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Research Article

What increase students' creative thinking skills? employing problem-based learning-digital mind map in biology learning

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Abstract: Creative thinking has widely discussed due the urgency at the 21st century life. These thinking process helps people to tackling situation and problems in daily life. This study aimed to analyze the secondary students' creative thinking through Problem-based Learning integrated with Digital Mind Map (PBL-DMM). This study was conducted at Solok Secondary High School, West Sumatra, Indonesia. Using quantitative research design, 60 students were taught by PBL-DMM. Creative thinking was testing by essay test in three times. The essay tests previously validated by the expert appraisal and once were testing to the former students to measure the empirical validity and reliability. All tests were declared valid and reliable. The result of the treatment was students' creative thinking increase within three time of tests. This finding means that PBL-DMM can helps students to promote their creative thinking during the learning process. Digital mind map taking role as a tool to organize students' concept, knowledge, and information.

Keywords: creative thinking skills; digital mind map; problem-based learning

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1. Introduction

A human being who is able to thrive in the 21st century is someone who has the 21st century skills with various life. which needed by future workers in response to Industry 4.0 (Saleem et al., 2024). Students in the 21st century must have various abilities such as problem solving, critical thinking, creative thinking and innovation, and communication and collaboration (OECD, 2019). The skills possessed by students largely determine the success of students who are influenced by the guidance and direction of the teacher. Teachers are directed to prepare students to have the ability to think critically, and creatively (Dilekçi & Karatay, 2023) and problem solving (Fülöp, 2021). To face the challenges of the 21st century, teachers therefore play an important role in developing students' skills, knowledge and attitudes.

The importance of developing creative thinking is expressed by Tendrita et al. (2016) That creative thinking is important to be trained so that students can cultivate various ideas and arguments, ask questions, agree on the truth of arguments, be able to be open-minded, and responsive to different points of view. Creative thinking is concerned with innovation, the ability to create new things, apply new forms, use imaginative skills, or transform existing things into something new and unique (Bin Mazla et al., 2020). According to Torrance (1968) creative thinking has four dimensions: fluency (production of ideas), originality (production of unusual ideas), elaboration (persistency in introducing details to products), and flexibility (production of different ideational categories). Providing students to be creative and guiding them to create innovative ideas is an important goal of the education and training process (Avcı & Durak, 2023).

Research that has been done to improve creative thinking in learning is carried out by Kusmawan et al. (2018), using group investigation model have increased creative thinking skills in mathematics learning. Other research conducted by Rahmazatullaili et

al. (2019) namely increasing creative thinking using the PjBL model in mathematics learning, the results of creative thinking ability increased after the intervention. A study conducted by Nurqolbiah (2016) The improvement of creative thinking skills that show positive results in classes that apply the PBL model is influenced by the nature of PBL which emphasizes active learning. The advantage of the PBL model compared to other learning models in improving creative thinking is that when students are given problems, then they are asked to obtain interactive, active learning model solutions. Other studies conducted by (Nur et al., 2020) using ERcORE, while Nur Zakiyah et al. (2024), (Pasaribu et al., 2023) using STEM learning, Supratman et al. (2020, 2021) using POPBL, online learning using video Hendriyani et al (2022) to promote students' creative thinking in biology learning.

However, students in problem-based learning have difficulty organizing the knowledge obtained during learning activities. In problem-based learning, students explore knowledge through observation, literature study, discussion, or experiments without having a special strategy for organizing the information they obtain. Therefore, students when studying in PBL can be given help with mind maps. The shortcomings of the PBL model are overcome by using the help of a mind map. However, research reports that mind maps have a negative impact on some students because they are not satisfying and also it might be awkward for part of the students who are not good at drawing since it involves drawing and coloring (Kadagidze, 2016). Therefore, using technologies in mind map process make it easier. The use of digital mind maps is very useful to support aspects of learning. Digital mind maps can help students solve problems, think critically, store and remember information, interpret the concepts learned, and help students to think creatively (Kadagidze, 2016). This method is also encouraging students to become the meaning constructors and active participants (Yan & Kim, 2023).

