The Impact of Discovery Learning on Students' Mathematics Learning Outcomes

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Abstract. The aim of this study is to describe the impact of discovery learning on students' mathematics learning outcomes. Empirical evidence of the positive impact of this method was collected from the results of searching in reputable online journal database and synthesized using a systematic literature review method. Twenty articles were found that meet with the following criteria: (1) research articles containing empirical evidence of the impact of discovery learning on students' mathematics learning outcomes, (2) articles published in the period 2000-2018, (3) the subject of research is a group of students on formal education from elementary school to higher education. The selected articles are further synthesized and analyzed. The result of the review shows that discovery learning has a positive impact on students' mathematics learning outcomes on cognitive, affective, and psychomotor aspects. Each step in discovery learning has an important role in learning mathematics. However, to develop the student’s particular ability or skill, the teachers should emphasize certain steps that have the greatest potential to improve them, without eliminating other steps.

1. Introduction

Research trends in mathematics education change over time. Over the past few decades, the research focused on changing the learning paradigm from teacher-centered with knowledge transfer to student-centered with construct knowledge [1]. This is based on the idea of constructivists who claim that learning happens when students construct their own knowledge through a series of activities involving the ability of thinking and knowledge that have been previously owned [2]. In other words, students become active learners, while teachers are more as facilitators to provide support and challenge to students in order to learn optimally [3,4].

Bruner [5] believes that students have a central role in learning by finding their own knowledge. In discovery learning, students build concepts by involving prior experience and knowledge that have been previously owned through a series of activities of observation, exploration, investigation, and problem-solving [6–8], then proposes a conjecture and conclude a general concept [9]. Therefore, learning becomes more meaningful and what is learned can be stored longer in students' memories [10,11]. It is clearly consistent with the constructivist view that the purpose of learning is to make students understand, not just answer questions correctly [12].

Westwood [11] and Moore [13] say that the discovery learning process begins with the presentation of information or problems that are carried out by the teacher (Problem Formulation), then students...
identify problems, collect, process, and analyze data from these problems (Exploration). From the results of exploration, students establish a conjecture (Establish a Conjecture). After that, students check the validity of the conjecture by looking at various reference sources and discussing it with other individuals or groups, so that a conclusion is obtained (Verification). After students get a conclusion, the teacher confirms the truth of the conclusions that have been obtained, provides reinforcement, and rectifies if there is a misconception so students get the right conclusions about the concepts that have been learned (Confirmation). These five steps make students active and get a good learning experience.

Although the core of discovery learning is for the students to find their own new knowledge, a number of experts still recommend teacher guidance [14,15]. Teacher guidance in discovery learning is needed to ensure students work on the right path so as to minimize the occurrence of misconceptions, but still provide opportunities for students to be active in constructing their own new knowledge [11,16]. Therefore they still have a central role in the class.

Discovery learning, as a learning method that emphasizes the active role of students in building new knowledge, has various advantages. A number of studies provide empirical evidence that discovery learning has a positive impact on cognitive learning outcomes in mathematics, such as learning achievement [17], critical thinking skills [18], creative thinking skills [19], mathematical reasoning ability and communication [20]. In addition, discovery learning also has a positive influence on the affective aspects, such as motivation [21] and beliefs [22]. Because of the many empirical evidence that shows the positive impact of discovery learning on student learning outcomes, it is necessary to present the evidence comprehensively.

This study aims to describe the impact of discovery learning on student mathematics learning outcomes by finding out what abilities and skills can be developed through this method and which discovery learning steps have an important role. This finding can provide valuable information to the teacher regarding which steps should be emphasized to develop a particular ability or skill. Thus, this learning method can be applied precisely based on the learning goals.

2. Method
This study uses systematic literature reviews by referring to the following steps: (1) identifying research questions, (2) developing research protocols, (3) determining the database location of research results, (4) selecting appropriate research results, (5) choosing good quality research, (6) extracting the selected research results, (7) synthesizing results, and (8) presenting results [23].

2.1. Research question
This study aims to answer questions about what abilities and skills can be developed through discovery learning and which steps of discovery learning should be emphasized to develop them.

2.2. Data collection
2.2.1. Database searched. Searching for research papers was conducted on the reputable online database journals: Scopus, ERIC, and Science Direct, focusing on the subject of mathematics education.

2.2.2. Search keyword. The keywords used in the search for research papers on the online database are "discovery learning", "discovery learning in mathematics" and "discovery method".

2.2.3. Selection of papers. Selected papers for further review must meet the following criteria: (1) research papers that contain empirical evidence of the impact of discovery learning on mathematics learning outcomes, (2) papers published in the 2000-2018 range, and (3) research subjects are elementary, middle and tertiary level students at the formal education level.
2.3. Data analysis

2.3.1. Extraction of selected papers. 20 selected papers that meet the criteria in 2.2.3 were extracted by observing the following data: author, year of publication, research method, research subject, geographic origin of data, and research results.

