The Role of Innovative Learning Environment in Improving Students’ Mathematics Learning Outcomes: A Systematic Review

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Abstract

A good mathematics learning outcome can reflect a good quality of Education. However, factual conditions about Indonesian students' mathematics learning outcomes still need to be more hopeful. Because of that, this systematic review aims to analyze previous studies about the role of innovative learning environment (ILE) in increasing students' mathematics learning outcomes as a beginning step for increasing Indonesian students' mathematics learning outcomes. To reach the objective, we defined inclusion and exclusion criteria to collect articles from other countries about ILE in mathematics over the last six years, from 2018 to 2023, using Google Scholar. After that, we systematically analyzed the selected articles and described them in a three-point discussion to answer research questions, namely: (1) The definition and characteristics of ILE; (2) The definition of mathematics learning outcomes which developed through ILE; and (3) The role of ILE in increased students' mathematics learning outcomes. The result showed that ILE was proven to play a role in improving student mathematics learning outcomes, and results were best when learning focused on collaborative aspects. Thus, applying ILE can be one solution to fix the low students' mathematics learning outcomes.

Keywords: Innovative learning, Innovative Learning Environment, Students' Mathematics Learning Outcomes, Systematic Review

INTRODUCTION

Mathematics learning outcomes have a vital role in Education. It reflects the quality of Education in a country, especially in Indonesia. It is seen from the role of mathematics as a mandatory lesson from elementary school to senior high school in Indonesia (Ministry of Education and Culture, 2016). Moreover, it is one of the fields evaluated internationally, for example, PISA. However, the factual conditions regarding Indonesian students' mathematics learning outcomes are still unsuitable with hope. In the international realm, the results of the PISA (Program for International Student Assessment) of Indonesian students showed a score of 0.8% in the categories of science, reading, and mathematics for a share of top performers in at least one subject (level 5 or 6) in 2015 (OECD, 2016). Then, this score decreased in 2018 to 0.6% and was still below the average PISA standard of 15.7% (OECD, 2019). The data aligns with students' low average scores on the National Mathematics Examination. From 2016 to 2018, Indonesian students from elementary to senior high school only achieved an intermediate value between 37.22-51.45, and the achievement was low all over the mathematics material test (Sumaryanta et al., 2019). Besides that, the study result from Apriliana et al. (2019) also showed that students at one of the junior high schools only got a score of 10.40 in the experimental class
and 7.11 in the control class in the mathematical critical thinking ability test. Based on these data, we know that Indonesian students' mathematics learning outcomes still need to be improved, so serious efforts are required to improve them.

One possible effort made to increase students' mathematics learning outcomes was to implement innovative learning (Byers et al., 2018b, 2018a; Campbell, 2020; Groff, 2013; Hornstra et al., 2015; Imms & Byers, 2017; Istance, 2011; Kivunja, 2014; Schuitema et al., 2012; Supena et al., 2021; Suyitno et al., 2021). During the last decades, significant public funding has been directed to create innovative learning environments (hereinafter referred to as ILE) in schools (Dovey & Fisher, 2014; Mulcahy et al., 2015). The shift from a traditional learning environment to an innovative one could create considered pedagogy to support students in becoming independent lifetime learners capable of navigating the complexities of society mediated by technology and base knowledge (Mulcahy et al., 2015; Mulcahy & Morrison, 2017). So, that matters positively impacted enhancing students' mathematics learning outcomes.

However, empirical evidence about the contribution of ILE in increasing students' learning outcomes was still minimal (Blackmore et al., 2011; Brooks, 2011), specifically in learning Mathematics. Therefore, further research is needed to complement these deficiencies. To develop further research, we need to conduct a preliminary study through a systematic review of the application of ILE in mathematics so that further research can be more efficient and provide better results. According to Wilson (2013), a systematic review has many excellent bibliographies and information. So, we conduct this systematic review to analyze the previous studies' results about the role of ILE in increasing students' mathematics learning outcomes as a preliminary study for further research.

**METHOD**

This study was based on previous research in the last six years on applying ILE in mathematics. The articles used in this study were identified and systematically reviewed with the following four steps adapted from Dixon-Woods (El Islami et al., 2022).

