A Synthesis Research on Inquiry-Based Learning for Mathematical Processes and Skills

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Abstract

The purposes of this synthesis research were 1) to consider the use of Inquiry-Based Learning (IBL) to improve teaching and learning mathematics, and 2) to investigate keys of essential questions and assessments. The research methodology of this study was a systematic review of research studies and documents published in the span of 10 years from 2008 t0 2018. This paper synthesized the findings of using IBL in mathematics learning for Grade 1 to 12, higher education and perceptions of teachers. The first part of the findings illustrates that IBL suites for supporting teachers facilitate students build knowledge by asking questions and drive the learning process forward, and the second part focuses on essential questions and assess students' learning based on Bloom's Taxonomy and mathematical skills and processes. Finally, the research findings can be applied for further research using variety forms of activity of IBL such as 5E_IBL Cycle (Engagement, Exploration, Explanation, Elaboration, and Evaluation) in other topics of mathematics and other disciplines learning.

Keywords: synthesis research, inquiry-based learning (IBL), mathematical skills and processes

Introduction

The movement towards teaching students to have mathematical skills and processes has been prominent in the Basic Education Core Curriculum B.E. 2551 (A.D. 2008). The standard of mathematical skills and processes refer to ability in problem-solving, reasoning, communication and presentation of mathematical concept, linking various bodies of mathematical knowledge, and linking mathematics with other disciplines; and attaining ability for creative thinking (Ministry of Education, 2008). In addition, mathematical literacy is a learner's ability to reason mathematically and to formulate, employ and interpret mathematics to solve problems in a variety of real-world contexts (OECD, 2017).

Inquiry-based learning (IBL) is one of the active learning approaches that can be applied in the classroom action research to help students learn through thinking about thinking

through posing and asking questions to get the solution reasonably. An inquiry-based learning (IBL) for mathematical processes and skills deals with a variety of questions to help the learners' ability to learn mathematical concepts and mathematical skills and processes.

Before applying IBL in teaching school mathematics, synthesis research is important to provide the foundation of knowledge as a systematic investigation. The researcher breaks down the main concepts or ideas into the important parts or points about the research topic and investigate. Data of this study was compiled based on the involvement using IBL to improve teaching and learning mathematics and investigate the essential questions and assessments across teaching and learning mathematics.

Purposes of the study

This study described the application of the IBL approach in learning and teaching mathematics by using systematic reviews to bring together and integrate the findings of multiple studies for a guideline of conducting further classroom action research in high school mathematics. There were 2 purposes of the study as follows:

1. To consider the use of IBL to improve teaching and learning mathematics, and
2. To investigate the keys of essential questions and assessments

Research Scope

1. Sample

Sample of research and documents related to mathematics education in the level of basic education, higher education level students and teachers' perceptions.

2. Content

Contents related to essential questions to support the inquiry-based learning included Bloom's Taxonomy and mathematical skills and processes required in the Basic Education Core Curriculum B.E. 2551 (A.D. 2008).

3. Duration

In semester 1 of the academic year 2018 to review the research studies and documents published in the span of 10 years from 2008 to 2018.

Methodology

This study was conducted an integrative review of the literature from the reference lists of the research and documents using thematic synthesis (Braun & Clarke, 2006). The four themes/main ideas were reviewed as follows:

1. Concepts and benefits of IBL
2. Pedagogies of IBL
3. Essential questions
4. Assessment to assess learning outcomes

Findings

The synthesis findings present in two sections. The first section focuses on improving teaching and learning mathematics by using IBL. It includes concepts, benefits, and pedagogies. The second section focuses on the essential question and assessment to assess learning outcomes.