Studies on digital mind maps in various educational field have been done, for instance at the English for Foreigner Learning (EFL) (Yan & Kim, 2023), for the training of British Library staffs (Keinan-Schoonbaert & Rees, 2019), to documenting the process on archeologic features (Markiewicz, 2024), at the civic education learning (Winata & Rahmat, 2022), physical education (Thabet Awad & Maged Hegazy, 2015), at the undergraduate pre-service biology teacher learning (Hidayati et al., 2020, 2021), in tertiary education learning (Abd Karim et al., 2022), undergraduate students social-science learning (Taadi et al., 2019), and inclusive learning (Reham, 2017). However, there has been no research examining the use of digital mind maps in secondary school students. Therefore, we tried to reveal the effectiveness of digital mind maps in high school biology problem-based learning.

This paper contribution to literature was provide information how teachers teaching in the 21st century should be, with the innovative learning, using technologies such as mind map software in purpose to shaping the students the 21st century skills. Also, the learning we have studies, can contributes to achieving high quality human resource through education with the problem-based learning instead.

2. Materials and Methods

2.1 Research Design

This study was quantitative design which aims to develop creative thinking skills in biology learning for high school students. The study was employed one class and 60 students who learn with PBL-DMM. The research was carried out for 1 semester at SMA Negeri 1 Solok on biodiversity material, classification of living things, viruses, bacteria, fungi and Protists. The lesson plan has been done with the Problem-based Learning (PBL) assisted with the digital mind map. The lesson plan meets all requirement of schools' curriculum. Simply, the lesson plan includes the description of students and teacher activity, essay test, student's worksheet, and learning material, such as slides. The validity of lesson plan was determined by conducting expert appraisal consisted of the instructional and technical review (Kundariati & Rohman, 2020). Meanwhile, the

implementation of the PBL-DMM lesson plan have been done at two classes of Solok, West Sumatra high school.

We were test the students in three times to ensure the process of the learning. In this case, problem-solving test also act as the formative assessment. Formative assessment provides information to the researcher, do they teach the students well. If it's not, teacher should fix problem in the classroom so the students will gain their achievement. The research material is grouped into three parts. Part one is the material on Biodiversity and Classification of Living Things which is carried out in one PBL learning cycle. Part two is Virus and Bacteria which is carried out in one PBL learning cycle. While part three, namely Protists, and Fungi which are carried out in one PBL learning cycle. The research design in this study can be shown in Figure 1.

2.2 Research Participant and Research Instruments

The subjects of the study were 60 grade X students of SMA Negeri 1 Solok, West Sumatra, Indonesia. Classes are selected by random sampling technique. All students involved in this study have expressed their willingness to become participants. The study has obtained permission from the city and school education office. Essay test was used to assess students' creative thinking. Essay test was followed creative thinking indicators, i.e. which refers to four indicators namely fluency, originality, elaboration, and flexibility (Treffinger & Young, 2002) The essay test is prepared by referring to the learning objectives of six materials on biodiversity, classification of living things, viruses, bacteria, fungi and Protists (Rubric can be seen in Table 1).

Table 1. Creative Thinking Skills Assessment Rubric

Indicator	Criteria	Score
Fluency	Mention/write down 4 or more different ideas, suggestions or alternative answers	4
Originality	Mention/write down some unique ideas that are interesting and logical, relatively new and relevant to the given problem	4
Elaboration	Explain some logical details on existing ideas so that the formulation of ideas becomes easier to apply and clear	4
Flexibility	Write down some alternative answers that are very logical and relevant to the given problem from different points of view	4

The essay test comes with an answer key that is used to check the student's answers. The results of students' answers are given a score of 1-4. The empirical validity and reliability of the instruments were evaluated by conducting a pilot test on 32 eleventh grade students of senior secondary schools in Solok. Pearson's correlation test has been employed to gauge the validity of test. The results of the empirical validity test show valid question items with a value of 0.463-0.742 greater than r table (5%) 0.444 which means that all questions are valid. Furthermore, according to Cronbach's coefficient, reliability is 0.782 which means a reliable test instrument.

