Heliyon 9 (2023) e19512

Contents lists available at ScienceDirect

Heliyon

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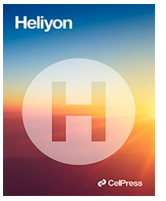


A comparison between problem-based conventional learning and creative problem-based learning on self-regulation skills: Experimental study

Flavia Aurelia Hidajat

Department of Mathematics Education, Universitas Negeri Jakarta, Indonesia

ARTICLE INFO

Keywords:
Creative
Self-regulation skills
Problem-based conventional learning
Creative problem-based learning

ABSTRACT

Currently, the problem-based learning (PBL) method is a research trend used to improve students' self-regulation skills. This study highlights two methods derived from the PBL method, which applies the PBCL method (problem-based conventional learning) and the CPBL method (creative problem-based learning). Previous research stated that applying the PBCL and CPBL methods is often used to increase students' self-regulation skills; however, no study has compared the two methods to identify a more effective method for maximizing students' self-regulation skills. This study aims to compare students' self-regulation skills between applying PBCL and CPBL. Quasi-experimental methods were used in this experimental research. The research design was a posttest-only control group design. The population was 79 secondary school students in Probolinggo, Indonesia. A mathematics post-test and self-regulation skills questionnaire were the techniques used during data collection. An independent T-test and determination test were used during the data analysis. The results showed a significant difference between students' self-regulation skills in applying the CPBL and PBCL methods (Sig. = 0.000 < 0.05). The CPBL method is more effective than the PBCL method in improving students' self-regulation skills. Educators can use the implications of the results of this study to apply the CPBL method in their lesson plans to maximize students' self-regulation skills.

1. Introduction

Self-regulation skills are essential for students to achieve their academic achievements. Self-regulation skills are active learning activities for students that lead to the development of creative thinking through independent learning [1–3]. Students with self-regulation skills can self-regulate their behavior creatively and shape their thinking patterns in order to discover new knowledge [4–6]. By producing new knowledge continuously, students can improve their self-regulation skills in computer-assisted online learning [7,8]. Students are challenged to apply their self-regulation skills to find new and original knowledge in their learning process [9]. Overall, self-regulation skills can lead to creative behavior [10], self-efficacy [11], increasing students' motivation and meta-cognitive [4], and finding new ideas for achieving students' academic achievement [3].

However, several studies have shown that self-regulation skills can prevent the acquisition of new knowledge and hinder student academic achievement. Research by Muwonge et al. [12] states that only 47.8% of 527 students can apply self-regulation skills well. The study by Wong et al. [9] also said that it is difficult for students to use their self-regulation skills to find new and original knowledge

E-mail address: Flaviaaureliahidajat@unj.ac.id.

https://doi.org/10.1016/j.heliyon.2023.e19512
Received 25 December 2022; Received in revised form 19 August 2023; Accepted 24 August 2023
Available online 26 August 2023

in their learning process. Most students' self-regulation skills cannot develop during the learning process due to the demands of the curriculum and the duration of time that does not allow the development of students' self-regulation skills and differences in student backgrounds. Students cannot control their self-regulation skills to produce new knowledge, hindering academic achievement [13,14].

The self-regulation skills of students who cannot produce new knowledge are shown in a preliminary study of 30 students. The test results from the preliminary research for 30 students were the same, and a representation of student test results is shown in Fig. 1.

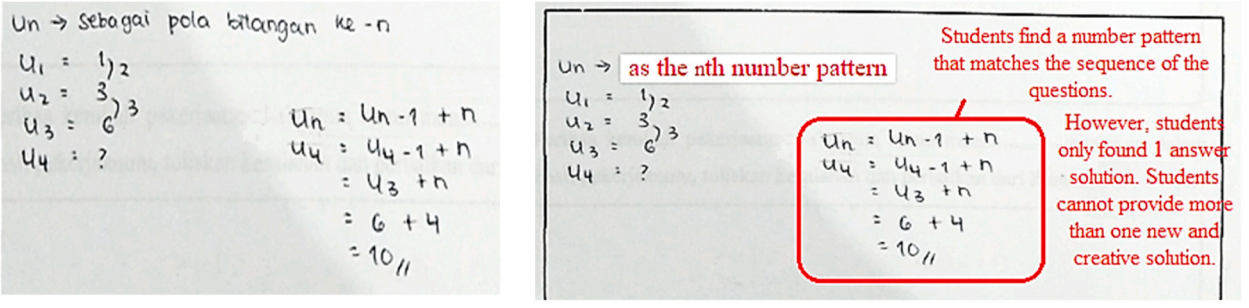
Fig. 1 shows an example representing a student's self-regulation skills that fail to develop a new solution. Students understand the context of the problem because students find a pattern of numbers " $U_n = U_{n-1} + n$" to determine the fourth term. This is correct. However, students only gave one single answer. Students can only provide alternative answers that are one new solution. Creative students can provide more than one new answer by forming the appropriate pattern. For example, $U_n = \begin{cases} U_{n-1} + n; & n \leq 4, n \in N \\ 10 & ; n > 4, n \in N \end{cases}$. Therefore, students' self-regulation skills to find new solutions are still low. On the other hand, the application of habits from self-regulation skills to students takes a long time [15]. However, using sustainable self-regulation skills with appropriate learning methods can improve student learning processes to produce new knowledge [16].

