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Application of C-PBL (Context and Problem Based Learning) on Temperature and Heat Materials to Transform Students' Mental Models

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ABSTRACT

This research aims to determine students' conceptual understanding through the C-PBL (Context- and Problem-Based Learning) learning model. The method used was quasi-experimental with a posttest-only control group design. The population in this study were all class XI students in one of the high schools in Bandung. The sampling technique uses cluster random sampling. The samples used were class XI MIPA 1 as the control class and class XI MIPA 3 as the experimental class. Both classes were given a final test (posttest) after applying the C-PBL model in the experimental class and the discovery learning model in the control class. The research results showed that there were differences in students' conceptual understanding in the experimental class and the control class. Analysis of research results using hypothesis testing of the difference between the experimental and control classes averages using the t-test. The t-test was conducted using Microsoft Excel, and the sig results were obtained. (2– tailed) of 0.00. These results show that the C-PBL model significantly influences the mental physics model.

Introduction

Physics subjects are generally considered problematic by some students. Physics is scary. Indeed, physics concepts are always based on formulas discovered by physicists. Sometimes, there are too many physics formulas, and they are abstract, so they often confuse students when studying them. Examples of abstract objects in physics learning are atoms, molecules, energy, solar systems, galaxies, etc. (Sari, 2017; Ornek et al., 2008). One of the physics concepts that is difficult to understand and abstract is the concept related to thermodynamics, namely heat and heat transfer. It was also found that concepts have many misconceptions, namely: 1) heat transfer such as convection and radiation (Kartal et al., 2011; Kibirige, 2021), 2) misconceptions regarding temperature and heat (Georgiou & Sharma, 2015; Langbeheim et al., 2013), 3) there are misconceptions about covalent bonds, 4) misconceptions about thermal bonds (Leinonen et al., 2013). Heat and heat transfer are mandatory topics studied in schools from junior high school to college. Physics teachers must have a scientific understanding of this topic. Therefore, one of the challenges in teaching Physics is helping students develop a scientifically appropriate understanding of heat phenomena based on their existing ideas and beliefs (Sari, 2017).

The understanding that exists and is appropriate in one's thinking will help describe phenomena and process understanding to analyze new phenomena in the form of internal representations (Sari et al., 2020). Another thing considered essential and closely related to the learning process is students' conceptual understanding of the material provided. Concepts in learning are fundamental for students to master. Teachers do this to avoid misunderstandings. Dahar

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(1996) said that allowing students to progress with inappropriate concepts can cause learning problems in the future. This explains how important it is for a concept to be understood and mastered correctly. Apart from that, Dahar (1996)also explains that understanding concepts is the basis for students in developing their knowledge. Based on this, teachers' role is vast in increasing students' understanding of concepts so that misconceptions do not occur. Based on the problems described above, efforts are needed to complete a learning process that can change misconceptions and build conceptual understanding in students in physics learning, especially regarding temperature and heat. One way is through social constructivism, which is applied in schools through various learning methods such as 1) problem-based learning, 2) cooperative learning, 3) project-based learning, 4) situational learning, 5) cognitive apprenticeship, and 6) context-based learning. One learning model is predicted to be able to help understand the concept of Problem-Based Learning (PBL).

According to Tania (2021), Problem-Based Learning (PBL) is a learning model that helps teachers develop students' problem-solving abilities when studying material. Chin and Chia (2006) and Batlolona (2020) state that PBL problems stimulate student learning activities. This research uses the application of C-PBL to help students transform mental models into more scientific ones so that they can understand why and for what purpose they are learning. The final form of learning activities in PBL is that students are asked to apply what they have learned, further learning assignments, homework, or other forms (Ibrahim, 2005). Based on this, to change misconceptions and build students' conceptual understanding, researchers tried learning activities using PBL, which did not simply apply existing and commonly carried out PBL stages but used context and problem-based learning (C-PBL) which emphasized the context side of PBL (Baran & Sozbilir, 2018; Tse et al., n.d.).

