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The Effect of Case-Based Learning on Students' Problem-Solving Ability

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Abstract

This investigation stems from the observed low problem-solving skills among students as indicated in prior research. The primary objective is to evaluate the impact of employing case-based learning on students' problem-solving aptitude concerning buffer solutions. Carried out during April-May 2023, the study involved 11th-grade students at a public high school in Jakarta, Indonesia. Employing a quasi-experimental design, two classes were chosen as samples and randomly assigned roles via the flipping coin method: one as the experimental group (11 MIPA-1) and the other as the control group (11 MIPA-4), each comprising 36 students. A problem-solving assessment using an essay test featuring nine questions was administered, with the data analyzed through t-tests. The findings revealed a positive correlation between case-based learning and enhanced problem-solving skills among students in the realm of buffer solutions. In essence, the implementation of case-based learning proved effective in bolstering students' problem-solving capabilities. Consequently, educators are encouraged to integrate the case-based learning approach to elevate students' problem-solving proficiency across various subjects.

Keywords: *Case-Based Learning, Chemistry, Problem Solving, Buffer Solutions*

INTRODUCTION

The 21st century has witnessed rapid advancements in science and technology, leading to a transformation in the educational landscape. Modern education, often termed as twenty-first-century learning, emphasizes the importance of equipping students with the skills to identify problems, gather information from various sources, engage in analytical thinking, and collaborate to foster critical thinking and problem-solving abilities (Trilling & Fadel, 2009). According to Cho et al. (2015), problem-solving is recognized as a foundational skill closely interconnected with other essential competencies of the twenty-first century, including critical thinking and creativity, as highlighted in scholarly literature.

Students' problem-solving ability refers to their capacity to employ cognitive processes to address challenges by collecting data, scrutinizing information, considering multiple potential solutions, and selecting the most optimal course of action. This ability is closely intertwined with students' competence levels and critical thinking abilities. Chuang (2011) states that students who have high problem-solving abilities will have higher competence and better critical thinking skills as well.

Previous studies reported that students' problem-solving skills needed to be improved (Valdez & Bungihan, 2019). Likewise, findings from a study by Ijirana et al. (2020) conducted in Indonesian high schools revealed students' deficiencies in various stages of problem-solving. They were found to only address problems without comprehending, planning, or reflecting on their solutions. To enhance students' problem-solving abilities, transitioning from teacher-centered approaches like lectures to student-centered learning is suggested. One effective instructional model for enhancing students' chemical literacy is case-based learning.

According to research by Williams (2005), case-based learning (CBL) proves effective in fostering critical reflection and nurturing students' learning capabilities. Furthermore, it was found to enhance self-motivation, promote group collaboration, and stimulate independent learning (Mesthrige et al., 2021). Additionally, findings from a study by Li et al. (2019) indicate significantly improved exam results among students engaged in CBL.

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Chemistry is one of the natural sciences that has its own characteristics and requires skills in solving chemistry problems in the form of concepts, principles, laws, theories, and facts (BSNP, 2006). Buffer solution material is material that requires students to have good mastery of concepts and mathematical abilities. Therefore, good student problem-solving skills are needed so that students are able to support these competencies.

LITERATURE REVIEW

Problem-Solving Ability

Problem-solving ability, as outlined by Van Merriënboer (2013), pertains to comprehending problems and executing associated procedures adeptly. The conceptualization of problem-solving ability often revolves around the phase model, which links problem-solving ability to specific phases of problem-solving. According to Shute et al. (2016), problem-solving skills entail mastering rules and applying them in alignment with problem-solving phases. Mastery of rules is associated with the phase of analyzing given elements and constraints within the problem. On the other hand, implementing rules relates to stages such as planning the solution path, utilizing tools and resources effectively and efficiently, and evaluating outcomes.

According to Polya (1945), to solve a problem one needs to understand the problem, plan a solution, apply it, and evaluate the results. Understanding the problem includes the ability to identify known elements, relationships-related values, and elements to be searched for. Planning for completion, namely, the ability to choose the appropriate problem-solving approaches and methods to solve a given problem (Jam et al., 2010). Implement problem-solving strategies and check back by interpreting the results by writing conclusions from the results of the settlement.