A suitable learning method for improving students' self-regulation skills is the problem-based learning method (PBL). PBL refers to independent learning in solving problems or questions that are non-routine or unstructured [14]. Non-routine problems can improve students' self-regulation skills to search for previous information and produce new knowledge independently [17]. The problem as the primary key in the PBL method is an essential mediation for the effectiveness of students' self-regulation skills in the learning process [3]. Thus, PBL effectively creates self-regulated learning to improve the quality of teaching and learning mathematics [18]. This is because PBL has a high level of orientation to improve self-regulation skills through creative learning and higher-order thinking [19]. This shows that there is a combination of problem-based learning (PBL) methods with creativity to improve self-regulation skills. The method in this study is called creative problem-based learning (CPBL).

Several studies implicitly study creative problem-based learning (CPBL). The study of Liu and Pásztor [20] applies the PBL method to higher-order thinking. Higher-order thinking refers to creative thinking to produce new knowledge [2,21,22]. Research Eladl & Polpol [23] and Qiu & Lee [24] state that creatively designed problem-based learning methods can develop self-regulation skills to find original and new ideas. Students can self-regulated to determine appropriate problem-solving strategies to find new solutions [25,26]. Previous studies have yet to explicitly explain the combination of the PBL method and elements of creativity. This study will design learning by combining elements of creativity with the PBL method (section 2.4) to implement the CPBL method. On the other hand, this study will also apply the PBL method without intervention from elements of creativity (section 2.4); this is called problem-based conventional learning (PBCL).

On the other hand, some literature studies problem-based conventional learning (PBCL), which positively improves students' self-regulation abilities. Problem-based conventional learning methods with assignments increase students' self-regulation skills in producing new solutions [27]. Conventional learning can improve learning outcomes, self-efficacy, self-regulation skills, and student achievement in discovering new knowledge [28]. Through scaffolding or direct guidance from teachers to students, conventional learning can support students' self-regulation abilities and improve their academic achievement in computer-based online learning [29]. On the other hand, Vebrianto and Osman's research [30] shows that conventional learning causes students to self-regulate in every activity, process, behavior, and problem-solving strategy to discover new knowledge.

Based on the explanation above, two PBL method derivatives influence the development of students' self-regulation skills, which are the CPBL and PBCL methods. Several studies [31–33] demonstrated a positive role of CPBL in improving students' self-regulation skills, while other studies [28,34] demonstrated a role of PBCL in the development of self-regulation skills and found new knowledge. However, no research compares the best problem-based learning methods between CPBL and PBCL to maximize students' self-regulation abilities. This shows a gap in the study regarding applying the two methods derived from the PBL method. Therefore, this study aims to compare students' self-regulation skills when using PBCL and CPBL methods, where the results of this study are expected to identify more effective methods for maximizing students' self-regulation skills. Therefore, this research is original and



a. Preliminary Study **b. Translated from a.**

Fig. 1. a. Preliminary study
Fig. 1bTranslated from Fig. 1a.

crucial for maximizing students' self-regulation skills through the PBL method.

The author's attempt to achieve the previously mentioned study objectives was to form an experimental group of students who received the CPBL method and a control group of students who received the PBCL method. The CPBL and PBCL groups received identical post-test and self-regulation skill questionnaires. The results of the post-test and student self-regulation questionnaire were compared with the statistical mean and independent *t*-test. In addition, determination tests were analyzed to test the correlation between CPBL and self-regulation skills. The results of this study will show the best problem-based learning method between CPBL and PBCL to maximize students' self-regulation skills. The contribution of this research is aimed at teachers, students, and researchers in the field of the PBL method. The contribution to teachers worldwide is that study results serve as a reference for teachers in designing the best problem-based learning methods to maximize students' self-regulation skills. Regarding contribution to students, the PBL method supports their self-regulation skills in creatively finding ideas, solutions, and new knowledge. In addition, the contribution to researchers is knowledge about the development of the PBL method between CPBL and PBCL methods, which is best for maximizing students' self-regulation skills. Therefore, this research question is as follows.

1. Based on the mean of the post-test, what are the differences between students' self-regulation skills in applying creative problem-based learning (CPBL) and problem-based conventional learning (PBCL)?
2. Based on the self-regulation skills questionnaire data, what are the differences between students' self-regulation skills in applying creative problem-based learning (CPBL) and problem-based conventional learning (PBCL)?
3. What is the correlation between creative problem-based learning (CPBL) and self-regulation skills?

2. Material and methods

2.1. Research participants

The population in this research were students in a state secondary school in Probolinggo, Indonesia. The ethical approval of this research is the approval from the Ministry of Education and Culture of the state secondary school, Probolinggo, Indonesia. The ethics committee that approved this research gave permission from the head of public secondary schools in Probolinggo, Indonesia. The approval of all participants in this study was obtained with a letter of permission from the Department of Education and Culture of the public secondary schools in Probolinggo. A cluster sampling technique was used in this research because this sampling technique provides an easy way to divide the population and form research groups separately and randomly [35]. The research sample was 79 students. This type of research is quasi-experimental with two groups: the experimental and the control groups. Class A as the experimental group amounted to 41 students, and class B as the control group amounted to 38 students. The design of this study used a post-test-Only Control-Group design, where this study did not use a pre-test, the experimental group was carried out in the CPBL, and the control group was carried out in the PBCL; the two learnings were compared on the post-test mean and self-regulation skills questionnaire data. The post-test-Only Control-Group design for this research is shown in Table 1.