Problem-based Learning (PBL) will be more meaningful when problems are related to context. Context-problem Learning (C-PBL) is a series of problems presented in real-life contexts and issues to support students' control over their learning Potter & Overton (2006). For students, it provides an opportunity to test theory through real-life examples. The C-PBL approach works by setting open-ended problems for students with engaging scenarios that help illustrate how students' understanding of the subject can be applied and the importance of problem-solving skills. Therefore, it would be highly desirable to instill connections with everyday life, contemporary research, society, or technology of Physics into our teaching by using context- and problem-based approaches to encourage more meaningful learning of Physics.

Several previous research results regarding C-PBL, for example, Summerfield (2003), have tested C-PBL for analytical chemistry, describing contexts in industrial, pharmaceutical, environmental, and forensic chemistry. These resources provide learning outcomes in analytical chemistry and assist in developing transferable skills. In another study, sport was used as a context to meet learning outcomes in biochemistry, simple thermodynamics, and materials chemistry Potter & Overton (2006). C-PBL is widely used in the Western world; for example, it comes from the University of Hong Kong. Tang (1997) applied C-PBL to various cases, proving that C-PBL allows students to learn more deeply. Applying C-PBL to multiple cases with context-based PBL syntax, namely orienting the problem given to students, it is proven that C-PBL allows students to learn more deeply (Baran & Sozbilir, 2018).

By paying attention to the description above, it is necessary to have a strategy or learning model that can transform students' understanding of concepts. Previous research shows that C-PBL has been studied to increase students' knowledge of concepts, but it has never been tested in chemistry and physics learning. Even though the physical object of Physics is the context, it is a phenomenon in everyday life. Therefore, this research investigates the application of the C-PBL learning model to transform students' understanding of concepts.

Methods

The method used in this research is quasi-experimental. The design used in this research was a nonequivalent control group design with a posttest-only control group type. The research population was all class XI MIPA in one of the high schools in Bandung. The sampling technique uses cluster random sampling (Sugiyono, 2019). The research sample consisted of an experimental class and a control class. The experimental class received the application of the C-PBL (Context- and Problem-Based Learning) learning model, while the control class received the application of the discovery learning model. The samples used in this research were class XI MIPA as the control class and XI MIPA 3 as the experimental class, each with 33 students. The research design is shown in Table 1.

Table 1
Research Design

Class	Treatment	*Posttest*
Experiment	X	O
Control	Y	O

Information:
X : Learning Model C-PBL
Y : Learning Model *Discovery Learning*
O : *Posttest*

The instrument used in this research was a mental model test instrument in the form of an essay. Before use, the instrument is validated by an expert who aims to find out that the instrument used uses excellent and correct Indonesian language rules, does not use ambiguous language, does not contain errors or misconceptions, can be read well, and has no typos. Based on expert opinion, the questions are suitable for use and must be revised due to typing errors. Test questions that are ambiguous and difficult for students to understand are revised so that students do not misperceive when answering the questions.

Instrument testing aims to determine validity, reliability, distinguishing power, and difficulty level. From the instrument testing results, it can be seen that seven questions were valid out of the ten questions tested with a reliability of 0.5 (medium category). Of the seven valid questions, four have a medium level of difficulty, two easy questions, and one difficult question. These seven questions were used in this research.

Analysis of students' mental models was carried out using the t-test. Before carrying out the t-test, a prerequisite is to test the normality of the data. If the normality and homogeneity test requirements are met, a mean difference test is carried out using the t-test. If the prerequisite tests are unmet, data analysis uses non-parametric statistics, namely the Mann-Witney test.

Result and Discussions

One of the physics concepts that is difficult to understand and abstract is the concept related to thermodynamics, one of which is related to temperature and heat. The abstract material characteristics of temperature and heat must be studied from various points of view, especially the microscopic point of view. Phenomena are closely related to temperature and heat and can be understood macroscopically. However, when you want to explain the mechanism by which temperature and heat increase or decrease, you cannot only use a macroscopic point of view.

