Problem-based Learning on Creativity Domain in Problem Solving for Secondary School: A Systematic Literature Review Analysis

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Abstract: Problem-based learning (PBL) is one of the 21st century teaching and learning strategies in STEM education. STEM is an acronym for Science, Technology, Engineering and Mathematics. Ministry of education has found that PBL can be successfully applied to STEM field. PBL has the potential to develop creativity in problem solving and make students think creatively. It is also considered as an active learning method that encourages the students' interest in understanding STEM concepts. Therefore, it is becoming a necessity to see how far the creativity domain in problem-based learning has been applied towards students especially in secondary school. Because there was lack of research about that. This systematic literature review analysis aims to focus on the similarities and differences such as the steps of problem-based learning applied, the creativity domain in problem solving, the findings of the study and the gap of research between all the articles. The study article was selected through a database of Scopus and Science Direct Journals according to keywords. Keywords used in the search are problem-based learning AND creative thinking AND secondary school. The search has been limited between 2009 until 2019. The thirteen of articles have been chosen to be analyzed based on the four steps in systematic literature review. The four steps included frame a question, run a search, the abstract and tittle of individual papers have to be read, and the information need to be abstract from selected set of final articles. The results reported the most suitable of creativity domain used in problem solving by the past researchers were fluency, flexibility, originality, elaboration and evaluation. However, generally the domain of creativity to be measured is not described in detail at every step of the problem-based learning even though problem-based learning strategy was very effective in improving students' creative thinking.

Keywords: Creativity Domain, Problem-based Learning, Secondary School, STEM Education.

1. INTRODUCTION

In recent year, the importance of providing students with education in the fields of Science, Technology, Math and Engineering (STEM) has been emphasized [41]. In order to implement effective STEM education, one of the skills that students need to develop is critical thinking skills and creative thinking skills. Creative thinking skills are crucial to the success of Vision 2020 in the education system in Malaysia. This is because a developed country can produce students who are critical, creative and innovative. Most STEM students in European, Western, Eastern and Asian countries in particular Malaysia are still unable to demonstrate creative open-ended questions [16]-[19]. To solve creative open-ended questions, it requires students to think creatively about any aspect of fluency, flexibility, originality and elaboration in providing a variety of methods or solutions to problems [22].

However, several previous studies have shown that overall students' creative thinking skills scores are still at a weak and moderate level [32]-[42]-[45]. This is likely to be due to weak teaching and learning strategies among teachers such as teachers still using traditional teaching methods where students are passive, and their creativity is not encouraged [27]. Therefore, several previous studies have suggested the strategy of problem-based learning can improve students' creative thinking skills [23]-[26]-[43]-[44].

Problem-based learning is one of the active learning approaches that can help students become actively involved in the classroom [39]-[15]-[36]. Based on these facts, the ideal learning model for creativity and problem solving is the problem-based learning [7]. Several previous studies have shown that problem-based learning strategies have a positive impact on students' creative thinking in the STEM field [45]-[26]-[21]. However, past researchers have failed to show in detail where the domain of creativity lies in steps of problem-based learning strategy. Therefore, this study aims to gain information on the use of problem-based learning strategies to develop creative thinking skills of secondary school students in any field of STEM.

2. LITERATURE REVIEW

Nowadays, the creative thinking skills is the important skills among students that should be stimulated in solving daily problems [7]. According to [17], schools are beginning to recognize the need for students to practice and develop domains of creativity such as fluency, flexibility and originality. This is because to allow the students in developing a wider range of creative processes such as the students can practice developing a domain of fluency creativity when they want to come up with many ideas or solutions to problems they face. The development of this creative domain will be more meaningful if the idea is original and more flexible [34]. According to [12] and [14], creativity is a teacher's ability to try to inspire students through appropriate environment and training. For example, learning environments such as encouraging the use of open-ended questions in which students need to identify problems at the same time stimulates students' suggestions for thinking about specific ways of solving problems. In addition, training can also encourage students to think creatively through a variety of problem-solving methods [34].

