provides conclusions.

RESEARCH METHODS

To develop mathematical modules based on a guided discovery that can help the development of critical thinking skills and learning independence used design research type formative evaluation. The stages of design research type formative evaluation consist of two stages, namely the preliminary stage and the formative evaluation stage (Tessmer, 1993; Mardiyanti, 2013). Formative evaluation stages include self-evaluation, prototyping (expert review, one-to-one, and small group), and field tests. Procedures of formative evaluation are presented in Figure 1.

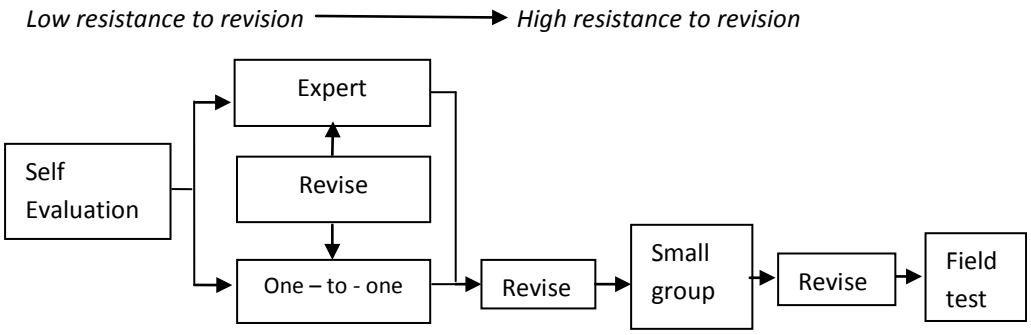

Figure 1. Design Formative Evaluation (Tessmer, 1993; Mardiyanti, 2013)

At the preliminary stage, the researcher performs the following activities: determining the place, the subject of the study, and arranging the research schedule. Then in the formative evaluation stage researchers conducted self-evaluation and prototyping. In the self-evaluation, stage researchers conduct curriculum analysis, material analysis, and completion of teaching materials. This teaching material is hereinafter referred to as prototype I. Prototype expert reviews and teachers validate in parallel. The results of the revision at this stage are called prototypes II. Prototype II was tested in a small group consisting of six students consisting of two high-ability students, two moderate-capable students, and two low-ability students. The revised results at this stage are called prototypes III. Prototype III was tested in field tests in the class which was the subject of the study. The focus of prototype III is to see the potential effects of mathematical modules developed on critical thinking skills and learning independence.

The instruments used in this study were validation sheets, teacher and student comment sheets, interview guides, observation sheets, videos, photos, and field notes. All instruments are used to collect data in this result. Then all data were analyzed using descriptive analysis and data triangulation.

RESULTS AND DISCUSSION

The development of this module uses research design research methods based on two stages, namely the preliminary stages and the stages of formative evaluation. The stages that have been carried out are as follows:

Preliminary stage

The research will be conducted in the second semester of the academic year 2017/2018 in the seventh-grade students of SMP N 3 Pajangan and MTs Muhammadiyah Karangkajen. The research subjects were class VII B of SMP N 3 Pajangan which amounted to 32 students. Documents used in 2013 in accordance with the curriculum of mathematics teaching junior high school and the material used is a social arithmetic. Based on the results of observations

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and interviews in SMP N 3 Pajangan and MTs Muhammadiyah Karangkajen, information was obtained that the teaching materials used by the teacher had not been able to stimulate students to carry out activities that could lead to the ability to think critically and independently in learning. Based on the analysis concluded that the available teaching material only presents simple problems that start from the example of the problem and end with similar exercises. This causes students difficulty in understanding the social arithmetic material. The ability of students to interpret questions into the language of mathematics and understand the concepts related to social arithmetic still need to be improved.

Based on the above problems, the completion of the mathematics module is based on the information and knowledge obtained at the analysis stage. Module completion consists of a cover page, preface, table of contents, core competencies and basic competencies, concept maps, module usage instructions, materials, and exercises. Modules created using *Microsoft Word 2010* and *Corel Draw*. At this stage a draft prototype I was obtained in the form of a mathematics module based on guided discovery.

Formative Evaluation Stage

In the formative evaluation stage, the first stage is a self-evaluation. At this stage, the researcher conducts his own assessment of the design results of the mathematical modules that have been made. Furthermore, the prototyping stage was carried out consisting of expert review, one-to-one, and small group. The expert review stage, the prototype I was given to 2 review experts, namely Dr. Sugiman, M.Sc. and Dr. Suprapto, M.Sc. At this stage, the validity of the module is consulted and examined based on content, stages, and language appropriately in accordance with the concept of guided discovery.