2.2. Research design

The design of this study consisted of a post-test-Only Control-Group design, where this study did not use a pre-test, the experimental group was carried out in the CPBL, and the control group was carried out in the PBCL; the two learnings were compared on the post-test mean and self-regulation skills questionnaire data. The post-test-Only Control-Group design for this research is shown in Table 1.

2.3. Research instrument

2.3.1. The students' self-regulation skills questionnaire

Self-regulation skills questionnaire adapted from Barnard et al. [36]. The self-regulation skills questionnaire in this study consisted of 24 items with six indicators: environment structuring, goal setting, time management, help-seeking, task methods, and self-evaluation. This questionnaire adds an aspect of creativity to each item. In addition, the questionnaire is based on the Indonesian context. For example, the item of "help-seeking" is "I share a problem with my group in online learning, so we try to find original and creative ideas to solve our problem." This self-regulation skills questionnaire uses a 5-point Likert scale, namely strongly disagree (1), disagree (2), neutral (3), agree (4), and strongly agree (5). This questionnaire aims to identify students' self-regulation skills in applying the CPBL and PBCL methods.

Table 1
Post-test-only control-group design.

Groups	Intervention	Post-test/Questionnaire
Experiment Group (in CPBL)	**X**	O_1
Control Group (in PBCL)		O_2

*Note: X : Problem-based learning.
O_1, O_2: Post-test and data questionnaire of creative self-regulation Skill.

A self-regulation skills questionnaire was given to all research participants at the end of learning at the last meeting. Before the questionnaire was given to the participants, the self-regulation questionnaire went through validity and reliability tests. The validity of this questionnaire is content validity and construct validity. Content validity through expert judgment. Content validation was carried out by two practicing validators (teachers and principals) and two expert validators (mathematics education lecturers at private universities in Kalimantan, Indonesia, and Ponorogo, Indonesia). The validator filled in the assessment items on the validation sheet. The Aiken index calculation from expert judgment results is 0.88 (high category). In construct validation, a questionnaire of self-regulation skills was tested on 30 secondary school students who were different from the research participants. Pearson's test analyzed the results of a self-regulation skills questionnaire by 30 students. Pearson test results are shown in Table 2.

Table 2 shows the Pearson correlation coefficients in probabilities for each indicator of self-regulation skills. Probability foral management indicators = 0.834 (Sig. = 0.000 < 0.05); goal setting indicator = 0.571 (Sig. = 0.001 < 0.05); time management indicator = 0.792 (Sig. = 0.000 < 0.05); help-seeking indicator = 0.776 (Sig. = 0.000 < 0.05); task method indicator = 0.720 (Sig. = 0.000 < 0.05); self-evaluation indicator = 0.698 (Sig. = 0.000 < 0.05). This shows that the six indicators of self-regulation skills in the questionnaire are valid. Furthermore, the reliability test of the self-regulation skills questionnaire is shown in Table 3.

In Table 4, the items represented by the six self-regulation skills indicators show Cronbach's Alpha value = 0.821 > 0.60. This indicates that each item represented by six (6) indicators on the self-regulation skills questionnaire is reliable. The Cronbach's Alpha value representing the reliability of the six self-regulation skills indicators is shown in Table 4.

In Table 4, the Cronbach's Alpha value of each indicator shows the reliability of 6 indicators, namely structuring indicator = 0.759 > 0.60; goal setting indicator = 0.836 > 0.60; time management indicator = 0.773 > 0.60; help-seeking indicator = 0.777 > 0.60; task methods indicator = 0.806 > 0.60; self-evaluation indicator = 0.799 > 0.60. Cronbach's alpha value of the six self-regulation skills questionnaire indicators is more than 0.60. This shows that self-regulation skill indicators are reliable.

2.3.2. The mathematics post-test

The mathematics post-test in this research related to the topic of number patterns. The students took the mathematics post-test at the third meeting. This mathematical post-test was done through content validation by calculating the Aiken index [37]. This validation involved four expert validators, namely two practitioner validators (teachers and school principals) and two mathematical education expert validators (mathematic education lecturers with master's qualifications in Mathematics Education). The expert judgment index shows 0.88 with high criteria. The post-test compares students' self-regulation skills in the CPBL and PBCL in online learning. The post-test was a case of the number pattern problem.

2.4. Data collection process

Furthermore, teachers gave the CPBL to class A as the experimental group and the PBCL to class B as the control group. The learnings for the control and experimental groups were conducted online through the MS Teams application. The subject matter for both groups was the same: the number pattern. The researchers implemented learning in the CPBL and the PBCL with written and verbal approval from the teachers and school principals. Researchers gave class teachers information about the CPBL and PBCL methods. Teachers were given 14 days to fill in the assessment scale for learning instruments. Implementation of the CPBL method and PBCL method followed Indonesia's 2013 curriculum learning regulations.