Case-Based Learning (CBL)

CBL operates within a constructivist-oriented learning framework. In CBL, students engage in selecting and modifying information, constructing ideas, and making decisions based on their existing knowledge, facilitating the formation of personalized understanding (Brandon & All, 2010). Positioned as a learner-centered educational approach, CBL endeavors to foster active learning and involve students in higher-order cognitive processes, such as problem-solving and critical thinking (Mesthrige et al., 2021). By encouraging active participation throughout all stages of learning, from conception to dissemination, CBL facilitates the acquisition of problem-solving and critical thinking skills (Reilly, 2010). In the CBL paradigm, students take center stage, with the teacher assuming a facilitative role, guiding collaborative problem-solving endeavors from diverse perspectives (Queen's University, 2011).

CBL requires students to have prior understanding (Williams, 2005). In the CBL model, students are given introductory material or initial knowledge that is used to solve cases. Cases are presented after students get a little knowledge as material for discussion. The stages of learning in CBL consist of seven stages, namely establishing cases, analyzing cases by groups, gathering information, determining steps for completion, making conclusions, presenting, and improving (Williams, 2004).

Research Question

This study investigates the effect of CBL on the problem-solving abilities of grade 11 students on the topic of buffer solutions. With regard to the study's objective, the research question is formulated as follows: "Does the implementation of case-based learning have an effect on students' problem-solving abilities concerning buffer solutions?"

METHOD

Study Design

In this study, a quantitative approach was adopted, employing a quasi-experimental nonequivalent control group design. The utilization of this design allowed for the assessment of the effectiveness of the case-based learning (CBL) on students' problem-solving abilities. Quasi-experimental research design involves the inclusion of two or more sample groups that are not randomly selected. One group receives a specific treatment, while the other serves as the comparison group (Cresswell, 2012). In this particular study, the experimental group underwent CBL implementation, while the control group received instruction through a scientific approach. A nonequivalent control group design is listed in Table 1.

Table 1. Nonequivalent control group design

Group	Pretest	Intervention	Posttest
Experimental	Problem-solving test	CBL	Problem-solving test
Control	Problem-solving test	Scientific approach	Problem-solving test

Participants

The study involved 72 11th-grade students from two entire classes in a public high school located in Jakarta, Indonesia. The classes selected were 11 MIPA-1 and 11 MIPA-4, chosen randomly through the flipping of coins. Class 11 MIPA-1 served as the experimental group, comprising 36 students (22 females and 14 males), while class 11 MIPA-4 acted as the control group, also consisting of 36 students (22 females and 14 males). The age range of the participants was between 16 and 17 years old.

Instrument

The research employed a problem-solving ability test consisting of nine essay items. Each item was graded on a scale ranging from 0 to 4, with a total test duration of 90 minutes. To aid assessment, each question was accompanied by an answer sheet structured according to problem-solving ability indicators. These questions were designed to evaluate students' proficiency in problem-solving within the context of buffer solutions. The research instrument was developed based on competency achievement indicators related to buffer solution content and aligned with problem-solving ability indicators. Following compilation, the instrument underwent validation and empirical testing, and its reliability was subsequently assessed. The Cronbach's α coefficient of the instrument was found to be 0.73, exceeding the threshold of acceptability (0.70) as outlined by Cohen et al. (2018). Thus, the instrument was deemed reliable for use in the study.

Procedure

The research was conducted in 3 meetings, each meeting lasting 180 minutes. The research was started by giving a pretest to the EG and CG. The CBL was then implemented to the experimental class and learning with a scientific approach to the comparison class. After learning, a posttest was carried out in the experimental class and control class to assess the effectiveness of the treatment in the experimental group and to assess the gaps between the experimental group (EG) and the control group (CG).

The CBL learning process in the EG consisted of seven stages. At the case determination stage, students form groups of 6 people and get CBL worksheets containing cases regarding buffer solutions. In the problem analysis stage, students read in groups, identify information, and identify problems in the cases presented. Furthermore, at the stage of seeking information and the stage of making completion steps, students search for information related to cases to solve problems with the help of questions contained in the student worksheet. Then at the conclusion stage, students draw conclusions from the discussion answers after completing the cases presented. After that, the presentation stage and the improvement stage.