First, we made the research question. The question is “what is the role of ILE in improving students' mathematics learning outcomes?”. Then, we defined some inclusion and exclusion criteria to identify the appropriate articles with research questions shown in Table 1.
Inclusion Criteria

- Related to the ILE in mathematics
- Contained the impact of an ILE on student mathematics learning outcomes
- Published in 2018-2023
- Indexed by Scopus

Exclusion criteria

- Articles on innovative learning in mathematics without the word “environment”
- Full-text articles are available for a fee

After that, we searched and analyzed articles containing inclusion criteria and excluded articles containing exclusion criteria. In this step, we use the Publish and Perish 8 application using the Google Scholar search option in the 2018-2022 range. We use "innovative learning environment" in the title column and "innovative learning environment, mathematics" in the keyword column. Of the 40 articles found, only five articles met the inclusion and exclusion criteria. The results studies of selected articles in this systematic review are presented in Table 2. Finally, we synthesized all the selected articles to answer the research questions.

Table 2. The Results of the Implementation of ILE in Mathematics Based on Selected Articles

<table>
<thead>
<tr>
<th>No</th>
<th>Author(s)</th>
<th>Journal (Year)</th>
<th>Scopus Category</th>
<th>Results of the Implementation of ILE in Mathematics</th>
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</table>
| 1  | Terry Byers, Wes Imms, Elizabeth Hartnell-Young | Studies in Educational Evaluation (2018a) | Q1 | • Statistically, implementing the ILE was associated with significant increases in student attitudes about the successful use of technology, more active and responsive learning experiences, and better behavioral and cognitive engagement in scholastic achievement in English and Mathematics.  
• The calculation of effect sizes revealed that all courses' academic outcomes increased due to the spatial change, with Mathematics showing the most substantial improvement. |
| 2  | Terry Byers, Wes Imms, Elizabeth Hartnell-Young | Studies in Educational Evaluation (2018b) | Q1 | • In the ILE, there was a shift toward more active pedagogies with higher levels of activity differentiation.  
• The open studio design of the ILE significantly reduced student distraction and off-behavior hours so student mathematics learning outcomes improve. |
| 3  | Louise Campbell | Research Papers in Education (2020) | Q1 | • The space in an ILE significantly facilitated teachers’ professional development through team teaching or peer observation.  
• Creating innovative learning spaces prompted mathematics teachers and students to experiment with non-traditional teaching and learning methods. It sparked a discussion |
RESULTS AND DISCUSSION

In general, findings about the role of ILE in mathematics can be seen in Table 2. To discuss this further, we must first know what an ILE means and what mathematics learning about 21-century pedagogies for teachers and students.

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<th>Authors</th>
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  • Risk management of applying ILE in mathematics was done by grouping students based on their abilities. Then, students with the lowest abilities are placed on the quietest side to minimize distractions to improve their math learning results. |
| 4 | B. Cavadas and M. Correia                  | Cuadernos de Psicología del Deporte (2022)       | • In this research, ILE dedicated to science & mathematics education by making a class layout, "The CreativeLab_Sci&Math," intensely focused on innovative educational methodologies.  
  • The results showed that ILE impacted active teaching methodologies, the application of interdisciplinarity activities, the development of students' pedagogical content knowledge, and the use of diversified technologies to support teaching and learning.  
  • The layout of the ILE facilitated the movement and the social interaction between teachers and students, with pedagogical purposes, and succeed promoted students' interest in the scientific content addressed. |
| 5 | U. Saastamoinen, L. Eronen, A. Juvonen, P. Vahimaa | Journal of Research in Innovative Teaching & Learning (2023) | • The effect of study aid on students' well-being increased the level of students' well-being in mathematics, Finnish, social sciences, technology, and the arts, with a small effect size statistically.  
  • The learning ground in ILE was planned with students, and it enables student-centered pedagogy through which the students acquire 21st-century skills, such as learn-to-learn skills and self-regulation. |
outcomes were developed through ILE. Therefore, we divide the findings into four discussion points below.