2.3 Data Collection and Data Analysis

Before treatment, students are taught to compile a digital mind map using the help of a website. Most students choose to use i-mind map and others use Mindomo. All of these websites help students to compile digital mind maps attractively and make it easier for students to learn. This session was conducted for 45 minutes and continued with biology learning. As for doing the test, it is done at the end of the lesson at the end of PBL. The test is carried out for 45 minutes and uses a paper-based test. Paper-based tests are used because students tend to be difficult to discipline and lack concentration if the test is carried out using the help of digital platforms. Students who have finished taking the test

are asked to collect from the teacher. The corrected answer sheet is corrected by referring to the answer key sheet and scoring the creative thinking test. Scores are given in the range 1-4. Next, the data is converted into interval scale data. The data analysis used is a descriptive statistical technique, i.e. n-gain score formula to see the improvement of students' creative thinking skills.

3. Results

3.1 The Development of PBL-DMM to Foster Students' Creative Thinking

The development of PBL-DMM learning tools integrated with creative thinking initiators begins with an initial analysis to identify student problems in schools so that they can formulate the right design. We integrate a digital mind map into the second step of PBL learning, namely organizing students to learn and step three, namely assist, independent and group investigation. The results of the development of learning tools and instruments are obtained through the results of validation sheets which are described in Figure 1.

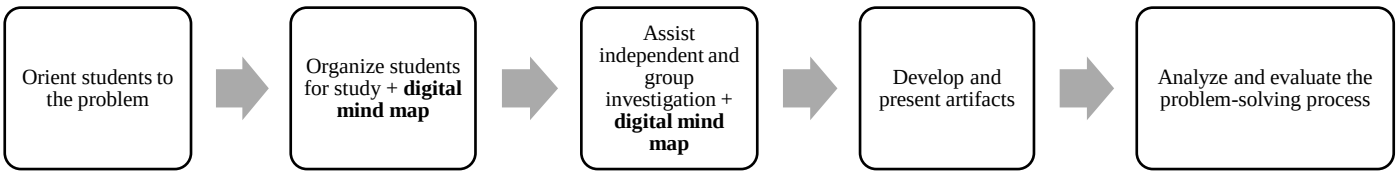

Figure 1. The development of learning tools and instruments process

The validity instrument of PBL-DMM to foster students' creative thinking can be seen in Table 2.

Table 2. The Validity Instrument of PBL-DMM

No.	Teaching Materials	Validity Score	Criteria
1	Syllabus	4.48	Very valid
2	Lesson plan	4.98	Very valid
3	Students' worksheet	5.00	Very valid
4	Handout	4.77	Very valid

Based on the Table 2, the all-teaching materials are in very valid criteria. Syllabus, lesson plans, students' worksheets and handouts can be used in biology learning.

3.2 Students' Creative Thinking Achievement

The PBL-DMM learning model was carried out 3 times a cycle in 16 meetings. Each cycle is carried out a formative test that aims to determine the achievement of the results of creative thinking skills after implementing one PBL learning phase. Educational research prioritizes quality development and process improvement, so that if there is a learning component that causes negative effects, efforts are needed to improve it. The components referred to in this case, for example, are the selection of perceptions, learning media, learning methods, and those that do not change and modify the independent variables in this study (PBL assisted by mind map). Intracycle evaluation aims to determine the effect or impact of improvements made on each PBL syntax performed. Considering that the implementation of PBL cannot be completed in one meeting. Mind maps are integrated in stages two and three of PBL. The data of students creative thinking can be seen in Figure 2.

Based on Figure 2, the achievement of creative thinking skills in PBL-DMM classes in three time of tests. The first test with a value of 66.88, increased in second test by 71.67 and again increased in third test with a value of 78.65, this shows that the model used is able to improve students' skills in creative thinking increasing in tests. This result show

that the model used is able to improve students' skills in creative thinking and improve in each cycle.