2.3.2. Synthesis of results. The synthesis of the results was carried out by looking at the extraction results at 2.3.1. Data regarding the impact of discovery learning on mathematics learning outcomes were grouped based on the cognitive, affective, and psychomotor aspects.

3. Results and Discussion

Table 1 shows the results of searching for papers related to keywords as specified in 2.2.2. and meet the criteria for selecting papers set out in 2.2.3, as many as 20 papers.

Table 1. Appropriate search results papers.

| No | Author (years of publication) | Research method | Subject | Geographic origin of data |
|----|--------------------------------|-----------------|---------|---------------------------|
| 1  | Liljedahl (2005)[22]          | Qualitative research | Undergraduate mathematics students | Columbia |
| 2  | Kyriaizis, Psycharis & Korres (2009)[24] | Computational experiment | School of Pedagogical and Technological Education | Greece |
| 3  | Balım (2009)[8]               | Quasi-experiment | Elementary School | Turkey |
| 4  | Saab, van Joolingen, & van Hout-Wolters (2009)[25] | Quasi-experiment | Secondary Schools | Netherlands |
| 5  | Yang, Liao, Ching, Chang & Chan (2010)[26] | Quasi-experiment | Elementary School | Taiwan |
| 6  | Akanmu & Fajemidagba (2013)[17] | Quasi-experiment | Senior High School | Nigeria |
| 7  | Saragih & Yuliani (2015)[18]  | Development research | Junior High School | Indonesia |
| 8  | Shieh & Yu (2016)[27]         | Quasi-experiment | Middle School | Taiwan |
| 9  | Maarif (2016)[28]             | Quasi-experiment | Junior High School | Indonesia |
| 10 | Kartikaningtyas, Kusmayadi & Riyadi. (2017)[29] | Quasi-experiment | Junior High School | Indonesia |
| 11 | In’am & Hajar (2017)[30]      | Descriptive-quantitative | Junior High School | Indonesia |
| 12 | Yurniawati & Hanum (2017)[31] | Classroom action research | Elementary School | Indonesia |
Papers that meet the criteria are then extracted by referring to 2.3.1. The extraction result data is processed and analyzed for further synthesis of the impact of discovery learning on mathematics learning outcomes grouped based on cognitive, affective, and psychomotor aspects. Table 2 shows the results of the synthesis of the effects of discovery learning on mathematics learning outcomes.

| No | Author (years of publication) | Research method | Subject | Geographic origin of data |
|----|--------------------------------|-----------------|---------|--------------------------|
| 13 | Khasanah, Usodo & Subanti (2018)[32] | Quasi experiment | Junior High School | Indonesia |
| 14 | Miatun & Muntazhimah (2018)[33] | Quasi experiment | Junior High School | Indonesia |
| 15 | Sulistiani, Waluya, & Masrukan (2018)[34] | Mixed method (quantitative-qualitative) | Junior High School | Indonesia |
| 16 | Hong, An & Triet (2017)[35] | Quasi-experiment | Primary, secondary and high school | Vietnam |
| 17 | Anggraini, Murni & Sakur (2018)[36] | Quasi experiment | Secondary school | Indonesia |
| 18 | Ramdhani, Usodo & Subanti (2017)[37] | Quasi experiment | Junior High School | Indonesia |
| 19 | Sahara R, Mardiyana & Saputro (2018)[38] | Quasi experiment | Junior High School | Indonesia |
| 20 | Tokada, Herman, & Suhendra (2017)[39] | Quasi-experiment | Junior High School | Indonesia |

Table 2. Results of the synthesis of the impact of discovery learning on mathematics

| Aspect | Variable | Number of research)* |
|--------|----------|----------------------|
| Cognitive | Achievement | 11 |
| | Retention | 3 |
| | Critical thinking skills | 2 |
| | Conceptual Understanding | 1 |
| | Analogy skills | 1 |
| | Inquiry skills | 1 |
| | Literacy ability | 1 |
| | Mathematical communication skills | 1 |
| | Drawing conclusions skills | 1 |
| | Beliefs | 2 |
| Affective | Motivation | 1 |
| | Self-regulated | 1 |
| | Observation | 1 |
| Psychomotor | Group discussion | 1 |

*some studies examine more than one variable

Table 2 shows that discovery learning has a major impact on mathematics learning outcomes, especially on cognitive aspects. Learning achievement is the main focus to study in the selected papers. In addition, discovery learning also has an influence on the affective and psychomotor aspects.
3.1. Impact of discovery learning on mathematics learning outcomes on cognitive aspects

The results of the synthesis of research papers as Table 2 shows that discovery learning has a positive impact on mathematics learning outcomes on cognitive aspects, which include learning achievement, mathematical communication, concept understanding, retention, critical thinking ability, inquiry ability, analogy ability, and conclusion drawing ability.