In the CG, the first stage of learning with a scientific approach is observing. At this stage, students observe the videos/images presented by the teacher, followed by listening and hearing the explanation of the material by the teacher. In the second stage, namely asking questions, students formulate questions based on the topics discussed. In the third stage, namely trying, students collect information/data through experiments, reading books, or other sources. In the fourth stage, namely reasoning, students use the information/data collected to answer questions. Then in the fifth stage, namely communicating, students convey answers to questions in front of the class orally and/or in writing.

Data Analysis

The collected data underwent processing and analysis to determine whether differences existed in the problem-solving abilities of students between the EG and CG. Parametric statistics, specifically the *t*-test, were employed using SPSS 25 software. The *t*-test evaluates whether there is a statistically significant gap between the means of both groups or within the same group under different conditions, assuming normal distribution and parametric data (Cohen et al., 2018). Both independent and paired *t*-tests were utilized in this study. Prior to conducting the *t*-tests, prerequisite tests were conducted: the homogeneity test using the Levene test and the normality test using the Kolmogorov-Smirnov test. If the data exhibited normal distribution and homogeneity (sig > 0.05), the *t*-test was deemed appropriate. Moreover, Cohen's *d*-effect size was computed to check the magnitude of the relationship, difference, or effect of a variable on other variables within the study. Cohen's *d* effect size categories are 0.00-0.20 (weak), 0.21-0.50 (moderate), 0.51-1.00 (strong), and > 1.00 (very strong), as mentioned by Cohen et al. (2018).

RESULTS

With the data meeting the assumptions of normal distribution ($p > 0.05$) and having homogeneous variance, parametric tests using inferential statistics were deemed appropriate for analysis. An independent sample *t*-test was performed to ascertain whether a significant gap existed in the mean scores between the CG and EG. The results of the comparison of the pretest mean scores of the CG and EG are exhibited in Table 2.

Table 2. Independent Sample T-test Result for Pretest

Indicator	Class	N	M	SD	*t*	*p*
Understand the Problem	EG	36	1.47	0.23	1.200	0.234
	CG	36	1.41	0.23		
Devise a Plan	EG	36	0.66	0.35	-0.321	0.749
	CG	36	0.69	0.32		
Carry Out the Plan	EG	36	0.52	0.21	0.254	0.800
	CG	36	0.50	0.21		
Look Back	EG	36	0.44	0.22	-0.300	0.765
	CG	36	0.46	0.21		
All Indicators	EG	36	0.77	0.19	0.191	0.849
	CG	36	0.76	0.19		

At the end of learning, posttests were given to both classes. The results of the comparison of the mean posttest scores of the CG and EG are listed in Table 3.

Table 3. Independent Sample T-test Results for Posttest

Indicator	Class	N	M	SD	*t*	*p*
Understand the Problem	EG	36	2.29	0.30	2.916	0.005
	CG	36	2.08	0.33		
Devise a Plan	EG	36	1.85	0.48	0.718	0.475
	CG	36	1.77	0.45		
Carry Out the Plan	EG	36	1.82	0.44	0.964	0.338
	CG	36	1.72	0.46		
Look Back	EG	36	1.65	0.48	0.667	0.507
	CG	36	1.57	0.47		
All Indicators	EG	36	1.89	0.30	2.511	0.014
	CG	36	1.73	0.26		

Based on the results of the independent *t*-test as presented in Table 2, the significance value for the pretest is 0.849, suggesting that the significance value is greater than 0.05. Consequently, the null hypothesis (Ho) is accepted. This suggests that there is no significant gap between the mean problem-solving scores of students in the EG and CG before intervention.

Based on the results of the independent *t*-test for the posttest, a significance value of 0.014 was obtained, indicating a significance level lower than 0.05. Thus, the null hypothesis (Ho) was rejected. This implies that there was a significant gap between the average problem-solving scores of students in the EG and CG after the treatment.

Further, a paired sample *t*-test was employed to assess if there was a significant increase between the mean pretest and posttest scores of students' problem-solving abilities in both the EG and CG. Moreover, Cohen's *d* was computed to explain the effect size and ascertain whether the observed gaps were substantial or attributable to various factors. The results of the paired sample *t*-tests for both the CG and EG are provided in Table 4.