1. Definition of Mathematics Learning Outcomes Developed Through ILE

Mathematics learning outcomes can be interpreted as the "product" of a student's efforts to acquire mathematical abilities. These abilities included mastery of mathematical material in terms of knowledge, attitudes, and mathematical skills in the form of facts, rules, formulas, and procedures as a result of the learning process as measured by tests and then accumulated into numbers or symbols (Baroody & Dowker, 2009; Gatti et al., 2019). Then, these numbers are processed to become evaluation material for academic staff to improve the following educational practices.

As time passed, the demand for students' mathematics learning outcomes increased. Since 2016, questions with higher-order thinking levels began to be included in the Indonesian state National Examination, which grew yearly (Ministry of Education and Culture, 2018). This step was done so Indonesian students would be better prepared to face the demands of the 21st century. Based on this explanation, we define students' mathematics learning outcomes in this systematic review as a student's achievement in mathematics in the form of mastery of knowledge, skills, and mathematical attitudes that align with the demands of the 21st century.

2. Definition of Innovative Learning Environment

Innovation is a word that can indicate a change. The term 'innovation' was used in much literature on Education policy and reports to describe a new idea, product, approach, or process (Fenwick, 2016). Innovative learning approaches were referred to a variety of instructional approaches referred to as new learning, natural learning, powerful learning, or active learning, which allowed students to play an active role in the independent learning process compared to more traditional approaches (Hornstra et al., 2015; Schuitema et al., 2012). The innovations in this paradigm called for various shifts: from task completion times scheduled to on-demand, from a "one size fits all" teaching approach to a teaching approach that suited the needs of each student, from competitive learning to collaborative learning, from context-bound classrooms to vast global learning networks, from textbook-based data to web-based resources, from summative to formative assessment of student performance, and from school learning to lifelong learning (Kivunja, 2014). Thus, it appears that innovative learning could provide more learning experiences that were fresh and "up to date" for students with novelty in various aspects of learning.

Innovative learning practices were one of the focuses that continued to be developed by experts in the field of Education to date. The OECD's Centre for Educational Research and Innovation (CERI) undertook a unique project to support this renewal effort under the name
Innovative Learning Environments (ILE) (Istance, 2011). ILE was defined as multi-modal, technological learning-infused, and flexible spaces that were more responsive to the needs of 21st-century learners than traditional classrooms (Groff, 2013). By identifying real cases of innovative learning environments worldwide, ILE aimed to inform practice, leadership, and reform by analyzing inspiring and innovative learning configurations for children and youth (Istance, 2011). Furthermore, Abrahamson et al., (2020) also introduced a series of heuristic design frameworks in innovative learning that supported students facing 21st-century challenges. The design was created to make fun and flexible mathematics learning activities in which physical movement is enacted as a component of conceptual reasoning. Therefore, innovative learning could be a suitable learning practice to meet the demands of the times, especially in the 21st century.

Based on the description above, we define innovative learning environment as fresh learning approach that contains novelty in various aspects of learning and is designed to suit the needs of students in the 21st century.

3. Characteristics of Innovative Learning Environment

The theoretical foundation of innovative learning provided in socio-constructivism, which was a term used to describe various views (Hornstra et al., 2015). The education experts involved in the ILE project explored the nature of learning through the perspectives of cognition, emotion, and biology, then synthesized these into seven transverse "principles" to guide the design of learning environments for the 21st century. These principles created unique learning environments to optimize learning and must be considered to drive broader systems strategy, reform, and change. Furthermore, the seven transverse principles were reformulated into five characteristics of innovative learning using the Education term below (Istance, 2011):

a. Learner-Centred; means the environment should focus on learning as the main activity.

b. Structured and Well-Designed; means learning required careful design and a high level of professionalism to be 'learner-centered' and have plenty of room for self-inquiry and learning.

c. Profoundly Personalised; means that the learning environment must be sensitive to individual and group differences in background, prior knowledge, motivation, and abilities and offer appropriate feedback.

d. Inclusive; it was sensitive to individual and group differences, including the weakest learners, and defined an inclusive education agenda.