The suggestions and comments obtained from the validators on mathematical modules based on guided discovery learning model on a prototype I based on the content, stages, and language are outlined in the following Table 1.

Table 1. Validators suggestions or comments on the mathematics module

Validation Indicator	Comments or Suggestions
Content	• There are several materials in the module that the writing rules are not consistent with KD. • There is an unattractive writing font. • Images on each question should be original images from the photos themselves. • Every problem is adjusted to the learning objectives. • Avoid plagiarism in the development of materials and questions.
Stages	• In the preparation of the module must be in accordance with the steps of the guided discovery learning model. • The formulation of a number of questions needs to be reviewed because there is unclear information and inappropriate use of sentences. • Sentences in questions and questions are more concise so that students are easily understood.
language	• Some questions still use non-EYD sentences. • Every foreign language usage must be italicized.

Then simultaneously one-to-one stage, this stage prototype I is given to teachers and students. The results of teacher comments were used to revise the prototype I to produce a prototype II. Furthermore, the results of student comments as students' responses to the developed

mathematics module. The results of the revision of the prototype I will produce a prototype II. This prototype II was then tested at the small group stage. At this stage, six students with two high-ability students, two moderate-capable students, and two students with low ability to do learning using prototype II and students were asked to comment on prototype II. Comments and findings in the small group stage were taken into consideration to revise prototype II so that prototype III was obtained as the final prototype (product). The following is a mathematics module based on guided discovery learning in arithmetic material as a valid and practical final prototype product which can be seen in Figure 2.

Figure 2. The Initial Display of Modules

The picture above is the revised initial view based on input from experts, teachers, and students. The initial view consists of titles, keywords, and learning objectives. Furthermore, for displaying the module contents according to guided discovery learning can be seen in Figure 3.

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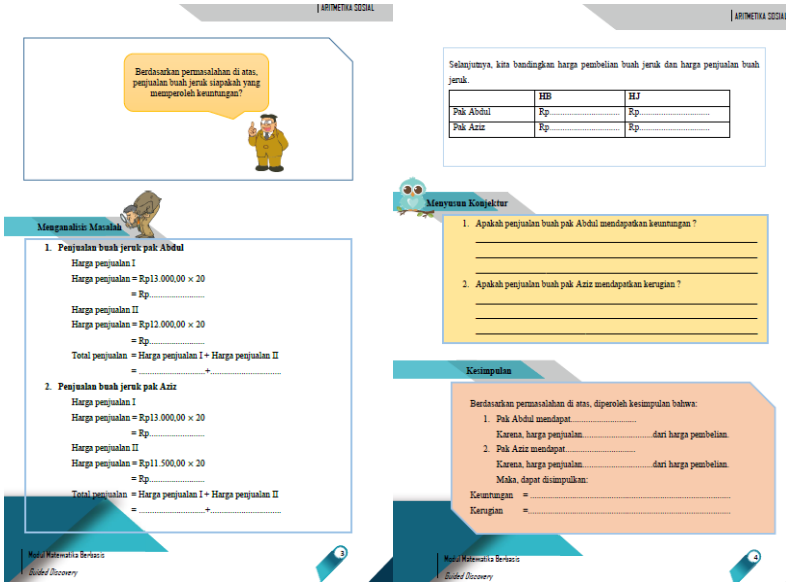

Figure 3. Steps of Guided Discovery Learning

The picture above explains the learning stages contained in the module contents. The learning stages used are guided discovery-based which consists of formulating the problem, analyzing the problem, compiling the conjecture, conclusion, and applying the conclusion. Problems in the module are presented with images to facilitate students in understanding problems, then at the stage of analyzing problems and conclusions requires students to be independent and think critically.

Field Test

At this stage, mathematics modules based on guided discovery learning in prototype III were tested on research subjects, namely students of class VII B SMP N 3 Pajangan with the number of students, namely 32 people. Mathematical modules based on guided discovery learning were tested for 4 meetings. The learning process was carried out on the 19th, 21st, 22nd, and 24th of February 2018. Before carrying out the research, the researcher conducted a socialization about guided discovery learning. The goal is for students to be better prepared for each learning process. Learning a process for four meetings; the first meeting was pretest and questionnaire, the second and third meetings were the learning process, and the fourth was the posttest and questionnaire meeting.