Accordingly, a study from [6] has suggested that there is less emphasis on creativity in the classroom if:

- Teachers are too limited in meaning to come up with new and original ideas that do not fit the curriculum knowledge.
- Teachers only consider key discoveries as students' creative achievements.
- Teachers simply believe that only a few students can be creative and not creative to other students.
- Teachers always think that increased creativity always requires extra special curriculum.

In addition, it is possible that students are low capability in the domain of creativity because of less effective teaching and learning strategies such as traditional teaching and learning. Due to misunderstanding of creativity adopted by teachers, this may hinder the development of creativity among students [6]. Therefore, the development of student creativity can be assisted when teachers use problem-based learning strategies [24].

Some researchers, in particular [38] explain that problem-based learning serves as a catalyst for creative thinking and provides opportunities for innovation. The problem is that most real-world situations are always associated with students, this allows for their involvement in the problem-solving process as a whole [34]. However, most learning applications are based on the problem of creativity leaning towards art and Language [34]. There are examples of problem-based learning environments used in STEM subjects [38] but they are only intended to enhance STEM knowledge, and not for student creativity in high school. Therefore, the investigation of creativity domain for high school students in a problem-based learning environment is worth considering.

The study of [3] has shown the effectiveness of problem-based learning compared to traditional teaching in the fluency and originality creativity of engineering students. The findings of their study have shown that problem-based learning can enhance the creativity domain of fluency and originality. In contrast, the study of [11] found that the fluency mean score was the highest and originality mean score was the lowest after University students was exposed to problem-based learning. On the other hand, [10] have identified that creative thinking skills in the domain of fluency, flexibility and originality of University students are still at a low level. Although many previous studies address the level of student creativity at the University level, there are few studies addressing the level of student creativity at the high school level and there are not many studies that focus on the creativity domain: fluency, flexibility and originality [30]. Therefore, this systematic literature review analysis study is aimed to identify the similarities and differences of all articles in problem-based learning on creativity domain such as the steps of problem-based learning applied, the creativity domain in problem solving, the findings of the study and the gap of research between all the articles.

3. METHODOLOGY

Research articles are selected through a database of Scopus and Science Direct Journals based on keywords used. Keywords used in the search are Problem-based Learning AND Creative Thinking AND Secondary School. For the purpose of obtaining the latest study, the search has been limited between 2009 and 2019. A total of 13 studies have been selected to be analyzed based on the four steps in systematic literature review analysis. The figure 1 have shown the four steps in systematic literature review analysis according to [5]:

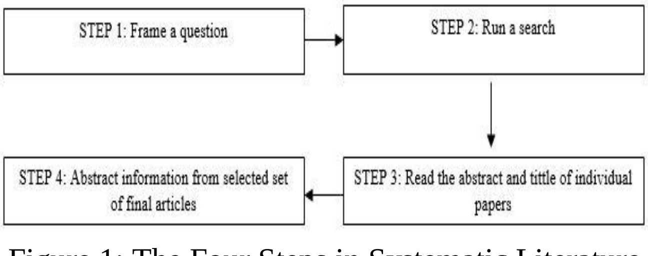

Figure 1: The Four Steps in Systematic Literature Review Analysis

For the first step which is framing a question. The researcher will ask the question to himself. For example, researchers want to use high school students as study samples, researchers want to focus on problem-based learning interventions, researchers look at problem-based learning and conventional learning and finally researchers want to see the impact of problem-based learning on creative thinking skills.

The second step which is run a search of the literature databases. After the researcher have known what she or he want, the researcher conducted a search of the literature databases. This helped researcher to identify the appropriate search terms. These search terms are arranged using Boolean Logic related controlled vocabulary, symbols of truncation or expansion, and placement of the terms in different sections of a reported study. In Boolean Logic, the researcher used the connectors, "AND", "OR", and "NOT" in various combinations to expand or narrow down search results and findings. For examples as shown below;

a) "Secondary Students" AND " Problem-based learning on creative thinking skills" will find only those articles that have BOTH secondary students AND problem-based learning on creative thinking skills as the subject topics.
b) "Secondary Students" OR " problem-based learning " will find all articles that have EITHER "Secondary Students" OR " Problem-based learning on creative thinking skills" in their subject topics, so the number of results returned will be larger.
c) "Secondary Students" NOT " Problem-based learning on creative thinking skills" will find only those articles that contain "Secondary students" but will exclude all articles that have "Problem-based learning on creative thinking skills" as their topic area.