2.4.1. Practice in the PBCL

Practice in the CPBL was carried out in the control group. In the PBCL, the control group received number pattern material from the teacher through Powerpoint. Students only listened to the part of the PowerPoint that the teacher read. Thus, students got assignments in the form of questions. This problems were routine, applying formulas, and not complex in nature. Learning was carried out for three weeks with four meetings. At the end of the lessons students completed a post-test that measured their creative self-regulation skills, and then students filled out a self-regulation skills questionnaire.

2.4.2. Practice in the creative problem based learning (CPBL)

The experimental group was involved in three stages of implementing the CPBL method of adaptation [38], namely providing realistic cases of a problem, solving these cases in small groups critically, and providing facilitator encouragement that fostered students' productivity. This stage was carried out in 4 online meetings with the MS Teams application for four weeks. Students got a

Table 2
Pearson Correlation Coefficients for self-regulation skills indicators.

Indicators	Sig. (2-tailed)
Environment Structuring	0.000
Goal Setting	0.001
Time Management	0.000
Help-Seeking	0.000
Task Methods	0.000
Self-Evaluation	0.000

Table 3
Reliability Test Results from the self-regulation skills Questionnaire.

Cronbach's Alpha	N of Indicators
0.821	6

Table 4
Reliability results of self-regulation skills Indicators.

Indicators	Cronbach's Alpha
Environment Structuring (ES)	0.759
Goal Setting (GS)	0.836
Time Management (TMg)	0.773
Help-Seeking (HS)	0.777
Task Methods (TM)	0.806
Self-Evaluation (SE)	0.799

realistic contextual case of a problem at the first meeting. The case was discussed and solved by six groups (each group consisted of 6–7 students). Students solved cases independently in groups, so the CPBL method emphasized students' self-regulation skills in groups. Sanaie et al. [39] state that learning that uses a cooperative approach in groups develops self-regulation skills in students' teaching and learning processes individually and independently. Qiu & Lee [24] also mentioned that learning with a group collaboration approach can develop self-regulation skills related to creative aspects.

In the CPBL, groups 3 and 5 received a support facility from the teacher because the discussions in groups three and five suddenly stopped. The observations showed that students had difficulty identifying the intent of the case (problems), and students' self-regulation skills had not been trained enough to find concepts independently. Van Alten et al. [13] mention that not all students can apply self-regulation skills directly. Students need more time to independently practice self-regulation skills to form new knowledge or concepts [40]. Students' self-regulation skills in groups can change over time with intervention from teacher support [41]. Support from the teacher for groups 3 and 5 provided open questions that directed the completion of cases. After the teacher gave open questions, students began to dare to express ideas so that discussions of the case problems became lively or productive to produce new ideas.

At the end of the lesson, students presented the discussion results and provided conclusions together. Students' self-regulation skills to find new concepts independently could be better trained in this condition. Thus, the teacher was only a facilitator, and the students were the learning center. This follows the opinion of Mulyadi et al. [42] that improving self-regulation skills directly affects increasing students' creativity in finding new concepts. After implementing the CPBL method, the experimental group took a post-test. The post-test results of the students are shown in Fig. 3.

Fig. 3a and b show the results of the post-test of students in the experimental group using two problem-solving techniques. For the first alternative solution, students used the arithmetic sequence formula, and for the second solution, students looked for a number pattern that matches the sequence. In Fig. 3a and b, students provided two solutions, but students needed to calculate the entire rectangle. Thus, the student's answer was not appropriate. Fig. 3c and d show that students only provided one solution using the "add 4 to each previous term" technique.

2.5. Data analysis

Data analysis went through several stages. The first stage was data analysis using an independent T-Test on two groups of independent samples. The homogeneity test had to be done before the independent T-Test (>Sig. 0.05). The research group was based on the post-test mean and the mean of self-regulation skills questionnaire data. Data analysis was carried out in the second stage using a determination test or goodness of fit (R^2). The determination test (R^2) aimed to determine the CPBL's contribution to students' self-regulation skills. If the analysis from the second stage showed a large enough contribution ($R^2 > 0.6$), then the data analysis was continued to the third stage. In the third stage, the identification of multiple correlations from a simple Linear Regression Test was carried out in the lesson. Multiple correlations (R) aimed to answer the third question in this research, identifying the correlation between CPBL and self-regulation skills. SPSS 22 software was used in data analysis in this research used.

3. Results

Based on the first question, the post-test mean of students' self-regulation skills between the experimental and control groups was compared with the independent T-Test analysis. It aimed to determine whether there is a significant difference in students' self-regulation skills between the experimental and control groups. The first time, Levene's test shows the statistical value of the F test $= 0.004$ and Sig. $= 0.951 > 0.05$. Thus, the diversity of students' self-regulation skills between the experimental and control groups based on the post-test mean was homogeneous. In the next analysis, the value of the independent T-test $= 64.773$ and Sig. $= 0.000 <$ 0.05 (α). Based on the post-test mean, this significantly differentiates students' self-regulation skills between the experimental and

control groups. The source of differences in students' self-regulation skills between the experimental and control group is shown in the post-test mean in Table 5.

In Table 5, the mean of post-test of the experimental group > the mean of post-test of the control group (87.4634 > 61.9737). This means that the students' self-regulation skills of the experimental group are higher than the control group.

