The Excellence of Guided Discovery Learning on Mathematical Knowledge-Based, Skill-Based, and Attitude

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Abstract. Guided discovery learning is one of the constructivist-based learning models that can be used in mathematical learning. The syntax of guided discovery learning is giving stimulus, identifying a problem, collecting information, processing information, verifying, and drawing a conclusion. There have been many studies that have examined the guided discovery learning model and proved its superiority. This study is a meta-synthesis research that examines some relevant studies. The purpose of this study is to combine and compare the findings of research to formulate the excellences of guided discovery learning model. There are 16 research findings from some countries that were reviewed for this study. The results of this study show that the guided discovery learning model has the advantages in improving mathematical knowledge, mathematical skills, and mathematical attitude. Mathematical knowledge can be mathematics learning achievement, cognitive ability, conceptual understanding, and mathematical reasoning. The examples of mathematical skills that can be improved by implementing this learning model including critical and creative thinking skills. Other advantages of this learning model can be seen from the mathematical attitude, such as self-confidence, STEM attitude, interest in math, and the will to get the best result in mathematics. Several noteworthy limitations of this study were discussed.

1. Introduction
Mathematics is a subject that supports other discipline subjects. Due to its important role, mathematics is taught in every educational grade. Unfortunately, there are students who still consider that mathematics is no more than counting and working with formulas. One of the reasons is that students are not actively involved in concept formulation, so students only focus on memorizing the formula without knowing its meaning. Therefore, learning process should apply a student-centered approach. Students do not only sit, listen, and memorize the material, but also strive to build their own knowledge.

One of the student-centered learning models is guided discovery learning. This learning is not merely finding something really new, but students are expected to find active knowledge by doing activities to find concepts, formulas and the like with teacher guidance. Students find the concept through the guidance and direction of teachers because, in general, most students still need the basic concept to be able to find something. This model is very suitable for mathematics because there are many formulas and concepts in mathematics that are related to it. Therefore, it can be designed a learning process where students do the activity of associating the formula or concept that has been obtained to find new formulas or concepts.
There are some experts who have described the definition of guided discovery learning. This learning is an inquiry-based approach in which students are given a question to be answered, problem to be solved, or a set of observation to be explained, and the work in a largely self-directed manner to complete their assigned tasks and draw appropriate inferences from the outcomes “discovering” the desired factual and conceptual knowledge in the process [1]. Guided discovery learning can also be interpreted as a constructivist approach to teaching in which students are encouraged to discover principles for themselves [2]. Discovery learning is also interpreted as a method that encourages students come to a conclusion based on their own activities and observations [3]. In line with the previous definition, discovery learning emphasizes student-centered engagement and learning experiences where students find ideas and gain their own meaning [4]. So it can be concluded that discovery learning is a learning approach that encourages students to conduct investigations so they can find their own principles and ideas. The word "guided" means that teacher gives guidance to the students during discovery process. The teacher’s role in this learning process is as a companion, ensuring that students have no problem during the process of discovery of the concept [5].

Westwood's guided discovery learning syntax is 1) identifying topics or problems, 2) teachers and students working together to connect ideas in investigating topics; 3) students working individually or in groups to collect and interpret data; 4) draw conclusions and temporary conclusions with the whole group and modified if necessary, and 5) the teacher straightens misunderstandings, summarizes the findings, and helps to draw conclusions [6]. According to Moore, the steps include identifying problems, proposing possible solutions, collecting data, analyzing and interpreting data, and testing conclusions [7]. We can conclude that syntax of guided discovery learning is giving stimulus, identifying problems, collecting information, processing information, verifying, and drawing a conclusion.

Based on the definition and steps of learning, we can be sure that guided discovery learning has advantages that can improve students’ abilities. There has been some literature that examines the implementation of guided discovery learning in mathematics learning. Therefore, we will carry out meta-synthesis to deduce the superiority of guided discovery learning especially in the aspects of mathematical knowledge-based, skills-based, and attitude.