For the third step which is selected the articles for literature review analysis by reading titles, abstracts and full texts. The researcher set up a scheme where the researcher decided to select and reject the articles for literature review analysis. For example, the article is relevant for the study question, the article does not discuss the outcome that is of interest to this research and the article is published outside of the date range. Because of that only 13 articles have been chosen to be analysed. For the last step is abstract the information from articles. In this matter, the researcher abstract the information from articles and then put all those needed information into table synthesis matrix according to subthemes: authors, the steps of problem-based learning applied, the creativity domain in problem solving, the findings of the study and the gap of research between all the articles. From that table analysis, the researcher can make some similarities and differences in the thirteen studies.

4. RESULTS

There are some similarities and differences in the thirteen studies. All of these similarities and differences are divided into four parts of the results, such as the steps of problem-based learning applied, the domain creativity in problem solving, the findings of the study and the gap of research between all the articles.

4.1 The Steps of Problem-based Learning Applied

Based on the meta-analysis of the 13 articles, the researchers found that there were three categories of differences in the application of problem-based learning phases;

a) Previous researchers have successfully extracted each phase of problem-based learning and also identified who pioneered the problem-based learning model used in their study [26]-[43]-[9]-[1].
b) The previous researchers successfully extracted each phase of problem-based learning but failed to identify which problem-based learning model was used in their study [45]-[23]-[18]-[29]-[28].
c) The previous researchers were unable to extract each phase of problem-based learning and did not specify which problem-based learning model was used in their study [24]-[25]-[44]-[21].

In the study of [26] and [43], they have similarities in which they used problem-based learning models from [2]. There were the phases of problem-based learning models from Arends; 1) student-centred problem-solving, 2) organizing students for learning, 3) helping self-learning and learning group, 4) Develop and present problem artefacts or presentations and 5) Analyse and evaluate problem solving processes.

Whereas, the study of [1] differs slightly from the studies of [26] and [43], which is the use of problem-based learning models from Arends in 2007. However, the problem-based learning phases are similar to those in the Arends' problem-based learning model phases in 2013. For the study of [9] used a problem-based learning model from Rusmono in 2012. The phases in problem-based learning are similar to the Arends problem-based learning phases of 2007 and 2012.

Meanwhile, the study of [45], [23], [18], [29] and [28] share similarities in which they successfully extract each phase of problem-based learning but failed to state which problem-based learning model is used in their study. In other words, they did not know the author of problem-based learning. According to [45] have identified the use of a problem-based learning model consisting of five phases; 1) orientation to students on problems, 2) organizing students for learning, 3) guiding individual and group research, 4) developing and delivering work-based creations, 5) analysing and evaluating processes to solve problems. In contrast to [23] who simply stated problem-based learning strategies meant that students solved problems, students transformed word problems into mathematical models, solved pictures, explored, must detect or sensitive issues, refined them in detail, and then completed them in various ways. For [29] did not show the phases of problem-based learning as fully as saying teachers should direct students to problems by providing a worksheet, students need to organize three questions and the final students using the inquiry strategy. In contrast to the study of [18] have stated that problem-based learning consists of three phases; (1) finding objective levels, looking for data or facts and finding problems as target questions, (2) determining as many ideas as possible, and (3) developing appropriate ideas for ideas.

4.2 The Creativity Domain in Problem Solving

Overall, the results of the meta-analysis have shown that there are 10 similar articles that successfully demonstrated the domain of creativity that they want to measure when solving problems in their research [45]-[26]-[43]-[23]-[44]-[24]-[9]-[29]-[1]-[21]. However, there are only 3 articles in the article failed to show the domain of creativity that they want to measure [28]-[25]-[18].