Based on the second question, The mean of students' self-regulation skills between the experimental and control groups were compared with an independent T-Test analysis based on the self-regulation skills questionnaire data. This aims to reconfirm the analysis results of the first question, namely that there is a significant difference in students' self-regulation skills between the experimental and control groups.

Levene's test shows the test value of F-statistics = 0.835 and Sig. = 0.364 > 0.05 (α). Thus, the diversity of students' self-regulation skills between the experimental and control groups was homogeneous based on the questionnaire data. The subsequent analysis showed that the value of the independent T-Test = 27.513 and Sig. = 0.000 < 0.05 (α). This shows that the difference in students' self-regulation skills between the experimental and control groups was significant. Comparison students' self-regulation skills based on the questionnaire are shown in Table 6.

In Table 6, the mean of students' self-regulation skills of the experimental group > the control group (4.5854 > 1.4737). This means that the students' self-regulation skills of the experimental group are higher than the control group.

In Table 7, R = 0.956 in the interval 0.90–1.00 from Schober et al.'s [43] coefficient correlation criteria. This shows that creative problem-based Learning (CPBL) methods strongly correlate with improving students' self-regulation skills. Based on Table 7, R Square = 0.915 or 91.5%. This shows that the contribution of the CPBL to students' self-regulation skills is 94.9%. While the rest = 100%–94.9% = 5.1% is a contribution from other factors not examined in this research.

4. Discussion and implications

This section will discuss the results of each research question. Based on the first question, the first result of this study is a comparison of the post-test mean, which shows that students' self-regulation skills in applying the CPBL method are higher than the PBCL method (87.4634 > 61.9737), with a significant difference. The mean difference is 87.4634–61.9737 = 25.4897. This shows that applying the CPBL method is more effective than the PBCL method in maximizing students' self-regulation skills. This is because the PBCL method uses open questions that encourage students' self-regulation skills to be creative in divergent solutions. This follows the opinion of Behnamnia et al. [44] that the use of open problems (cases) in online learning motivates students' self-regulation skills to develop their creativity. Meanwhile, the observation results show that students applying the PBCL method tend to be passive as the solved questions are routine and convergent, and the questions do not support student creation. Mulyadi et al. [42] state that problem-based conventional learning does not support student behavior to develop self-regulation skills and creativity. Problem-based conventional learning methods are unsuitable for online learning and result in low self-regulation skills in students [21].

Based on the results of the second question, the analysis of the questionnaire data through the independent *t*-test showed significant differences between students' self-regulation abilities in applying the CPBL and PBCL methods, which still supported the CPBL method as the best method for maximizing students' self-regulation skills. The difference is 4.5854–1.4737 = 3.1117. The CPBL method in this study uses complex problems as realistic cases to encourage students to apply self-regulation skills using various problem-solving strategies (Figs. 2 and 3). This follows the opinion of Singh [45] that learning strategies using realistic problems encourage students to use self-regulation skills and create new insights creatively. In the CPBL method, students actively apply self-regulation skills by mapping concepts, analyzing, determining creative strategies, and reflecting on their solutions. The CPBL method improves students' self-regulation through active and creative collaborative activities [14]. Group collaboration activities for concept mapping and goal setting through an iterative process of planning, creating, monitoring, and reflecting on learning can develop students' self-regulation skills in the CPBL method [46]. This is also reinforced by the opinion of Bishara [47], namely, learning that involves complex mathematics problems emphasizes the behavior of self-regulation, which is active in producing new ideas creatively compared to conventional problem-based learning methods, where learning appears to be more passive. The position of the CPBL and PBCL methods in improving students' self-regulation skills is shown in Fig. 4.

The results of the second study supporting the results of the first study; the creative problem-based learning (CPBL) method is more effective in maximizing students' self-regulation skills so that students are more flexible in finding alternatives to original and new solutions.

The impact of this study's first and second significant contributes to teachers, students, and research development about applying problem-based learning methods. The contribution to teachers worldwide is that teachers can create learning designs by using the CPBL method to maximize students' self-regulation abilities. It also contributes to developing students' self-regulation skills to produce new ideas, solutions and knowledge. In addition, students are used to working on questions that are non-routine, complex, open, creative, and innovative. The contribution of the results of this study to researchers is new information about the development of the PBL method, where the combination of the PBL method and an element of creativity, called CPBL, is one of the best methods for

Table 5
Comparison of students' post-test means.

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Students' self-regulation skills	Experimental groups	41	87.4634	1.79022	0.27958
	Control groups	38	61.9737	1.70035	0.27583

Table 6
Comparison of self-regulation skills based on questionnaire data.

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Students' self-regulation skills	Experimental groups	41	4.5854	0.49878	0.07790
	Control groups	38	1.4737	0.50601	0.08209

Table 7
Contribution and correlation of CPBL with creative self-regulation skills.