e. Social; means the principles assumed that learning is effective when it occurs in group settings, when learners collaborate, and when there is a connection to society.
In line with that, Hornstra et al. (2015) defined three main characteristics in innovative learning, namely collaborative learning, the authenticity of learning (AL), and the focus on self-regulation (SL) of the learning process. Furthermore, Muhali (2019) stated that 21st-century innovative learning has characteristics that lead to interactive, holistic, integrative, scientific, contextual, thematic, practical, collaborative, and learner-centered learning. Therefore, an educator needs to apply learning models/methods oriented to these characteristics (Muhali, 2019). Additionally, innovative classroom layouts provide space for students to explore their movements (Byers et al., 2018b, 2018a; Imms & Byers, 2017) so that they get a more meaningful learning experience (Abrahamson et al., 2020; Byers et al., 2018b, 2018a; Imms & Byers, 2017). According to Campbell (2020), creating innovative learning spaces was a 'stepping stone' that encouraged teachers and students to engage in non-traditional ways of the learning process and opened discussions about 21st-century pedagogy.

Based on the review above, we conclude that some of the characteristics that must exist in innovative learning include: having to recognize students' abilities to self-regulate their participation and involvement in learning, providing opportunities for cooperative and collaborative learning, supporting and being able to motivate students to create meaningful learning, be sensitive to individual learning needs, provide learning programs that are challenging but not too burdensome, emphasize formative assessment, provide opportunities for interdisciplinary learning that connects fields of study and personal interests for the creation of effective learning, and provide space for students to move with high mobility.

4. The Role of Innovative Learning in Improving Students’ Mathematics Learning Outcomes

Mathematics learning outcomes following the demands of the 21st century could be obtained by creating a learning process that supported them. Based on the previous description, one type of learning that could provide this opportunity was innovative learning. According to Istance (2011), the application of innovative learning became effective when all the principles and characteristics were presented as a whole, not separated from one another. That was confirmed by Hornstra et al., (2015), who stated that applying all the main characteristics to innovative learning had a good impact on various aspects of learning. This was inseparable from the role of the teacher, who has succeeded in carrying out the principles that exist in innovative learning. Teachers in innovative learning environments focused on developing students’ independent learning skills so that students could direct their learning (Boekaerts, 1996; Bolhuis & Voeten, 2001; De Corte et al., 2004; De Kock et al., 2004; Gijbels et al., 2006; Schuitjema et al., 2012). They focused on collaborative learning so that students could build knowledge in interaction with each other (De Corte et al., 2004). Furthermore, they provided
students with authentic learning experiences and active learning processes to create meaningful learning (Gijbels et al., 2006).

Additionally, Sasson et al., (2021) found that innovative learning spaces were better than traditional learning when learning was cooperative, adapted to differences between students, and integrated tasks that provided opportunities for students to choose. If explored further, innovative learning had the most substantial influence on increasing student mathematics learning achievement compared to self-efficacy, task orientation, and school investment regarding gender, ethnicity, and educational level of students' parents (Hornstra et al., 2015). This positive relationship was not found in reading ability (Hornstra et al., 2015). It means this achievement was more specific to students' mathematical skills. Similar results were found the other studies (Byers et al., 2018b, 2018a; Imms & Byers, 2017) that the application of innovative learning had a positive impact on student mathematics learning outcomes, especially in 21st-century skills (Fardah et al., 2021; Kivunja, 2014; Sasson et al., 2021; Supena et al., 2021; Suyitno et al., 2021; Triana et al., 2020). However, when the learning environment was judged more authentic and focused more on self-regulation, students showed less growth in mathematics achievement (Hornstra et al., 2015). It showed that the collaborative characteristics of innovative learning had a better impact on mathematics learning outcomes than the characteristics of authentic learning and self-regulation. In other words, the application of innovative learning had the opportunity to get the best results in improving student mathematics learning outcomes when its application focused on its collaborative characteristics.