The following shows a summary of the similarities and differences in the domain of creativity used by researchers in problems solving;

a) Fluency, Flexibility, Originality, Elaboration, Evaluation [45].
b) Fluency, Flexibility, Originality, Elaboration, Evaluation [26].
c) Fluency, Flexibility, Originality, Elaboration [43].
d) Sensitivity, Fluency, Flexibility, Originality, Elaboration [23].
e) Fluency, Flexibility, Originality, Elaboration, Evaluation [44].
f) Fluency, Flexibility, Originality, Elaboration [24].
g) Fluency, Flexibility, Originality, Elaboration, Evaluation [9].
h) Fluency, Flexibility, Originality, Elaboration [29].
i) Fluency, Flexibility, Originality [1].
j) Fluency, Flexibility, Originality [21].

4.3 Findings of Research

In the study of [45] found that student groups with high academic achievement had a relatively low level of flexibility (66.67%) and evaluation (64.52%) compared to fluency (74.42%), originality (73.47%) and elaboration (75.31 %). The student group with moderate academic achievement had a low level of elaboration (67.81%) and evaluation (54.65%) compared to the fluency (80.03%), originality (73.33%) and flexibility (73.17%). The student group with weak academic achievement had a low level of elaboration (66.76%), evaluation (51.53%) and originality (65.63%) compared to the fluency (80.85%) and flexibility (83.78%).

In addition, the study of [26] found that the average of mean creative thinking skills among students who have been taught problem-based learning are at a moderate level (0.49). The following had shown a summary of the mean scores for each creative domain;

a) Fluency domain mean score: 2.77.
b) Flexibility domain mean score: 2.93 (highest).
c) Originality domain mean score: 2.34 (lowest).
d) Elaboration domain mean score: 2.63.

The results of the study by [43] have shown that there are four categories of students namely less creative, medium-creative, creative and highly creative. The results of the study for each category of students are presented in detail as follows;

a) Less creative students: The fluency mean score is 17.5%, the originality mean score is 4%, and no students were unable to achieve the aspect of elaboration.
b) Medium creative students: Fluency mean score is 15%, flexibility mean score is 10%, originality mean score is 15% and elaboration mean score is 13%.
c) Creative students: The fluency mean score is 15%, the flexibility mean score is 9%, the originality mean score is 14% and the elaboration mean score is 16%.
d) Highly creative students: The fluency mean score is 15%, the flexibility mean score is 20%, the originality mean score is 6% and the elaboration mean score is 13%.

In addition, [23] study has proven that the most mistakes creativity domain in problem-based learning were flexibility (2.95) and originality (2.73). Meanwhile, the creativity domain of fluency (3.55), elaboration (3.30) and sensitivity (3.20) had better mean scores than flexibility and originality. For study of [44], as overall, the student creativity was good at 80.69 %. Students' creative thinking skills have been categorized into three groups of students based on their academic achievement. The improvement in students' creative thinking skills scores for each domain of creativity has been shown as follows;

a) Student with high academic achievement: fluency (100), flexibility (85), originality (90), elaboration (42), evaluation (59).
b) Student with moderate academic achievement: fluency (100), flexibility (44), originality (44), elaboration (10), evaluation (39).
c) Student with weak academic achievement: fluency (95), flexibility (50), originality (22), elaboration (0), evaluation (0).

The findings of the study of [24] has achieved a satisfactory level of creativity level at 49.22%. The aspect of flexibility and originality were good at 74.61% and 68.36%, respectively. Meanwhile, the aspect of elaboration was very good at 100%. The findings of the study of [9] have shown an increase in N-gain scores in the domain of fluency creativity (0.67). The decrease in N-gain scores occurred in the domain of flexibility (0.49). Meanwhile, a slight increase in the N-gain score in the domain of originality (0.55). The elaboration of N-gain score was 0.66 and the N-gain evaluation score was 0.59. However, overall students' thinking skills were at a moderate level. According to [29], there are four levels of student creativity namely creativity level 0: non-creative students; creativity level 1: less creative students; creativity level 2: creative students; creativity 3: creative students; and creativity level 4: highly creative students. Their findings have shown that students' creative thinking skills were still low at the first test. This is because no student has reached the 3 and 4 levels of creativity. In the second test there was an increase in students' ability to reach the 3 and 4 levels of creativity.