Objective 1: To consider the use of IBL to improve teaching and learning mathematics

Teaching and learning are complex tasks. The number of research studies conducted in mathematics has focused on using innovative methods that influence the impact on student learning. In this study. The results of synthesis research on IBL were fully concentrated on the definition, benefits, and pedagogies so that they can provide effective support for students as follows:

Theme 1: Concepts and benefits of IBL

1.1 Concepts

The concept of Inquiry-Based Learning in mathematics learning is a student-centered method of instruction that focuses on real-world mathematics, asking a question and genuinely investigate their own questions. The teacher acts as a facilitator to help students reach conclusions which they must explain the reasonable rules or formula for their conclusions and then construct the new knowledge from the previous knowledge (Kim, 2017; Lightfoot, 2018; Guido, 2017). There are four keywords to be focused on putting inquiry-based learning into practice, i.e. student-centered, real-world mathematics, facilitator, and construct new knowledge.

1.2 Benefits

Since inquiry-based learning is a student-centered method, some of the benefits are broken down by specific areas of learning as shown in the following findings.

1.2.1 Develop students' thinking skills: Inquiry-based learning develops students' deeper understanding of mathematics concepts, retention, problem-solving ability, mathematical discourse, and transfer ability to build lifelong learning through real-world mathematics (Drabkin, 2016; Brune, 2010).

1.2.2 Stimulate students' curiosity: Inquiry-based learning engages students to improve attitudes about mathematics and active in learning process. Students are engaged to share ideas, develop arguments, and challenge to continue deeper questions and rethinking in their thinking for mathematical problem-solving (Brune, 2010; Calleja, 2016). Asking the right questions can be used in developing the mathematical skills and process

Theme 2: Pedagogies of IBL

2.1 Students' and teacher's roles

Inquiry-based learning in mathematics classroom change the role of students and teachers in the learning process (Khan, 2012). The role of the teachers encourages students to use students' prior knowledge to construct new concepts, challenge students through effective questions, manage the classroom discussions of alternative viewpoints and make connections between their ideas. In addition, the teachers encourage the students to think critically, solve problems, collaborate, and communicate effectively from multiple activities with sufficient openness for inquiry-based learning (Alberta Education, 2010; Brune, 2010; Ulm, 2012; Skoumpourdi, 2017). Inquiry-based learning emphasizes students' roles in the learning process, they comprehend the problem, construct connections between previous and new knowledge, consider strategies appropriate for solving the problem, rethink about thinking to reflect on the strategies and solutions

2.2 Variety of using IBL

The use of an active learning strategy in mathematics classroom helps to engage the students interested in the contents of mathematics. Inquiry-based learning is an innovative teaching strategy that can be applied in other method which are described in the following examples.

2.2.1 5E Inquiry-based method

The 5E inquiry-based method gives the students to make sense of concepts and minimize the role of the teacher which is composed of five steps: Engage, Explore, Explain, Elaborate, and Evaluate. Generally, the 'Elaborate' step allow students apply what they have learned should be spent the longest time and 'Explain' step should be shortest (Bryson, 2018). In designing the inquiry-based learning activities by employing the 5E instruction model, the teachers should build up an inquiry learning environment to allow students do activities in the process of questioning, observing, categorizing, explaining, developing, and share their solutions with other students (Wu & Lin, 2015).

2.2.2 Facilitating inquiry-based learning in technology-based learning

Technology-based learning can build students' capacity to learn mathematics by employing inquiry-based learning which focused on 'Asking', 'Investigation', 'Creating', 'Discussion', and 'Reflection'. For example, SMILE (Stanford Mobile Inquiry-based Learning Environment) which allowed students learn mathematics with mobile devices and wireless communications. SMILE math learning model composes of seven phases: Phase 1 Introduction and device exploration, Phase 2 Prompt for problems, Phase 3 Student grouping and generating questions, Phase 4 Question generation, Phase 5 Question solving, Phase 6 Result review, Phase 7 Reflection (Song, Kim & Karami, 2012).

Objective 2: To investigate keys of essential questions and assessments

There are many questions that teachers provide to encourage and assess students' learning. Opportunities to elicit student thinking can be incorporated into lessons and move that thinking forward (Suurtamm, Koch, & Arden, 2010). The kinds of essential questions could be asked to make student move on Bloom's Taxonomy from lower order thinking (knowledge, comprehension, application) to higher order thinking (analysis, synthesis, evaluation) (Watanabe-Crockett, 2017). However, the mathematical skills and processes should be integrated in asking the right questions such as questions to help students predict and plan for problem solving, make connections, clarify reasonable of solutions, or share mathematical representation (Ontario Ministry of Education, 2011).