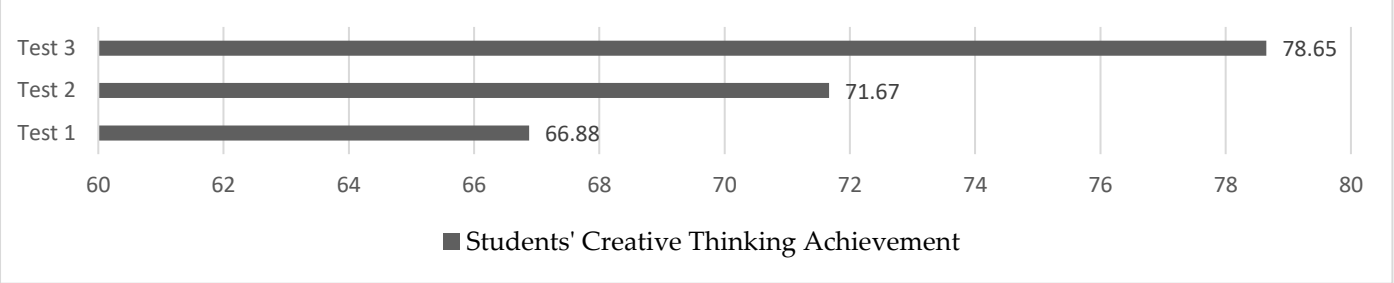

Figure 2. Students' Creative Thinking Achievement

3.3 Students' Response to the PBL-DMM Learning

Students are asked to answer several item questions related to learning motivation and PBL-DMM learning suitability. Student responses to the PBL-DMM learning model are collected through questionnaires given at the end of learning. A summary of student response questionnaires is presented in Table 3.

Table 3. Learners' Responses to the PBL-DMM Model

No.	Aspect	Percentage (%)
1	PBL	88.17
2	Creative thinking	93.33
3	Digital mind map	92.33
4	Creative thinking using digital mind map	94.58
	Average	92.72

There are six aspects asked in the questionnaire, namely PBL, creative, mind map, creative assisted mind map. Overall, students give positive responses to the learning applied. This is shown by the overall percentage of student responses of 92.72%. We showed some positive student responses in PBL-DMM learning, for example;

"*Lessons that use mobile phones are cool, make the mind map also cool, help to learn*" #student 1

"*Digital mind map helps me learn, I like to embellish pictures and decorate mind maps so interesting*" #students 2

But there are also students who express negative responses, mainly because they feel bored.

"*At first I liked the mind map, but after a long time I got bored because I was told to make a mind map*" #students 3

4. Discussion

4.1 The integration of Digital Mind Map into Problem-based Learning (PBL-DMM)

This research examines the effectiveness of PBL assisted with digital mind maps in high school's biology learning. We integrate digital mind maps in the second (organize to learn) and third (assist individual or group investigation) stages. We have a reason that this digital mind map is used as a tool in compiling information notes. For example, almost similar research is research Hidayati et al. (2019). However, she used a digital mind map at the beginning of the PBL step. For comparison, we try to visualize our integrated digital mind map in Table 4.

Next, we put this integration into lesson plans and student's worksheets. We use student's worksheets that have been integrated with the PBL phase. The process of compiling a digital mind map takes around 30 minutes or maybe less or more. Students also have different time frames for creating DMM. We found facts that students' learning motivation is not certain at each class meeting, which is influenced by many factors. Even though online tasks make students more motivated (Mendoza et al., 2023), but this this cannot be generally. Motivated students are more likely to participate actively in classroom

discussions, collaborate with peers, and take ownership of their learning process (Thibodeaux et al., 2019). This proactive approach fosters a positive learning environment where knowledge retention and application are prioritized.

Table 4. The Comparation of integration DMM to the PBL

No.	References	PBL-digital mind map phase
1.	Hidayati et al. (2019)	(1) students organized **DMM** to connect concepts, (2) students introduced to problems, (3) students were organized to learn, (4) students were guide to learn as an individual or group, (5) students were asked to present the result in group discussion, (6) students were asked to do reflection and evaluate the learning process.
2.	Current study	(1) Students identify the problems, (2) students learn and looking for information through observation, literature review, or any activity. Then, they write down the information they obtain with **DMM**, (3) students were make investigation individually and, in a group, then write down the information they obtain with **DMM**, (4) students develop and present the problem solutions, (5) students were evaluate the solutions they have made.

4.2 PBL-DMM Impact on Students Creative Thinking Skills

Based on research data analysis, there is a significant difference in the creative thinking skills of students who learn with the DMM-assisted PBL learning model, meaning that there is an influence of the Digital Mind map-assisted PBL learning model on students' creative thinking skills. Based on the results of the analysis, creative thinking skills in the experimental class (PBL-DMM) were higher than the control class that only used the PBL model. PBL assisted digital main map, students are given opportunities for students to develop creative thinking skills, indicators developed include flexibility, originality, elaboration and fluency (Treffinger & Young, 2002). The results show that students have been able to produce new solutions related to the problems. Students be able to think creatively and develop their higher order thinking skills. This finding relates to studies which state that PBL assisted with digital mind map can enhance students creative thinking and critical thinking (Hidayati et al., 2019, 2021; Karim & Mustapha, 2020). In the other study, PBL assisted with digital mind map also improve student's communication skills and their learning outcomes (Hidayati et al., 2020).