Table 4. Paired Sample T-test Results of EG and CG

Indicator	Class	Difference		*t*	*p*	Cohen's *d*
		M	SD			
Understand the Problem	EG	0.82	0.37	-13.256	0.000	3.06
	CG	0.67	0.38	-10.595	0.000	2.38
Devise a Plan	EG	1.19	0.52	-13.614	0.000	2.85
	CG	1.08	0.53	-12.313	0.000	2.77
Carry Out the Plan	EG	1.30	0.42	-18.628	0.000	3.79
	CG	1.21	0.48	-15.054	0.000	3.42
Look Back	EG	1.20	0.48	-15.003	0.000	3.24
	CG	1.11	0.49	-13.519	0.000	3.07
All Indicators	EG	1.12	0.40	-16.594	0.000	4.39
	CG	0.96	0.28	-20.505	0.000	4.29

Table 4 demonstrates that the significance value of the paired *t*-test results in both the EG and CG is 0.000, which is less than 0.05, leading to the rejection of the null hypothesis (Ho). This suggests a significant gap between the average problem-solving abilities of students regarding buffer solutions before and after learning, evident in both the EG and CG. Furthermore, based on the results of Cohen's *d* calculations, all indicators in both the EG and CG exhibit a high effect size. However, the Cohen's *d* value in the EG (4.39) surpasses that of the CG (4.29). This suggests that the effect of the application of CBL on students' problem-solving abilities concerning buffer solutions is notably higher in the EG compared to the CG. Thus, it can be argued that the implementation of CBL has a high influence on students' problem-solving abilities in chemistry.

DISCUSSION

The primary objective of our study was to assess the impact of case-based learning (CBL) on students' problem-solving abilities concerning buffer solutions. The findings indicate a notable increase in the average scores of students from the pretest to the posttest, suggesting that CBL effectively enhances students' problem-solving skills in this domain. This aligns with prior research, such as the study by Yoo and Park (2015), which demonstrated the effectiveness of the CBL in elevating students' problem-solving abilities. Additionally, findings from research conducted by Brandon and All (2010) also support this, indicating that CBL encourages students to actively construct their own knowledge and autonomously produce solutions to address problems.

Prior to treatment, the problem-solving abilities of students in both the EG and CG showed similar results, which based on the results of statistical tests in the pretest revealed that there was no significant gap in problem-solving abilities in the two classes. After the pretest was carried out, each class received a different treatment. During the treatment, students in the EG applied the CBL, and students in the CG applied the scientific approach.

Based on the statistical test results, both the EG and CG demonstrated increased scores in their problem-solving abilities before and after the learning interventions. This indicates that both instructional models, case-based learning (CBL) and the scientific approach, have a positive impact on students' problem-solving abilities regarding buffer solutions. However, the increase in scores that occurred in the EG was higher than in the CG. Furthermore, the effect size calculations also revealed that CBL exerts a stronger influence on enhancing students' problem-solving abilities compared to the scientific approach. Consequently, students in the EG exhibited superior problem-solving abilities in the context of buffer solutions compared to those in the CG. These findings align with the results of a study by Yoo and Park (2015), which demonstrated the positive effects of CBL on communication skills, problem-solving abilities, and motivation to learn. This may be because CBL focuses on using real or simulated case studies as a basis for learning. Students are given one or several cases that represent real-world situations, and then they analyze, plan, and make decisions based on the information provided in these cases.

In the EG, learning using CBL begins with an initial explanation by the teacher as the initial knowledge used to solve cases. Learning in the EG is taught in groups by working on worksheets. The worksheets presented in the EG are adapted to the stages of CBL learning. The first stage is setting cases, students are presented with a case related to the material to be studied. The cases given are cases that students often encounter in everyday life, so giving cases is expected so that students are interested in the material to be studied and can stimulate students to think actively. According to Jonassen and Hernandez-Serrano (2002), cases can be used as instructions for students to help them learn to solve problems.

The second stage in CBL is analyzing the problem. At this stage, students work in groups on worksheets containing cases. The worksheet is equipped with procedures that guide students in analyzing the problems found in the cases presented. At this stage, students are trained to identify important information in cases and identify what problems must be resolved in cases. In this case, students in EG are expected to be able to understand the core problem of the case, break down complex problems into smaller components, and understand the relationships between these components, enabling them to identify solutions appropriately. As highlighted by Reff (1999), the ability to recognize and understand the problem serves as the cornerstone for constructing an effective problem-solving process.