Temperature and heat must involve a microscopic perspective which is believed to be the main factor in giving rise to problems so far in understanding the concepts of temperature and heat, the emergence of misconceptions and unscientific mental models as well as the low understanding of the concept among students is the main factor in problems in the classroom (Amalia et al., (2017); Dwi Cahyaningtyas et al., (2023). There are misconceptions about temperature and heat such as; Kibirige, 2021; Pathare & Pradhan, 2010), 2) misconceptions about temperature and heat (Georgiou & Sharma, 2015; Karabulut & Bayraktar, 2018; Langbeheim et al., 2013), 3) there are misconceptions about covalent bonds (Istiqomah et al., 2021), 4) misconceptions about thermal bonds (Leinonen et al., 2013), as well as the absence of learning that facilitates the construction of mental models on temperature and heat material. As a result, temperature and heat are understood only to the extent of memorizing concepts or mathematical formulations, so when facing problems related to the analysis of natural phenomena, students find it challenging to solve problems because scientific mental models are not constructed in their thinking and they lack understanding of concepts. Studying the concept of temperature and heat material from mental models and indicators of concept understanding is needed because it will be a foundation for students to construct scientific knowledge in Physics subjects at a higher and more complex level.

The role of mental models as an internal representation and understanding of a person's concepts in understanding a phenomenon is vast considering the primary function of mental models, namely being able to explain and predict a phenomenon, as well as the function of indicators of conceptual understanding, namely explaining and interpreting a phenomenon. Students who have scientific mental model construction and conceptual understanding will have the ability to identify and analyze new phenomena because, in their minds, representations are already embedded that are ready to be implemented in explaining and predicting behavior or tendencies of physical phenomena, as well as being able to interpret and explain phenomena. In studying temperature and other heat materials at a higher level, especially those with dynamic characteristics, students will quickly form mental models and understand concepts because they are accustomed to constructing mental models and understanding concepts in Physics subjects.

Providing students' learning in Physics material regarding the concepts of temperature and heat so that it is meaningful is not enough to transfer the material through lecture activities or LKPD assignments to students who only fill in definitions and teach exercises and practicums without being accompanied by the teacher. However, the concept of temperature must be studied from macroscopic and microscopic dimensions. Learning the concept of temperature macroscopically is a typical lesson usually carried out in conventional school learning. As a result, students can only understand the concept of temperature from what is observed: the results of thermometer measurements. Moreover, the focus of learning the concept of temperature is the conversion of temperature scales, which is not essential to study in depth. Someone who goes to a country that uses a different temperature scale from their country of origin can do a conversion on the internet, and the results will come out without having to calculate equations using mathematical formulations, increasing the student's cognitive load: memorizing formulas.

The concept of temperature must be studied from a microscopic dimension or point of view. Examining the kinetic theory of gases more deeply, which can link the macroscopic quantity of temperature with the microscopic quantity, the average speed of translational motion of the molecules that make up a substance must be central in studying temperature. Thus, one will understand why metal gets hot when hit with a hammer. Molecular motion needs to be investigated as early as possible so that students in Physics learning have a scientific understanding. It will be more meaningful if constructed using a scientific mental model and students' understanding of concepts.

Applying C-PBL with the syntax contained in the PBL syntax has been proven to improve the understanding of thermodynamics material, especially in temperature and heat material. This can be seen from the effectiveness of learning planning, which is considered very effective in learning thermodynamics (Baran & Sozbilir, 2018). Indeed, in previous research, C-PBL has not been able to construct mental models and increase students' understanding of concepts. Still, C-PBL has improved learning of thermodynamics (Baran & Sozbilir, 2018) and problem-solving skills on momentum and impulse material (Yuberti et al., 2019). So, judging from previous research and the effectiveness of classroom learning on temperature and heat material, researchers believe the C-PBL syntax can support students in achieving learning goals. Apart from that, the syntax in C-PBL is also based on the characteristics of the abstract and dynamic concepts of temperature and heat. Students who can interact and get to know C-PBL will be inspired when they can follow the syntax in C-PBL.

Apart from that, the effectiveness of C-PBL in constructing mental models can also be seen from the effectiveness of implementation, one of which is the students' achievements in understanding concepts and creating mental models after being given the application of C-PBL. Another characteristic that differentiates C-PBL from the application of PBL is that it lies in the first syntax in orienting the problem given by students. The issues presented in C-PBL are like problem scenarios in everyday life. Meanwhile, only pictures are provided in the first application of PBL tax, namely, orienting the problem. So, in orienting the problem, students do not understand it yet.