Model	R	R Square
1	0.956[a]	0.915

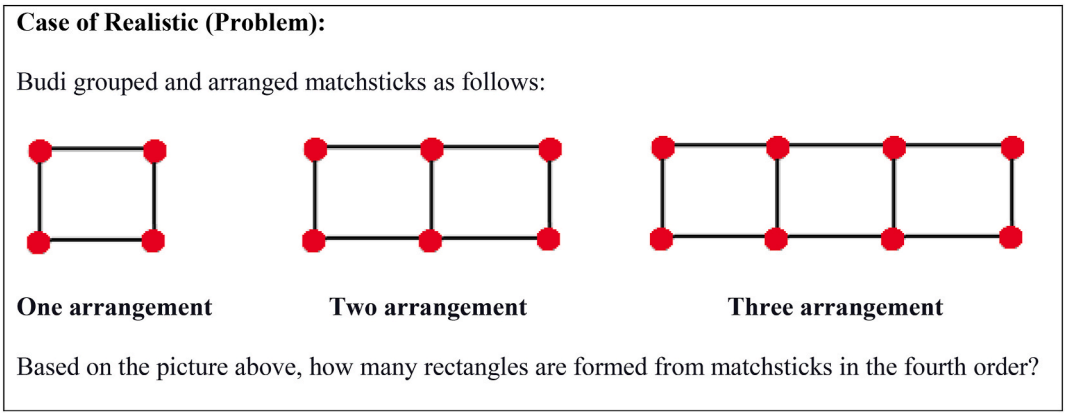


Fig. 2. The realistic case in the implementation of the CPBL.

maximizing students' self-regulation skills. However, the research subjects were still limited to secondary school students, and the issues did not represent students from different cultures in Indonesia. It is hoped that future research subjects will be more diverse and broad, representing students in Indonesia.

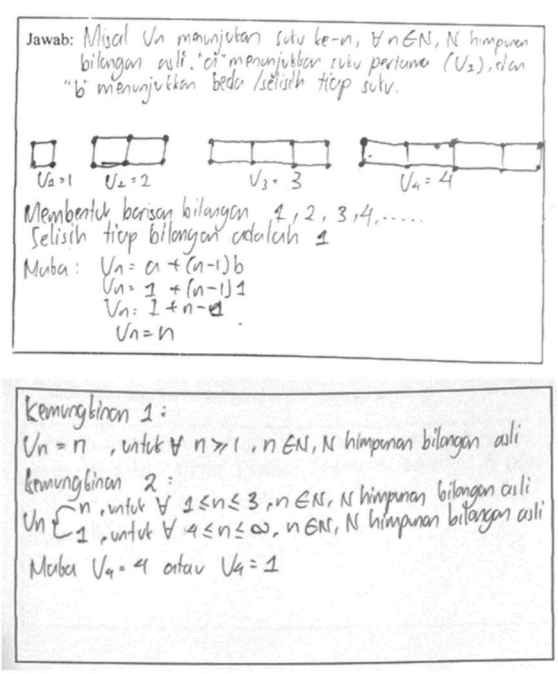
Based on the third question, the correlation coefficient test (R) results through linear regression analysis showed $0.956 > 0.8$. This indicates that the practical application of the CPBL method correlates strongly with students' self-regulation skills in online learning. This allows the opinion of Callan et al. [48] that there is a correlation between learning that involves creative problem-solving and students' self-regulation skills. Self-regulation skills motivate creative problem-solving in pedagogical learning practices [49]. Thus, the CPBL method is effective pedagogic learning in improving students' thinking skills, self-regulation skills, and self-evaluation. Yoon et al. [50] stated that self-regulation skills are students' dispositions to regulate or control themselves in their creative learning process to acquire new knowledge. In addition, previous studies have not examined the correlation between the CPBL method and creative self-regulation skills. Therefore, the correlation between the CPBL method and students' self-regulation skills is one of the new and essential study results to improve school learning practices.

However, the results of this third study have limitations. The limitation of this study is that this research only measures the correlation between creative problem-based learning (CPBL) and self-regulation skills, but this study has not tested the effect of CPBL on self-regulation skills. How does the CPBL method influence students' self-regulation skills to acquire new knowledge? Is the influence positive or negative? Therefore, this limitation can be a question for further research.

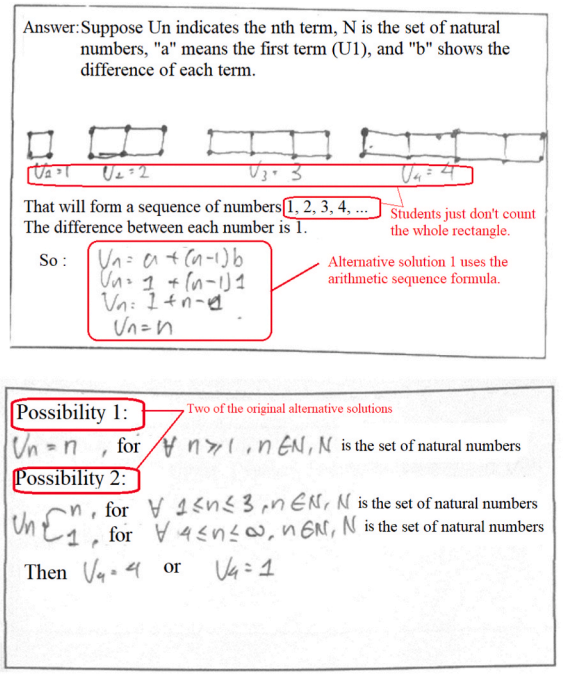
The results of the study as a whole concluded that CPBL is the best problem-based learning method for maximizing students' self-regulation skills. Applying the CPBL method in online learning can improve students' self-regulation skills in higher-order thinking and produce creative ideas [31,51]. The creative concept of self-regulation skills focuses on creating new strategies or solutions for creative problem-solving [52]. However, the R-square value from the linear regression analysis shows that 8.5% of other factors (besides the CPBL method) influence the improvement of students' self-regulation skills. This relatively small percentage refutes the author's indication that CPBL is the only one that can affect students' self-regulation skills. However, this small percentage can be the beginning of further research regarding other supporting factors that can help maximize students' self-regulation skills. In addition, different conditions, cultures, levels of education, etc., need to be considered for research on applying problem-based learning methods.