3.1.1. Ability to understand concepts, retention and learning achievement. The ability to understand concepts, retention and learning achievement are three interrelated aspects. With a good understanding of concepts, students become more competent [3] so that they have good learning achievement. In relation to discovery learning, Svinicki [10] says that the characteristics of discovery learning are active and meaningful learning, because in the process of discovering new knowledge students connect it to their previous experience and knowledge. The opportunity given to students to explore and engage directly helps students in understanding the concept better [28]. Retention or memory of students will be claimed to be better because new knowledge is obtained through a meaningful process [11]. This is a great reason why discovery learning can improve the ability to understand concepts, retention, and student learning achievement.

3.1.2. Critical thinking, literacy and inquiry skills. One important step of discovery learning is that students explore the problems presented [7]. At this stage students conduct a series of activities to compile, process, organize, and analyze data from the problems that are given. Students are given the freedom to work in groups and use various relevant sources in their efforts to investigate and discover new knowledge. At this stage, students' critical thinking skills can develop [18]. On certain issues with high levels and complexity, this exploration stage is also able to develop students' high-level thinking skills [40]. Thus the formulation of the problem greatly influences students' thinking skills. In addition, the opportunity given to the students to explore and construct their own knowledge is able to improve literacy skills [39].

3.1.3. The ability of analogy and drawing conclusions. Schunk [9] states that in discovery learning, students are encouraged to involve inductive reasoning to acquire knowledge by formulating and testing hypotheses through direct experience. In this case, students start from studying specific information or examples to formulate general rules, concepts, and principles. This is supported by Westwood [11], that in the stage of discovery learning students are encouraged to make conjectures and then draw a conclusion with the guidance of the teacher. Thus, reasoning abilities, analogies, mathematical generalizations, and student conclusions are increased [28,31].

3.1.4. Communication skills. In the process of investigation or exploration, students usually work in small groups. Through discussion in groups, students practice communicating with others. Maarif [28] said that in groups students can interact and collaborate well. In addition, at the final stage students are asked to write down or verify the findings of the investigation [31].

3.2. Impact of discovery learning on mathematics learning outcomes on affective aspects

In Table 2, it is known that discovery learning has a positive impact on motivation, beliefs, and self-regulated. The first step of discovery learning is that the teacher presents a problem. At this stage, the teacher can display interesting problems that can raise students' curiosity so that they are motivated to investigate. This is the reason why discovery learning can affect student motivation in learning mathematics.

In addition, when students succeed in discovering their new knowledge through a series of activities, this can make them proud, thus growing beliefs in their minds that they are able to develop their concepts well [22]. Meanwhile, in relation to self-regulated, discovery learning facilitates students to explore through a series of activities. In this case, students are trained to develop effective...
strategies according to their abilities, so their self-regulated ability will be better. Fauzi and Widjajanti [41] claim that self-regulated learning has a positive relationship with motivation and achievement.

3.3. Impact of discovery learning on mathematics learning outcomes on psychomotor aspects

Table 2 shows that discovery learning has a positive impact on psychomotor aspects, especially on the ability of observation and discussion. Balim [8] and Arend & Kilcher [7], explain that to get a conclusion, students must explore and investigate. At this stage, students’ ability to observe is trained to be able to observe and identify the problems being investigated. Also in this exploration activity, students are encouraged to discuss with their groups to get conclusions. In this case, the formulation of the problems carried out by the teacher also has an impact on the students’ observation ability.

From the results of the discussion above, the impact of discovery learning on students' mathematics learning outcomes can be mapped as shown in Figure 1.

![Figure 1. The impact of discovery learning on students’ Mathematics learning outcomes](image)

4. Conclusion

This study can be concluded that the impact of discovery learning on students' mathematics learning outcomes includes cognitive, affective and psychomotor aspects. Each step in discovery learning has an important role in learning mathematics. However, to develop the student’s particular ability or skill, the teachers should emphasize certain steps that have the greatest potential to improve them, without eliminating other steps. In this study, it was found that the problem formulation step has great potential to improve student’s observation, motivation, and critical thinking skills. Then, exploration step has big potential to develop student’s achievement, retention, critical thinking, conceptual understanding, inquiry, analogy, beliefs, self-regulated, observation, and group discussion skills. Establish a conjecture step has high potential to increase student’s retention, analogy and drawing conclusions skills. Verification step has the potential to develop drawing conclusion, communication, and group discussion skills. Then confirmation step can help the student to develop their conceptual understanding and communication skills.
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