Apart from that, the role of C-PBL is enormous in the construction of students' mental models and understanding of concepts seen from the syntax in C-PBL namely the first syntax begins with students' orientation to the problem through guiding questions on scenarios in everyday life that have been given. In this section, the teacher exposes students to new situations by providing several phenomena in daily life, such as temperature and heat material scenarios, and asks students to comment regarding what has been observed. Next, the teacher waits a few moments for students to formulate answers. The purpose of this syntax is to introduce students to the material to be studied so that students feel confident in providing a basic explanation of the relationship that has been observed. After confronting students with existing problems, the teacher continues explaining the material being studied.

The second syntax is organizing students. In this syntax, students are divided into several homogeneous study groups consisting of five men or five women from each group. The teacher encourages students to link observed problems with previous knowledge through several guiding questions appropriate to the indicators for all students. This is done to explore students' understanding of the material being studied so that a mental model process and understanding of concepts is created, and students can act independently in making decisions and dare to express opinions.

The third syntax guides individual and group investigations. In this syntax, the teacher encourages students to collect the needed information by conducting experiments and investigations. Next, the teacher waits a few moments and allows students to formulate answers or have a small discussion. This aims to train aspects of mental models and conceptual understanding, namely providing further explanations regarding the problems being studied, taking appropriate strategies and tactics to solve problems, training students' basic understanding, and training students' confidence in their abilities in taking each step. Alternatively, actions to solve the issues and the confidence to dare to express opinions. At this stage, the teacher must ensure all students actively participate in discussion activities. In this section, students are directed to be able to conclude solutions or answers to the problems given. One aspect of mental models and conceptual understanding is the ability to conclude a problem.

The fourth learning syntax is developing and presenting results. At this stage, students report the results of the discussions that have been carried out. After the presentation, the teacher provides several questions about the problems the students have discussed by randomly appointing students to answer the questions. If the answer is correct, the teacher asks for responses from other students to ensure that all students are actively involved. However, if the student experiences difficulty answering, the teacher's role is to ask different questions whose answers guide solving the answer. At this stage, students are required to be able to complete each question and answer the questions given by other friends. Positive mental models and understanding of concepts are also trained in students through the opportunities to express their thoughts regarding the questions asked.

The fifth syntax stage is analyzing and evaluating the process and results of problem-solving through context. In this section, the teacher asks final questions to different students to further emphasize that all students have understood the indicators. When answering questions, students train their mental models and understanding of concepts.

So, judging from the results of observations made by observers, the role of teachers as learning centers is starting to decrease. The teacher functions more as a facilitator who directs and motivates students during the learning process so that students are actively involved in the learning process. The guiding questions at the C-PBL stage involve students interacting directly with objects, phenomena, and experiences related to the learning material. This helps students to understand the material being studied. This research (Baran & Sozbilir, 2018) explains an improvement in the learning process in class after implementing C-PBL.

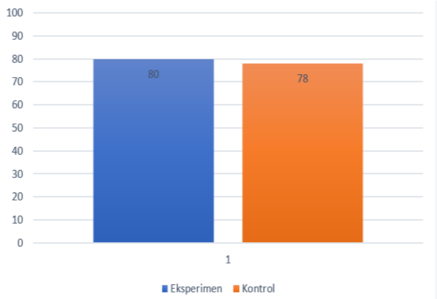
Thus, the C-PBL learning implemented according to the students was very effective as seen from the student response questionnaire, which scored 87.78 in the excellent category. By implementing C-PBL, students become happier in learning and want to be able to apply it to other learning materials, especially physics learning. The students also agreed that C-PBL learning facilitated students in transforming mental models and increasing their understanding of concepts. This is because the stages in the C-PBL learning model construct students' knowledge regarding the concepts being studied and facilitate students working together in groups to solve existing problems. Students generally agree that the C-PBL model helps them understand the learning material through the provided guiding questions. This makes them active in learning bravely responding and trains them to communicate and collaborate.