Creative thinking can definitively be expressed as a mental activity, which results in the discovery of new solutions to each problem. PBL assisted by digital mind map consistently and continuously trains students' thinking creatively. The PBL model assisted by digital mind map also facilitates and supports students to gain the experience students need in solving problems. This is also stated by Spector (2016) who states that the emergence of creativity needs to be supported by thinking beyond previous experience and focusing on cognitive processes accompanied by creative products. And also supported by Şenel and Bağçeci (2019) that schools are one of the most suitable environments to train students in practicing creative thinking, as long as the school environment is designed with a culture of thinking and processing under the guidance of teachers.

PBL has proven beneficial in developing students' cognitive and motivational development (Yew & Goh, 2016).PBL encourage students to be active, collaborative, student-centered learning process that develops problem-solving skills and independent learning skills needed to face challenges in real life and careers (Geitz et al., 2016; Kundariati et al., 2023). Also, promote students to develop and explore problems by increasing awareness of different ways of thinking, solving problems (Baysal, 2017), and literacy (Suwono et al., 2023). Schettino (2016) states that PBL can make the learning environment more conducive so as to encourage more optimal learning. Problem-based learning is closely related to constructivist theory that emphasizes student activity. With the application of PBL, students are expected to develop creative thinking skills because they are actively involved in compiling knowledge, developing thinking skills, investing, and solving problems. Thus, students have a more active role in the learning process, and are expected to achieve more positive results in the development of critical and creative thinking skills.

4.3 The Role of Digital Mind in Problem-based Learning

Mind maps are a good tool to provide students with the opportunity to exchange information during discussion activities. Visual representation of the mind map provides continuous image access to the results of other friends so that it becomes a trigger for memory or stimulation to be more competitive. As other members add new concepts to the mind map, the ideas of the other members may change. So that a more complete and richer mind map emerges and is rich in ideas. This will trigger the creation of new schematics in the group (McCrea & Lorenzet, 2018). Mind maps can spur discussion and stimulate deeper processing and elaboration of information. Students in the tutorial group, who used a mapping tool (mind map), felt much more accepting with the analysis and structuring of the problem compared to students in the control group (without using a mapping tool). Mind mapping helps students to create questions related to the topic they learn (Stokhof et al., 2020).

Mind maps in problem-based learning can develop students' ability to analyze, and synthesize problems, and they tend to consider mind maps as useful tools in the learning process., thus the use of a digital mind map in the PBL model will cover the weaknesses of the model. The integration of mind maps in PBL structures will improve the shortcomings that exist in these structures (Hidayati et al., 2021). Digital mind map helps students learn, mind maps also encourage the creation of deep learning, especially if used in conjunction with PBL. Another study by Lestari and Seebut (2016) states that learning using PBL integrated with digital mind maps can significantly improve students' analytical thinking skills. Based on these findings, it is concluded that PBL can have a positive impact on learning. The example of digital mind map can be seen in Figure 3.