2. Research Method
This study used meta-synthesis, which is a type of qualitative research. Meta-synthesis is a method that examines research and investigates the results of several studies and tries to interpret the data obtained as a result of this investigation [8]. This study aims to combine and compare the findings of the research to formulate the advantages of guided discovery learning model. There were 16 research findings on the guided discovery learning model from several countries that were reviewed for this study.

3. Result and Discussion
The general characteristics were chosen to describe the corpus (16 articles) were the authors, the year of publication, the geographic origin of data, the school grades, the research methods, the subjects, and the outcomes. To avoid misinterpretation of this information, we only presented the results based on what is explicitly reported by the authors.

| No. | Authors (years of publication) | Geographic origin of data | School grades | Research method | Subject | Outcomes                          |
|-----|--------------------------------|---------------------------|---------------|-----------------|---------|-----------------------------------|
| 1   | Achera, Balecina, & Garvida (2015) [9] | Philippine                | High School   | Quasi experiment | Geometry | Performance of mathematics        |
| No. | Authors (years of publication) | Geographic origin of data | School grades | Research method | Subject | Outcomes |
|-----|--------------------------------|---------------------------|---------------|----------------|---------|----------|
| 2   | Akanmu & Olubusuyi (2013) [10] | Nigeria                   | Senior School | Quasi experiment | Not mentioned | Performance of mathematics |
| 3   | Casad & Jawaharlal (2012) [11] | California                | Grade 4       | Survey          | Not mentioned | Mathematics achievement, STEM attitudes, intentions to obtain good math grades |
| 4   | Hong, An, & Triet (2017) [12] | Vietnam                   | Primary, secondary and high school | Quasi experiment | Arithmetic sequence | Mathematics achievement |
| 5   | Imawan (2015) [13]            | Indonesia                 | University (2nd semester) | Quasi experiment | Solid Geometry | achievement, self-confidence, critical thinking skills |
| 6   | In’am & Hajar (2017) [14]     | Indonesia                 | Grade 7       | Descriptive-quantitative quasi experiment (used two experiment groups) | Geometry | Mathematics achievement |
| 7   | Kartikaningtyas, Kusmayadi, & Riyadi (2017) [15] | Indonesia | Grade 8 | Not mentioned | Geometry | Mathematics achievement |
| 8   | Martaida, Bukit, & Ginting (2017) [16] | Indonesia | Grade 7 | Two-dimensional arithmetic | Not mentioned | Critical thinking, cognitive ability |
| 9   | Nuryakin & Riandi (2017) [17] | Indonesia                 | Grade 8       | Not mentioned | Critical thinking |
| 10  | Olorode & Jimoh (2016) [18]   | Nigeria                   | University    | Not mentioned | academic achievement |
| 11  | Prased (2011) [19]            | Nepal                     | Not mentioned | Exploration     | Not mentioned | interest in mathematics, creativity |
| 12  | Reynolds (2016) [20]          | USA                       | Middle school | Development research | Not mentioned | Knowledge-building |
| 13  | Robi, Hobri, & Dafik (2018) [21] | Indonesia | University (4th semester) | Descriptive research with qualitative approach quasi-experimental research (non equivalent pre-test and post-test control group design) | Two-dimensional arithmetic | Critical thinking |
| 14  | Saputra, Fatimah, & Priatma (2016) [22] | Indonesia | Grade 7 | Not mentioned | Mathematical reasoning |
From the Table 1, it was known that most of the data are from Indonesia (9), while other data are from Nigeria (2), Nepal (1), USA (1), California (1), Vietnam (1), and Philippine (1) are also presented. The corpus consists of articles published in the last 8 years, from 2011 to 2018. The articles showed that guided discovery learning can be applied from elementary to university grades. The results of these studies was guided discovery learning can improve mathematics achievement, conceptual understanding, mathematical reasoning, critical and creative thinking skills, cognitive abilities, self-confidence and STEM (Science, Technology, Engineering, and Mathematics) attitudes. In more detail, the main findings of the articles were summarized in table 2 below.