The excellent response given by students was because the implementation of C-PBL reflected the characteristics of science learning and involved students actively in classroom learning. The physics learning experienced by students is exciting and challenging because the C-PBL learning model requires concentration and activeness of students in the learning process. This question is to the research results of Baran & Sozbilir, 2018 which explain that the C-PBL learning model is oriented to real-world problems and helps students develop thinking and problem-solving skills through guiding questions that can explore, direct, and guide students. Students can obtain information and knowledge. C-PBL learning can also motivate students to understand a problem more deeply and achieve the intended answer to achieve learning objectives.

Data from the posttest results of the experimental class and control class are presented in Figure 1. Based on Figure 1, the learning outcomes of the experimental class are higher than those of the control class. The high learning outcomes of the experimental class were caused by the mental model of the experimental class students being better than that of the control class, both overall and for each indicator. These results are almost the same as research by Hermanto et al. (2023), which shows that research on the PBL (Problem-Based Learning) learning model can improve students' mental models. Research by Hermanto et al. (2023) indicates that the C-PBL (Context-and Problem-Based Learning) learning model can improve students' mental models.

Figure 1

Result Data for Experimental Class and Control Class



The construction of students' mental models after implementing C-PBL can be claimed as an indicator of the effectiveness of C-PBL implementation. The construction of mental models can be seen from the many positive transformations of students' mental models. Positive transformation is a change in mental models from less scientific mental models before learning to scientific ones after learning. Negative transformation is a change in the mental model from a scientific mental model before learning to a less scientific one after learning. Meanwhile, zero transformation is no change in mental models after learning.

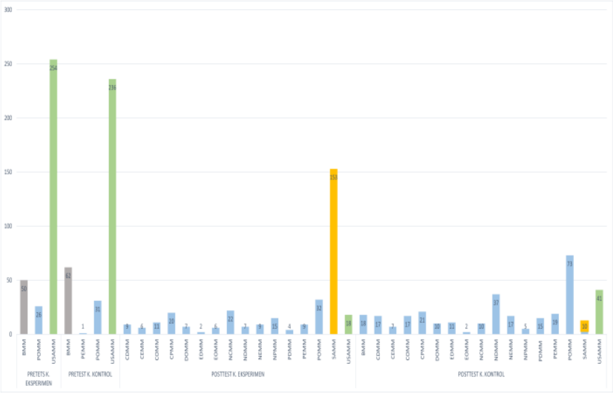
The scientific mental model is indicated by all aspects of the mental model being answered correctly (can be seen in Appendix D). Meanwhile, a mental model is more scientific if the mental model after learning has more aspects of the mental model that the students answered correctly. Thus, a mental model that is less scientific means a mental model that, after learning, has fewer aspects of the mental model that are answered correctly by students.

The profile of mental models in both classes before and after learning can be seen in Figure 2. The presentation of the bar diagram in Figure 2 starts from the BMM mental model, namely the one that does not fill in at all, which is located on the far left, and then successively to the right of the x-axis, the unscientific mental model USAMM, the hybrid mental model, and up to the scientific mental model, SAMM on the far right on the x-axis.

Based on Figure 2, we can see that during the pretest, both control and experimental classes students showed the emergence of the USAMM and unscientific mental models. Still, the USAMM mental model was the most common in the control class. Even the number of unscientific mental models in the experimental class before learning was there, but not as much as in the control class. The experimental and control classes showed the emergence of the BMM mental model, namely, not at all. This indicates that, before learning, most students in both the experimental and control classes had unscientific mental models. The emergence of another mental model before learning in the experimental class is a mental model with only predictive aspects (POMM). Meanwhile, the control class has mental models with only prediction aspects (POMM) and a combination of prediction and explanation aspects (PEMM).

Figure 2

Data on Student Mental Model Construct Learning Results



Furthermore, SAMM was most achieved by students from the experimental class after learning about the emergence of scientific mental models. The emergence of scientific mental models after learning also occurred in the control class, but not as much as in the experimental class. Meanwhile, for unscientific mental models, USAMM, after learning, was still found mainly in students in the control class. This was also the case in the experimental class, although the numbers were still much lower than in the control class.