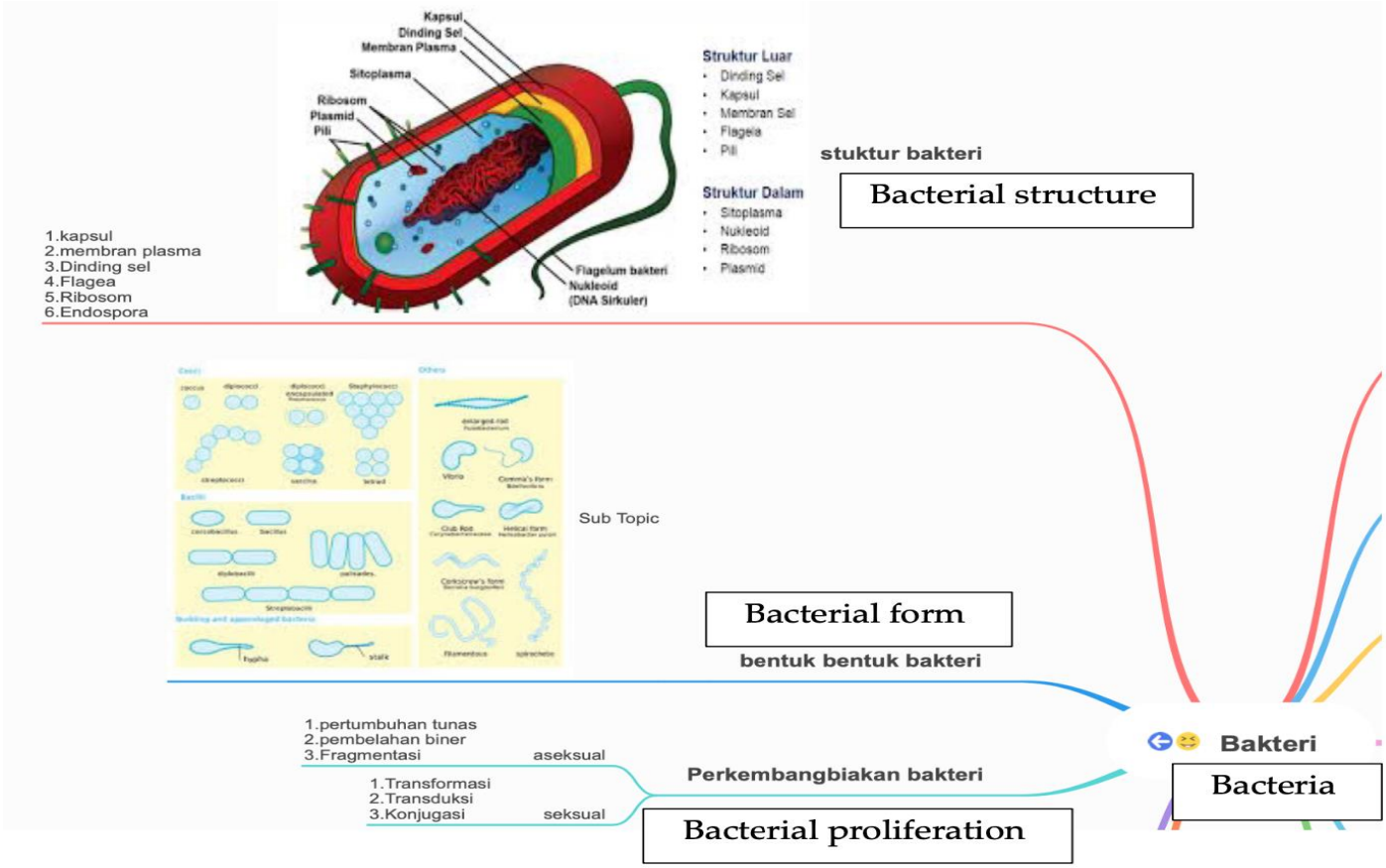

Figure 3. Students' Digital Mind Map, *students' digital mind map results showing several mind maps branches on the topic of bacteria; bacterial proliferation (green line), bacterial shape (blue line), bacterial structure (red line). Students also add illustrations of bacterial structures.*

5. Conclusions

The result of this study was students' creative thinking and problem-solving increase. This finding means that PBL-DMM can helps students to promote their creative thinking during the learning process. The increasement in creative thinking due to the PBL model assisted by digital mind map consistently and continuously trains students' thinking skills. The PBL model assisted by digital mind map also facilitates and supports students to gain the experience students need in solving problems. Digital mind map taking role as a tool to organize students' concept, knowledge, and information. Mind maps are a good tool to provide students with the opportunity to exchange information during discussion activities. Visual representation of the mind map provides continuous image access to the results of other friends so that it becomes a trigger for memory or stimulation to be more competitive. Yet, the fact that there is also student who get bored by using digital mind map open our eyes that learning should not be monotone. Innovative learning means teachers should employing any kind of strategies which can make the class get better, increase student's engagement, and improve the learning outcomes. Therefore, our suggestion is to explore any possibilities of integration other learning tool in PBL-DMM strategy.

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Conflicts of Interest: Authors declare there are no conflicts of interest.

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