5. Conclusion

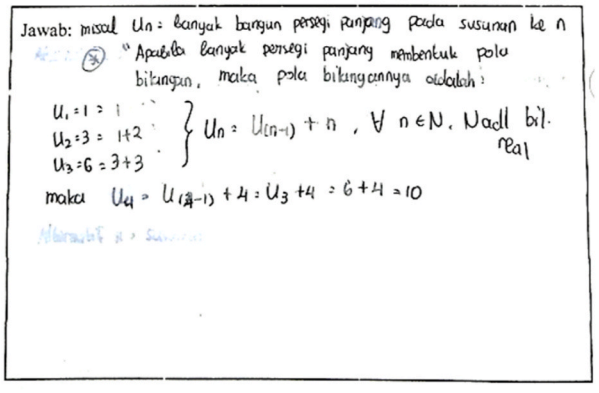
Based on the research objectives and questions, this study concluded that based on the post-test mean and the self-regulation skills questionnaire data, the difference in students' self-regulation skills between applying the CPBL and PBCL methods was significant. The



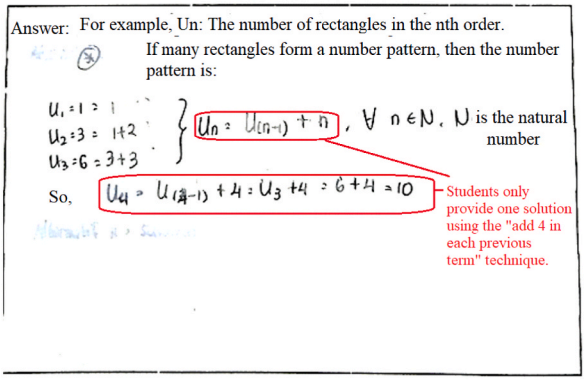
a. Student's results with two of the original solutions



b. Translated **a**



c. Students' results just for one solution using the "add 4 in each previous term" technique



d. Translated **c.**

Fig. 3. a. Student's results with two of the original solutions
Fig. 3b. Translated Fig. 3a
Fig. 3c. Students' results just for one solution using the "add 4 in each previous term" technique
Fig. 3d. Translated Fig. 3c.

CPBL method is more effective than the CPBL method for maximizing students' self-regulation skills. There is a strong correlation between CPBL and students' self-regulation skills, namely the value of $R = 0.956 > 0.8$. The CPBL method significantly improved students' self-regulation skills by 91.5%. However, this study only involved secondary school students in Probolinggo, Indonesia. Further research on applying CPBL and PBCL to measure students' self-regulation skills can be conducted in groups representing educational levels ranging from elementary to college students. In addition, the participant criteria can be extended to provinces or countries with different cultures.

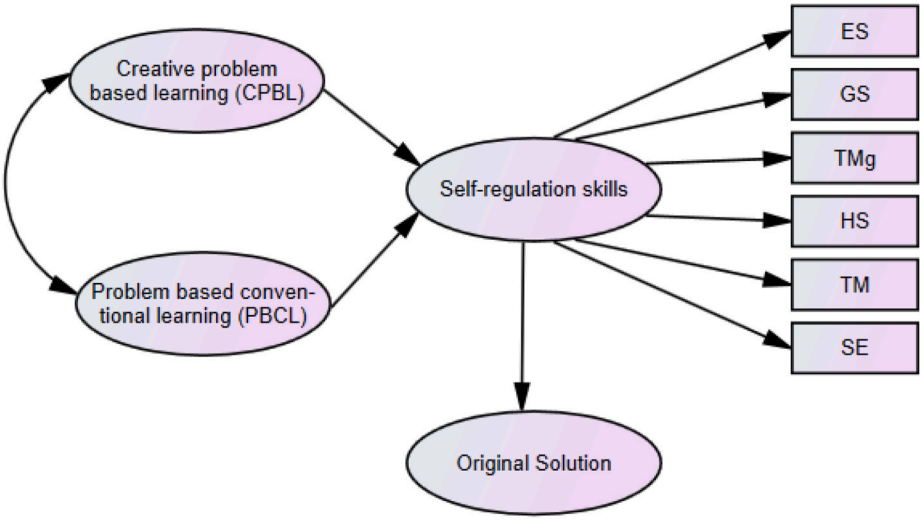


Fig. 4. The model of the CPBL and PBCL.

Funding statement

This research received funding from Drtpm Kemdikbud-Ristek (43/UN39.14/PG.02.00. PL/VI/2023).

Ethical approval

This research was approved by the Ethics Committee of the Ministry of Education and Culture of the state secondary school, Probolinggo, Indonesia (The ethical approval number: 420/125/425.103.81/2020).