According to Watanabe-Crockett, an essential question that sets in the inquiry-based learning cycle focuses on (1) a question for the previous knowledge of the lesson, and from this more specific question will arise, (2) a question for curiosity which related to content or concept that the learners are expected to know, (3) a question for the connection or the synthesis of ideas and information that students get new ideas and understanding, (4) a question for communication and sharing the essential understanding, and (5) a question to assess students' demonstration specific issues in relation to the full range of curriculum goals.

Conclusion and Discussion

An important aspect evident in this synthesis research that using the inquiry-based learning has shifted the teacher-centered for doing traditional teaching to the student-centered, with a focus on encourage student thinking skills through the essential questions. Research on the concepts and benefits of IBL shows that it can improve teaching and learning reach to learning outcomes. A pedagogical mindset, teachers enable students to deepen their

understanding by connecting the previous knowledge to construct the new knowledge as a cycle of IBL and 5E IBL as shown in Figure 1.

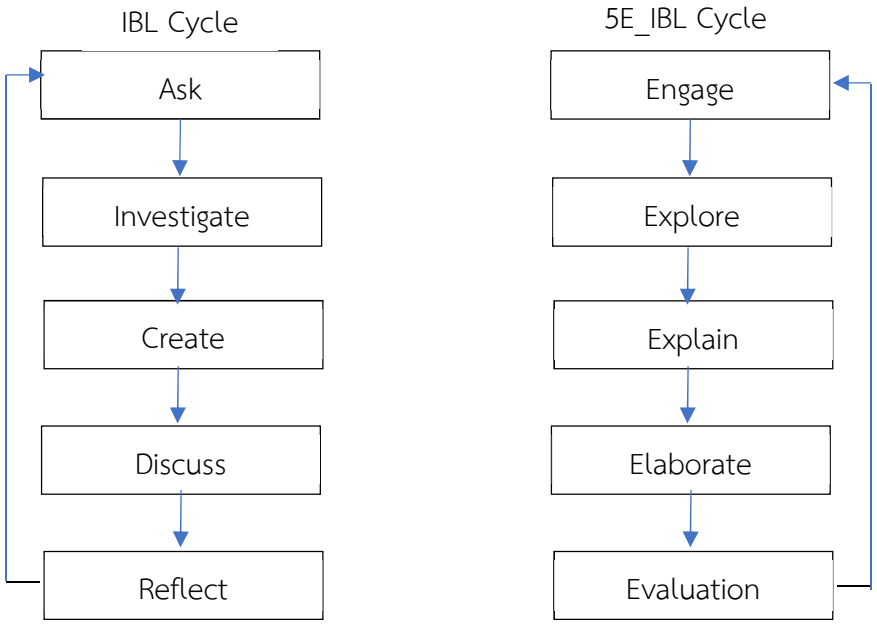

Figure 1: Comparison between IBL Cycle and 5E IBL Cycle

From the first step of both cycles, the students are engaged to become interested in and curious about the topic and formulate their own questions such as, 'What do I already know about this? What do I want to know?'. The second step, the students are asked to investigate or explore in which they observe, describe, and collect data. The third step, the students generate new thoughts, ideas or explain concepts and ideas in their own words The fourth step, the students make conceptual connections between new and former experiences and share their ideas with each other. The final step, the students assess or reflect their own progress by comparing their understanding with their prior knowledge or think again about the initial question, the process taken, and actual conclusion. The teachers act as facilitators to ask the essential questions in each step to help them deeper into the concepts or topic areas.

In conclusion, IBL Cycle in mathematics can involve variety forms of activity as suggested by Calleja (2016), including: articulating questions for engagement, exploration, explanation, elaboration, and evaluation (Bryson, 2018). Moreover, Bloom's analysis tools are perfect for providing questions to assess students' mathematical process and skills using higher-order thinking referred in Watanabe-Crockett, (2017).

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