The study of [25] have shown that students' creative thinking skills improve when students use problem-based learning strategies instead of conventional learning. The findings of their study are also supported by [28] study. They have shown that the average N-gain score of students 'creative thinking skills is at a high level (0.78) after using problem-based learning compared to conventional learning where the average N-gain score of students' creative thinking skills is 0.52. Furthermore, [1] agreed that problem-based learning is an alternative learning model that can enhance students' creative thinking skills.

In addition, the research of [18] have revealed that the data shown students with low academic achievement can achieve fluency and flexibility. The student with medium academic achievement also can achieve fluency and flexibility too but was not well structured in originality. However, the student with high academic achievement able to achieve the aspect of originality. According to [21], the results showed that the creative thinking level of students with high capability by problem-based learning was at level 4 or very creative because students were able to demonstrate fluency, flexibility and novelty.

4.4 The Gap of The Research

After analysed all the articles, the researcher found two important similarities gap of all the past researchers such as;

a) The domain of creativity is not described in detail at every step of the problem-based learning even though problem-based learning strategy is very effective in improving creativity domain such as fluency, flexibility, originality, elaboration, evaluation and sensitivity. In this case, they were reporting to evaluate creative domain in problem solving by using problem-based learning but did not explicitly state the creativity domain in every phase of problem-based learning. There is no specific guidance or theoretical framework on how the implementation problem-based learning enhanced creative thinking skills in aspect of fluency, flexibility, originality, elaboration, evaluation and sensitivity [45]-[43]-[23]-[44]-[24]-[9]-[29]-[28]-[25]-[1]-[18]-[21].

b) Did not explored and explained in depth how the process of creative thinking student got higher, medium and lower level in each of creativity domain [45]-[26]-[43]-[23]-[44]-[24]-[9]-[29]-[28]-[25]-[1]-[21].

c) They were reporting to use student worksheet as their instrument for accessing students' creative thinking skill but do not explicitly state the instrument based on whom or adopted and adapted or created by themselves. In this case, there are also lack of research about Hu and Adey's instrument usage when they are doing creative thinking skills in STEM fields [45]-[26]-[43]-[23]-[44]-[24]-[9]-[29]-[28]-[25]-[1]-[21].

5. DISCUSSIONS

Overall, problem-based learning by Arends are more favourable model used in creative thinking skills among thirteen articles. It is because the steps in problem-based learning stated are easier to be used by the past researchers [1]-[26]-[43]. However, there was still lack of applicable usage of Arends' model towards other reseachers. This is because the Arends' model not so familiar to others researcher and make them to use the more applicable and familiar model such as Oon-seng Tan. Actually, the steps in problem-based learning from those articles are based on Oon-seng Tan's model who is a piooner of model problem-based learning. [37] also emphasized that there are four components that need to be taken into account when implementing problem-based teaching and learning processes. The four components are problem presentation, problem solving questions, problem-based learning steps and problem presentation and assessment. In addition, Oon-seng Tan's model are more related to creativity [39]. So that, the past researchers implement Arends' model that was adopted and adapted from Oon-seng Tan on 2003. However, the model of Oon-seng Tan can be used to obtain better data collection and to meet the needs of researchers in problem-based learning in creative thinking skills.