The next stage is to find information and make steps for completion. At this stage, students look for information, data, or supporting literature to solve problems according to the questions contained in the worksheet. The questions on the worksheet direct students to solve cases according to the right steps. Learners are trained to look for the right information before solving problems. Then after collecting information, in the end, students will be able to solve problems independently using the acquired knowledge. Collecting data makes students more skilled in thinking analytically, objectively, and systematically in dealing with problems. Data collection helps students reduce the risk of errors or inappropriate solutions. In interpreting the data that is owned correctly, students use scientific reasoning skills (Ghanizadeh, 2017).

The next stage is making conclusions. At this stage, students draw conclusions from the discussion answers after completing the cases presented. Drawing conclusions is a crucial part of the learning process that can help enhance problem-solving skills. Drawing conclusions trains students to integrate the information and skills they have learned to achieve a deeper understanding of a problem. By drawing conclusions, students are required to analyze information and formulate solutions to problems or answers based on existing evidence. After that, students present the results of their discussions and make improvements if the answers are not correct. In this case, students will ask questions or opinions if they find differences from the results they encounter so that it will strengthen their own understanding of the concepts related to the topic or problem being discussed. In addition, all students are also given reinforcement by the teacher to better understand the concept. This can develop students' problem-solving abilities because, as suggested by Yu et al. (2015), conceptual knowledge and procedural knowledge are necessary factors for solving problems.

The advancement of students' problem-solving skills in this study was facilitated by the active engagement of students in the case-based learning (CBL) process. Within CBL, students were actively involved in analyzing problems, determining steps for resolution, and methodically following through with problem-solving. CBL facilitates students' learning within the context of problem-solving, enabling them to discern when to apply learned lessons and adapt these lessons to novel situations (Kolodner, 2006). This aligns with the findings of research conducted by Bosse et al. (2012), which suggest that CBL exposes students to multifaceted problems mirroring real-world scenarios, thus fostering discussions and the integration of knowledge to identify and resolve problems. Furthermore, learning through the CBL model can imbue learning with greater significance, as students actively participate in all phases of the learning process, from conceptualization to dissemination

(Reilly, 2010). Additionally, learning becomes more meaningful when students are introduced to cases that frequently arise in everyday life.

With the development of students' problem-solving abilities, it is hoped that there will be an increase in students' understanding of the learning process. This notion is supported by Jeotee's research (2012), which suggests that enhancing students' problem-solving skills correlates with an enhanced comprehension of the learning process. Based on the provided explanation, it is clear that CBL has a positive impact on students' problem-solving abilities, particularly concerning buffer solutions. Students in the EG who engaged in CBL demonstrated superior problem-solving skills compared to those in the CG. This is because, in the CBL process, students are accustomed to problem-solving activities, namely understanding problems, planning steps for completion, carrying out settlement plans, and checking again, where to develop effective problem-solving abilities, students' knowledge is needed about the processes involved in problem-solving (Shanta & Wells, 2022).

CONCLUSION

It can be concluded that, based on the results of our study, case-based learning (CBL) has a significant influence in enhancing students' problem-solving abilities regarding buffer solutions. This enhancement is evident in the average pretest and posttest scores of both the EG and CG. Specifically, the average problem-solving ability of students in the pretest was 0.77 for the EG and 0.76 for the CG, while in the posttest, it increased to 1.89 for the EG and 1.73 for the CG. The most substantial improvement in students' problem-solving abilities in the EG was observed in the indicators related to carrying out the settlement plan. In addition, Cohen's *d* value in the EG (4.39) also shows the effectiveness of CBL compared to the CG (4.29) in improving students' problem-solving abilities. A higher Cohen's *d* value in the EG indicates a stronger influence, affirming that CBL has a promising impact on students' problem-solving abilities concerning buffer solutions.

SUGGESTIONS

The study encountered several limitations, one of which was time constraints, restricting the research to only three relatively short sessions to assess the effectiveness of the learning model. Future researchers could mitigate this limitation by extending the duration of the learning process, allowing all stages of the case-based learning (CBL) model to be executed optimally. Moreover, this study solely focused on investigating the effect of CBL on students' problem-solving abilities regarding buffer solutions. Future research could explore the impact of CBL across a broader range of topics or subjects to further elucidate its efficacy in enhancing problem-solving skills in diverse contexts. Future researchers can carry out further research on the effect of CBL on other variables, or future researchers can apply CBL to other chemistry learning topics or other subjects so that the results are more comprehensive.

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