Based on the previous discussion, collaborative aspects of innovative learning had the best effect on improving students' mathematics learning outcomes. It was because this process provided space for them to discuss and exchange information, help and encourage each other, and provide mutual support in different forms so that their mathematics learning outcomes became better. The essence of the collaboration process was teaching each other (Sasson et al., 2021). During collaborative activities, students could work together to achieve common goals even though some minor conflicts were found between them (Triana et al., 2020). Abrahamson et al., (2020) supported this and found that gestures in collaborative activities made students jointly realize ideas by using mutually constructive gestures. These gestures could facilitate mathematics learning, particularly in the context of action-based technological tools for learning (Abrahamson et al., 2020). With this process, differences in students' mathematics learning outcomes based on their initial ability level will become invisible or have no effect. It was proven by the research results of Supena, Darmuki and Hariyadi (2021), which stated that the application of innovative learning supported by the 4C learning model positively influenced
students' psychomotor and affective learning outcomes and found no influence from academic skills.

On the other hand, Imms and Byers (2017) and Byers, Imms and Hartnell-Young (2018b), (2018a) found that an increase in student mathematics learning outcomes occurred due to support from the transition from conventional or traditional classroom layouts to classroom layouts with innovative learning environment designs. These ongoing studies compared students' attitudes regarding the learning experience, motivation, engagement in learning, and learning outcomes in mathematics, English, and humanities in each classroom layout for one school year. Meanwhile, the difference between the traditional layout classroom and the ILE design is shown in Figures 1 and 2 below.

Figure 1. Traditional Classroom Layout
Source: (Byers et al., 2018b)

Figure 2. Classroom Layout in ILE Design
Source: (Byers et al., 2018b)

The findings in that study showed varied results in the activities of teachers and students. Regarding students, ILE's classroom layout supported them to explore optimally through high mobility opportunities. Students' gestures could reveal knowledge, emerging or transitional expertise, and how learners schematized information (Abrahamson et al., 2020). As an implication, collaborative processes between students and students, as well as students and teachers, became more facilitated so that the collaborative aspects of innovative learning had a better impact on mathematics learning outcomes. In addition, these opportunities also provided higher chances for improving their learning outcomes through increased motivation, involvement in learning, and meaningful learning experiences.

Furthermore, from the teacher's point of view, using the ILE layout influenced the development of teacher pedagogy, which had implications for improving student academic results (Byers et al., 2018b, 2018a; Imms & Byers, 2017). This was because before the teacher implements innovative learning, the teacher needs to understand the theory first so that it has an impact on improving his pedagogy. In line with that, Triana, Anggraito and Ridlo (2020) said that all learning outcomes obtained by students in the research were inseparable from the
teacher's activities during the learning activities. Even though innovative learning focused on student activities, this could not eliminate the role of the teacher, so collaborative activities also need to be implemented between the teacher and students so that the chances of achieving an increase in student mathematics learning outcomes through innovative learning become higher.

In this regard, Sasson et al. (2021) identified five main pedagogical principles that teachers strongly agree on to support innovative learning programs, namely: building a learning community, designing an active learning environment, providing flexible instruction, creating a learning environment that takes students' learning into account, and building 21st-century skills, especially critical thinking. The teachers in innovative learning spent more time providing focused instruction, feedback (appraisal) and suggesting future direction (refinement) to individuals and small groups of students (Byers et al., 2018b). According to Abrahamson et al. (2020), teacher gestures in innovative learning were realized using points, symbolic, and conventional gestures to establish and maintain common ground. Therefore, the role of junior high school mathematics teachers in cultivating 21st-century skills in students could be done by having students work collaboratively in groups and discuss solving open-ended questions (Suyitno et al., 2021). This confirms that the collaborative aspect of innovative learning did not only occur between students but also between teachers and students.

Based on the study of the research results described above, we know that innovative learning positively influenced students' mathematics learning outcomes, and the best results occurred when education was focused on collaborative characteristics. Meanwhile, the intended collaborative activities were not only limited to the relationship between students but also the relationship between students and teachers, especially for teachers with good pedagogical abilities. In addition, another factor that supported the success of innovative learning was the creation of innovative learning layouts so that students had the opportunity to explore optimally.

CONCLUSION

Based on the results and discussion that have been described, the role of ILE in improving student mathematics learning outcomes was proven in previous research studies. It got the best results by applying ILE focused on collaborative aspects between students and students and students and teachers. In addition, another factor that supported this achievement was the innovative classroom layout design. The conclusion from this systematic review implies that ILE can be used to overcome the low mathematics learning outcomes of Indonesian students.

REFERENCES