Furthermore, almost all studies have been measured domain creativity of fluency, flexibility, originality, elaboration and evaluation. This is because all the domain creativity are the main indicators of creative thinking skills [33]. In fact, the domain creativity namely fluency, flexibility, originality in problem solving was first introduced by Torrance on 1990 and followed by Hu and Adey on 2002. Fluency in problem-solving refers to a student's ability to obtain many solutions to a problem [21]. Flexibility in problem-solving refers to a student's ability to solve a problem using many different methods or ways [21]. Originality in problem-solving refers to the student's ability to solve a problem with many different solutions and correct answers, especially to find an original solution which is not common for that student's grades or their knowledge level [21]. Elaboration in problem solving refers to the student's ability to solve a problem with another idea developed from an idea [21]. Evaluation in problem solving refers to the ability of students to evaluate the problem, evaluate their peers and the students have to do some reflection on their learning process. According to [30], although many previous studies on measuring creative thinking skills at University but there are not many studies that focus on the creativity domain: fluency, flexibility and originality at secondary school. This statement also supported by [1] and [21]. They also measured creativity domain: fluency, flexibility and originality at secondary school by using problem-based learning.

Besides that, there were still have the low and moderate ability of students' creative thinking described by some past researchers [31]-[20]-[8]-[26]. According to [8] have stated that the result is triggered by five main factors which is learning process is still informative, learning is still dependent on the teacher, learning is a memorizing activity, teachers rarely practicing the comprehension ability, teachers rarely practicing some experiment activities and learning of science is still the focus on the count. In the other hands, some articles have shown differ findings on mean scores of fluency, flexibility, originality, elaboration, evaluation and sensitivity based on the capability students' academic achievement [45]- [44]-[21]. The creative thinking skills was closely related to capability of students' academic achievement [4]-[21]-[18]. The students that have the high capability in academic achievement fulfilled all the aspects of creativity domain [21]. Therefore, all the thirteen articles have shown that the problem-based learning used by the students in their learning can enhance the students' creative thinking skills in aspects of fluency, flexibility, originality, elaboration, evaluation and sensitivity.

Last but not least, mostly the studies are focused on determine the effectiveness of using problem-based learning on creative thinking skills [18]. However, all the above studied still lack of emphasis on how the process of creative thinking student got higher, medium and lower level in each of creativity domain. They did not explore and explain in depth how the process of creative thinking in each phases in problem-based learning [45]-[26]-[43]-[23]-[44]-[24]-[9]-[29]-[28]-[25]-[1]-[21]. Moreover, the past researchers explained the steps of problem-based learning only [45]-[43]-[23]-[44]-[24]-[9]-[29]-[28]-[25]-[1]-[18]-[21]. The domain of creativity is not described in detail at every step of the problem-based learning even though problem-based learning strategy is very effective in improving creativity domain such as fluency, flexibility, originality, elaboration, evaluation and sensitivity. In this case, they were reporting to evaluate creative domain in problem solving by using problem-based learning but did not explicitly state the creativity domain in every phase of problem-based learning. There is no specific guidance or theoretical framework on how the implementation problem-based learning enhanced creative thinking skills in aspect of fluency, flexibility, originality, elaboration or evaluation or sensitivity. Besides that, they were reporting to use student worksheet as their instrument for accessing students' creative thinking skill but do not explicitly state the instrument based on whom or adopted and adapted or created by themselves [13]-[45]-[26]-[43]-[23]-[44]-[24]-[9]-[29]-[28]-[25]-[1]-[18]-[21]. In this case, they needed to use Hu and Adey instrument when they are doing creative thinking skills in STEM fields. This is because all thirteen articles using the general creativity instrument. [46] revealed in their study that, a test that uses creativity problems in a specific field is more appropriate as compared to a general creativity test to measure scientific creativity.

6. CONCLUSION

In conclusion, this concept paper has shown a pattern of recent studies on problem-based learning on creativity domain in problem solving for secondary school. Arends' model of problem-based learning was the most frequently used by the past researchers. The researchers' finding was recommended to use Oon-seng Tan model because of it is the pioneer of problem-based learning and the most suitable model for problem-based learning in creative thinking. Besides, there were still have the low and moderate ability of students' creative thinking described by some past researchers due to some factors. Therefore, more researches on problem-based learning are needed to improve the students' creative thinking skills such as fluency, flexibility, originality, elaboration, evaluation and sensitivity.

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