### Table 2. Main finding from studies reviewed.

| Article (#) | Main finding |
|-------------|--------------|
| 1 | The performance in Geometry of those students taught using group guided discovery was significantly higher than those students taught using the traditional lecture approach. |
| 2 | There was a significant difference in the performance of mathematics students taught using guided discovery learning strategy over the students taught using non guided discovery strategy. |
| 3 | The robotics program based on the guided discovery approach was successful. |
| 4 | The use of guided discovery learning was more effective than teaching with the traditional method. |
| 5 | The implementation of the Guided Discovery Learning Model on Solid Geometry subject was proven to be effective in improving students’ achievement, self-confidence, and critical thinking skills. |
| 6 | Studying geometry through discovery learning using a scientific approach could significantly promote student ability. |
| 7 | Contextual approach with guided discovery learning could be used in mathematics learning as the innovative way in geometry learning. |
| 8 | The critical thinking ability and cognitive ability of students applying discovery learning model was better than students with conventional learning. |
| 9 | The average of students’ critical thinking skills normalized gain score of both groups were in the medium category. There were significant differences between both group’s improvement. |
| 10 | Guided discovery learning strategy was more effective than the traditional lecture method in the teaching and learning. |
| 11 | Discovery learning could be effectively used to stimulate and maintain interest in mathematics and could promote creativity. |
| 12 | Using guided discovery-based game design in school could increase the students’ knowledge-building. |
| 13 | The critical thinking skills of students in solving the problems of two-dimensional arithmetic derived from the implementation of guided discovery learning was very diverse. |
| 14 | The improvement of mathematical reasoning skills of students learned with guided discovery learning was not significantly different than students who learned with the scientific approach. |
| 15 | Learning modules with discovery learning approach was effective to be used in the learning process. |
1) Learning devices based guided discovery model is able to improve the understanding concept and critical thinking mathematically ability of students and 2) students’ responses to components of learning devices and learning activities were positive.

Based on the findings of these studies, guided discovery learning had been proven empirically that has several advantages for developing students’ skills. Students’ skills that can be improved through this learning method are divided into three aspects, namely mathematical knowledge-based, skills-based, and attitudes. In the knowledge-based aspect, guided discovery learning can improve mathematics learning achievement [9]–[13], [18], [25], [26], cognitive ability [16], [20], conceptual understanding [24], and mathematical reasoning [22]. In the aspects of skills-based, guided discovery learning can improve critical [13], [16], [17], [24], [27] and creative [19] thinking skills. In the attitude aspect, guided discovery learning can improve self-confidence [13], STEM attitude [11], interest in mathematics [19], and a sense of wanting to achieve the best results in mathematics [11]. In addition, the use of guided discovery learning in mathematics learning received good responses from students [23]. In other words, students can enjoy learning process using guided discovery learning and do not feel burdened.

Most studies suggest that guided discovery learning is good for mathematics learning achievement (8 studies from 16) and for critical thinking skills (5 studies from 16). It occurs because the learning steps can support both capabilities. In guided discovery learning, teachers help students to construct their knowledge by actively in the process of knowledge construction, thus it improves the thinking abilities of students [12]. Thinking ability that is mostly studied is critical thinking skill. Therefore, the achievement of automatic math learning will also improve.

4. Conclusion and Recommendation
In this meta-synthesis, we identified and attempted to synthesize 16 studies of guided discovery learning that has been published from 2011 to 2018. The result of this meta-synthesis of guided discovery learning has some advantages when it was implemented in the mathematics learning process. These advantages are divided into 3 aspects, namely mathematics knowledge-based, skills-based, and attitude. In the terms of knowledge-based, guided discovery learning can improve mathematics learning achievement, cognitive ability conceptual understanding, and mathematical reasoning. In the aspects of skills-based, guided discovery learning can improve the ability of critical and creative thinking. In the attitude aspect, guided discovery learning can improve self-confidence, STEM attitude, interest in math, and the desire to get the best result in mathematics.

This research is a meta-synthesis research using narrative approach. Therefore, we recommend to further researchers to review the benefits of guided discovery learning by the meta-analysis that using quantitative approach. We can statistically generalize if we review the meta-analysis to obtain more accurate results.

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