The provision of pretest and posttest aims to obtain students' critical thinking skills data using guided discovery-based mathematics modules. Students are given a test question then the completion of each question is analyzed based on indicators of critical thinking skills namely; 1) Interpret; 2) Analyze; 3) Evaluate; 4) Referencing. The indicator is a unity in measuring students' critical thinking skills, so that when students are said to be able to think critically well if all the benchmarks formulated in indicators 1 to 4 can be met. The percentage of students' critical thinking abilities per indicator measured by scoring guidelines can be seen in Figure 4.

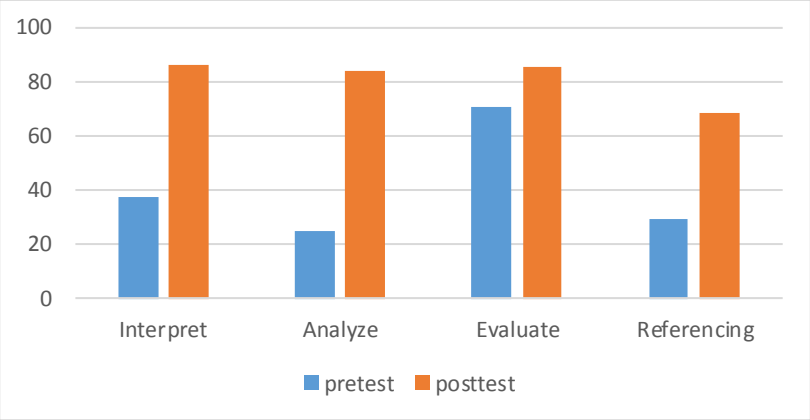

Figure 4. Percentage of students' critical thinking abilities

From Figure 3, it can be seen that from all indicators, it has increased from the pretest to the posttest. The biggest increase occurred in the aspect analysis indicators. This is due to the low pretest and high posttest value. While the smallest occurs in evaluation indicators. This happens because the highest pretest among the four indicators and the posttest value is high. Furthermore, the average data of students' critical thinking skills is presented in Table 2.

Table 2: Average students' critical thinking skills

pretest	*postest*	*N-gain*	interpretation
40.625	81.289	0.695	Medium

Based on Table 2 above shows that the average value of pretest students' critical thinking skills before being implemented using mathematics module based on guided discovery learning is 40,625. Then it increased at postest with an average of 81,289. While the *N-gain* value shows the development of students' critical thinking with a value of 0.695 in the moderate category.

A questionnaire was used to obtain data on student learning independence in using guided discovery-based mathematics module. Students are given a questionnaire that is used to find out the potential effects on learning independence. Learning independence indicators consist of 5 indicators, namely: 1) independence from others; 2) having a confident attitude; 3) disciplined behavior; 4) have a sense of responsibility; 5) behave on its own initiative. The results of the initial questionnaire percentage and final questionnaire can be seen in Table 3.

Table 3: Percentage of initial questionnaire and final questionnaire

Questionnaire	Percentage	Criteria
initial questionnaire	66.5 %	enough
final questionnaire	77.8 %	good

Based on the table above, that the percentage score obtained in the initial learning independence questionnaire was 66.5% while the percentage score obtained in the final learning independence questionnaire was 77.8%. Overall based on the results of the questionnaire analysis concluded that the indicator of student learning independence consisting of 5 indicators, namely: 1) independence from others; 2) having a confident attitude; 3) disciplined behavior; 4) have a sense of responsibility; and 5) behaving based on their own initiative has been fulfilled.

From the results of the interview, it is illustrated that most students like to use mathematics modules based on guided discovery. They reasoned that the module could help them in

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improving critical thinking skills and learning independence. Over all it can be concluded that the mathematics of guided discovery can stimulate or help students' critical thinking skills to solve problems and help independent students in learning.

CONCLUSION

This study has produced a product in the form of a guided discovery mathematics module that can help critical thinking skills and student learning independence. The instructional material developed is in the form of guided discovery mathematics modules on a social arithmetic material. Modules created using *Microsoft Word 2010* and *Corel Draw*. The developed mathematics module has been categorized as valid and practical. Valid can be seen in the comments of experts who stated that the prototype developed was well categorized and feasible to use. Practically, this is seen from the ease of students in utilizing modules that are developed and helping students in the learning process. Based on the development process obtained mathematics modules based on guided discovery learning have potential effects on critical thinking skills and student learning independence. This is seen in the field test stage where all. Teachers are expected to be able to use guided discovery-based mathematics modules in learning to help students develop critical thinking skills and learning independence.

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