Data availability statement

Data associated with this study has been deposited at https://bit.ly/DataAvailabilityOk.

Additional information

No additional information is available for this paper.

Author contribution statement

Flavia Aurelia Hidajat: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.Flavia Aurelia Hidajat reports financial support was provided by DRTPM KEMDIKBUD-RISTEK (43/UN39.14/PG.02.00.PL/VI/2023). The author does not have any conflict of interest regarding this manuscript.

Acknowledgments

The author would like to thank the State University of Jakarta with the scheme of the “International Collaboration of the State University of Jakarta, Ministry of Education, Culture, Research, and Technology (KEMDIKBUD-RISTEK)" for supporting this research.

Appendix A. Self-regulation Skills Scale

Indicators	Items	Nomor

(*continued on next page*)

(*continued*)

Indicators	Items	Nomor
Environment Structuring	I try to discover the cause of my failure during the learning process because I can improve my bad grades for a particular lesson and increase my mathematical creativity.	6
	A good learning environment supports my learning process towards increasing creativity.	12
	I always focus on learning during the learning process.	18
	I always design a creative and exciting learning environment according to my version to support my learning process.	24
Goal Setting	I am sure of how to achieve my study goals well and creatively.	5
	I always set my learning goals before learning to increase my mathematical creativity.	11
	I always make study goals in small notes for my study direction.	17
	I adapt my learning goals to the goals of the lesson at school.	23
Time Management	I make a schedule independently and creatively for the plan to achieve my study goals.	4
	I creatively seek information on the following material to prepare for the next lesson.	10
	I am good at managing my study time well and creatively.	16
	The time management that I have planned is almost in accordance with my learning targets to increase my mathematical creativity.	22
Help-Seeking	I share a problem with my group in online learning, so we try to find original and creative ideas to solve our problem	3
	I immediately ask my friends if there is material that I don't understand.	9
	I am looking for study reference sources to enhance my higher understanding and mathematical creativity.	1
	I have independent study groups to discuss non-routine questions creatively.	21
Task Methods	If the learning strategy that I apply fails, I will modify the learning strategy to achieve the next creative learning goal.	2
	I consistently devise appropriate and creative completion strategies for completing my learning assignments.	8
	If the learning strategy that I apply is successful, I will reapply the learning strategy for plans to achieve higher learning goals and achieve mathematical creativity.	14
	I always complete tasks with different and creative methods of completion.	20
Self-Evaluation	After the final exam results, I always did a creative self-evaluation by comparing the process, the things that have been done, and the previously planned study objectives with the final results.	7
	I always take the initiative creatively in making a resume from each material after learning ends.	13
	When my study results in this semester are not good, I ask myself about failure and the causes of failure and determine creative ways to overcome these failures so that they do not happen again in the following semester.	15
	I always do a creative self-evaluation for each of my final exam results that experience a decrease in grades.	19

Appendix B. Self-regulation Skills Questionnaires

Self-regulation skills questionnaires

Instructions

This questionnaire consists of statements that you experience. Give your answer by ticking (✓) in one of the columns. Alternative answers are as follows.

5: Strongly agree
4: Agree
3: Neutral
2: Disgree
1: Strongly disagree

*Note that there are no wrong answers, and the answers you provide will be kept confidential.

Identity:

Name: ……..
Age: ……..
Class: ……..
Gender: ……..

No	Items	5	4	3	2	1
1	I am looking for study reference sources to enhance my higher understanding and mathematical creativity					
2	If the learning strategy that I apply fails, I will modify the learning strategy to achieve the next creative learning goal					
3	I share a problem with my group in online learning, so we try to find original and creative ideas to solve our problem					
4	I make a schedule independently and creatively for the plan to achieve my study goals					
5	I am sure of how to achieve my study goals well and creatively					
6	I try to discover the cause of my failure during the learning process because I can improve my bad grades for a particular lesson and increase my mathematical creativity					
7	After the final exam results, I always did a creative self-evaluation by comparing the process, the things that have been done, and the previously planned study objectives with the final results					

(*continued on next page*)

(*continued*)

No	Items	5	4	3	2	1
8	I consistently devise appropriate and creative completion strategies for completing my learning assignments					
9	I immediately ask my friends if there is material that I don't understand					
10	I creatively seek information on the following material to prepare for the next lesson					
11	I always set my learning goals before learning to increase my mathematical creativity					
12	A good learning environment supports my learning process towards increasing creativity					
13	I always take the initiative creatively in making a resume from each material after learning ends					
14	If the learning strategy that I apply is successful, I will reapply the learning strategy for plans to achieve higher learning goals and achieve mathematical creativity					
15	When my study results in this semester are not good, I ask myself about failure and the causes of failure and determine creative ways to overcome these failures so that they do not happen again in the following semester					
16	I am good at managing my study time well and creatively					
17	I always make study goals in small notes for my study direction					
18	I always focus on learning during the learning process					
19	I always do a creative self-evaluation for each of my final exam results that experience a decrease in grades					
20	I always complete tasks with different and creative methods of completion					
21	I have independent study groups to discuss non-routine questions creatively					
22	The time management that I have planned is almost in accordance with my learning targets to increase my mathematical creativity					
23	I adapt my learning goals to the goals of the lesson at school					
24	I always design a creative and exciting learning environment according to my version to support my learning process					

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