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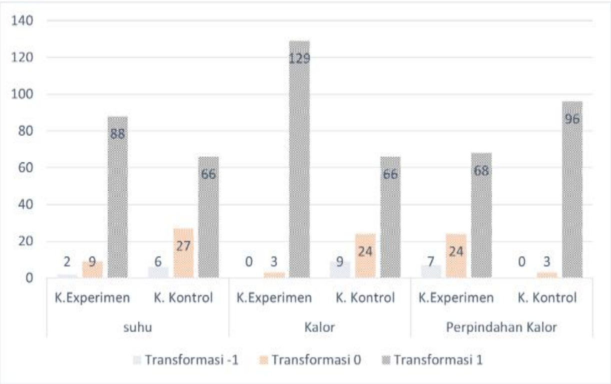
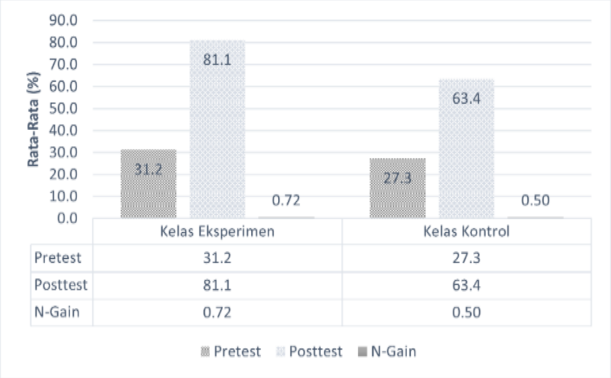
Figure 3
Mental Model Transformation in the Control and Experimental Classes



Based on Figure 3, we can conclude that positive transformations of mental models in the experimental class are always more numerous than positive transformations in the control class. The positive transformation shows the highest percentage of heat material in the experimental class and heat transfer in the control class. Meanwhile, there are fewer experimental classes in the zero transformation than in the control class. Zero transformations in the heat transfer subsection are in the experimental class, and more zero transformations are in the control class in the temperature and expansion subsections. Likewise, negative transformations are still often found in the control class and experimental class in the experimental class on heat material, and negative transformations in the control class are also heat transfer materials.

The construction of mental models in the control and experimental classes after participating in the learning is presented in Figure 3. The average percentage of mental model scores before learning was 27.3 for the control class and 31.2 for the experimental class. Meanwhile, the average percentage of mental model scores after learning was 63.4 and 81.1, respectively, for the control and experimental classes. The rate of n-gain normalized by the mental model for each class is 0.50 for the control class and 0.72 for the experimental class. The percentage of n-gain normalized by mental models for both classes is in the medium category. This confirms that the mental model construction of the two classes, seen from the normalized n-gain percentage after experiencing learning in each class, is in the high category in the experimental class and the medium category in the control class.

Figure 4
Bar Chart of Pretest, Posttest, and Normalized N-Gain of Mental Model Scores



For the normalized n-gain profile, the mental model in each subsection is shown in Figure 4. Based on Figure 4, the most significant percentage of n-gain normalized by the cognitive model occurs in the experimental class's heat transfer subsection of 0.82. Meanwhile, the smallest percentage of n-gain normalized by the mental model occurred in the temperature subsection at 0.49 in the control class. The rate of n-gain normalized by the mental model included in the high category (above 61%) occurs in all subsections in the temperature and heat material in the experimental class. Meanwhile, in the control class, the percentage of n-gain normalized by mental models, which were included in the medium category (above 39%), occurred in all sub-chapters in the material on temperature and heat.

Figure 5
Bar Diagram of Mental Model Construction in Each Aspect

Based on Figure 5, construction occurred in the mental model aspect of content knowledge, as indicated by the normalized average score percentage of 54.0% for the experimental class and 47.1% for the control class. The following mental model aspect construction after the content aspect is the prediction aspect, shown by the normalized average score percentage of 58.0% for the experimental class and 51.3% for the control class. Next is the construction of the mental model aspect after the prediction aspect, namely the explanation aspect, shown by the normalized average score percentage of 55.6% for the experimental class and 43.1% for the control class. Finally, the following mental model aspect construction after the explanation aspect is the depiction aspect, shown by the normalized average score percentage of 54.5% for the experimental class and 42.9% for the control class.

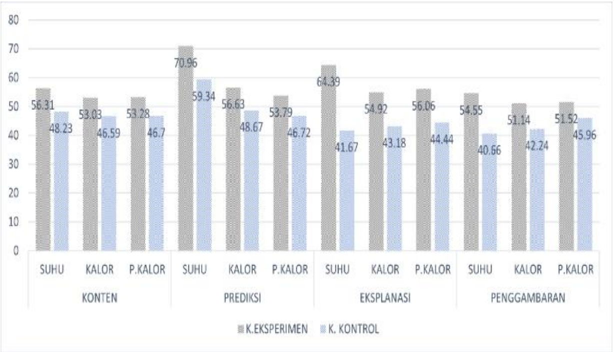
The content mental model aspect in the experimental class experienced the most miniature construction. It was in the high category in the experimental class. The mental model aspect of the explanation aspect in the control class experienced the most miniature construction and was in the medium category. Even though it is in the high category in the experimental class and the medium category in the control class, it is seen from the smallest value in the mental model aspect. The content aspect is shown by the average score percentage of 54.1% and 47.1%. The experimental and control classes experienced the most significant construction for the predictive mental model aspect. They were in the high category in the experimental class and the medium category in the control class. This predictive aspect is shown by the average score percentages of 58.0% and 51.3%—figure 4. The above confirms that the construction of mental model aspects in the experimental class is greater than the construction of mental model aspects in the control class. The construction of mental models for each aspect of each topic is presented in Figure 6.

Based on Figure 6, construction occurs in the normalized average percentage of mental model aspects in each topic seen in each element, such as content knowledge, prediction, explanation, and depiction. The average value of the experimental class is superior to the control class.

Analyze experimental data by applying the C-PBL learning model where the syntax of C-PBL is the same as that of PBL. It is just that the first difference is in the syntax. There are 5 phases, namely (1) orienting students to the problem; (2) organizing students to conduct research; (3) assisting with independent and group investigations; (4) developing and presenting work results; (5) analyzing and evaluating the problem-solving process. The problems used in PBL are problems faced in the real world. In this way, students collect temperature and heat material data directly. The indicator explains being trained in discussion and decision-making activities. During discussion activities, students are trained to use their language to express the findings obtained in learning. Discussion activities also increase curiosity, so students look for various information to use as learning resources.

Figure 6

Bar Chart of Normalized Average Percentages of Mental Model Aspects on Each Topic



The results of the posttest data normality test with a significance level of 5% were 0.177 > 0.05 for the experimental class and 0.064 > 0.05 for the control class, so it can be concluded that the data obtained was normally distributed for both the experimental and control classes.

Hypothesis testing with a significance level of 5% obtained a significance value of 0.000 < 0.05, so it can be concluded that there is a significant influence between the C-PBL learning model and students' understanding of concepts. Applying the C-PBL (Context- and Problem-Based Learning) learning model in the experimental class allows students to explore more information through opinions and exchanging information with their group friends (Hermanto et al., 2023). The C-PBL (Context- and Problem-Based Learning) learning model makes students more active than previous learning activities using the discovery learning model. After using C-PBL (Context- and Problem-Based Learning), students can carry out experimental activities that make them directly involved in exploring information they do not yet know and not only obtain information from the teacher (Baran & Sozbilir, 2018).

Based on the research results, the C-PBL (Context- and Problem Based Learning) learning model provides better mental model results than learning that applies the Discovery learning model. This can be seen in the experimental class's number of positive transformations. These results are based on research by Hermanto, Nurhayati, Tahir, and Yunus (2023), which shows that the C-PBL (Context-and Problem Based Learning) learning model can better influence students' mental models.

Conclusion

Based on research data and discussion, the conceptual understanding of students who use the C-PBL (Context-and Problem Based Learning) learning model is better than students who are not given the application of the C-PBL (Context-and Problem Based Learning -PBL. In the experimental and control classes, each showed a positive transformation of mental models. However, the experimental class was superior in positive transformation to the experimental class, as well as zero transformations and negative transformations, which are still found in every question.

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