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The Effectiveness of the Problem-Based Flipped Classroom Learning Model to Improve Conceptual Understanding of Physics Teacher Candidates on Crystal Structure Material

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ABSTRACT The limited time allocation for lectures in the classroom is an obstacle to presenting student-centered learning. This is one of the factors that prospective physics teacher students experience conceptual difficulties, especially in crystal structure material. So the purpose of this study was to determine the effectiveness of the problem flipped classroom learning model on understanding the concepts of prospective physics teacher students on crystal structure material. This study used a quasi-experimental method with a one-group pretest-posttest research design. The subjects of this study were 16 students who took solid-state physics courses. Data analysis techniques were carried out using normality tests, homogeneity tests, and pretest and posttest average difference tests. Then test the N-gain to see the increase in the pretest and posttest results and continue with the effect size test using the effect size. The instrument used was a test of mastery of the concept of crystal structure material. The results of the paired sample t-test analysis show that the Problem Based Flipped Classroom significantly influences learning outcomes with a t value of 11.439 with a significance of 0.000. Students' understanding of crystal structure material has increased with an N-Gain of 0.75, which is in the high category. This means that the pretest and posttest scores have a high increase. While the results of the effect size test obtained a score of d = 2.86, which means that learning with the Problem Based Flipped Classroom has a strong effect on student learning outcomes on crystal structure material.

Keywords Crystal structure, Problem Based Flipped Classroom, Concept understanding

1. INTRODUCTION

In general, prospective physics teachers are required to master physics content, and how to teach it (Wenning, 2006). Mastery of content is very important because it is part of professional competence. Mastery of good content will impact prospective teachers with an innovative attitude toward learning (Rollnick, 2017). The various innovative prospective teachers in question can be seen from their ability to determine the order of learning and themes from various concepts to guide students in the inquiry process in class (Purwaningsih, R, 2021). Based on this, understanding the concept is very important for prospective teachers because it is part of improving their quality as teachers and the basis for improving the quality of education.

Understanding the concept of prospective physics teachers is facilitated through lectures or learning in class. For example, in the Physics Education study program at the Indonesian University of Education (UPI), one of the courses presented to prospective physics teachers is Solid Matter Physics. Solid Substance Physics is one of UPI's elective courses in Physics Education. One of the materials in Solid Substance Physics is studying crystal structures. This material is important to learn as a basis for broadening and, at the same time, supporting the knowledge and understanding of prospective physics teachers towards their school material, besides playing a role in their professionalism as a physics teacher in high school (Parno, 2012)

Field conditions have not supported the importance of this crystal structure material. Based on research conducted by Ardhuha et al. (2019), students generally experience some difficulties in learning this material, including students having difficulty understanding terms in teaching resources, difficulties analyzing a crystal lattice, difficulty

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solving the problems contained in the problem, difficulty determining the Miller index of a crystal field. The findings during learning show that many students cannot achieve the expected learning outcomes, so they experience conceptual difficulties. This is obtained based on a review of the results of tests or exams, which shows that the percentage level of passing in this material only reaches 30%. The difficulties experienced by students are common. Even though they have completed many questions in the learning material during lectures, they still need help with conceptual difficulties for students (Byun. T, 2014). The difficulties experienced by students in understanding the concept of the crystal structure are caused by a need for more reading sources, such as textbooks, that can help strengthen understanding so that innovation is needed in learning. (Novia, H. 2013).

The learning process in the classroom generally begins with providing knowledge information directly, either through discussions, PowerPoint presentations, or presentation activities carried out by students. It ends with examples of questions and exercises to be completed at home. The learning model lecturers use in lectures greatly influences student learning processes and outcomes. Findings in the field show that generally, learning is carried out through providing information directly to students or using certain methods only or not varying, which tend not to give birth to student-centered learning. As a result, students tend to experience difficulties in building their knowledge independently (Sinaga, 2017). The occurrence of learning does not vary, considering that the time allocation for lectures in the classroom is very limited, so the limited time allocation becomes one of the factors that hinder lecturers from presenting student-centered learning, namely time allocation (Sinaga, 2017). So, learning is needed to facilitate flexibility in student study time and build student understanding.

One learning model that can support student study time allocation factors is Flipped Classroom. The advantages of using this learning model include student learning resources presented in the form of videos that are studied before lectures begin as a basis for knowledge so that classes can focus on building discussion processes and solving problems students raise. This learning model has no limitations in teaching space (Akçayir, 2018). Such a learning process can facilitate students to build their knowledge. It can also be used as a form of preparation before attending lectures so that lectures will effectively build conceptual understanding and training skills in solving problems (Subali B et al., 2015). In addition, this learning model also makes students push themselves to become independent learners (O'Flaherty & Phillips, 2015).

Flipped Classroom was introduced as a learning model by Bergmann and Sams (2012) to minimize the shortcomings of traditional learning methods, which are considered ineffective and sometimes fail to engage students during class learning. Flipped Classroom is a learning activity by minimizing instruction (in the form of providing knowledge information) directly and maximizes each student's interaction with learning resources (Johnson, 2012). The learning resources are reading material or learning videos (Alamri, 2019; Damayanti et al., 2016), carried out before lectures. So that students can focus on starting discussions, exchanging knowledge, and solving a problem in class. Thus Flipped Classroom can facilitate student-centered learning (Aşıksoy & Ozdamli, 2016; Nolam et al., 2021), has the potential to provide learning that is more structured and involves active participation from students in learning activities (sterlan et al., 2020; Aguilera- Ruiz et al., 2017; Aprianto, Ritonga, et al., 2020). In addition, learning must also be able to train students to find concepts and solve problems, so the Problem Based Flipped Classroom learning model can potentially support these learning conditions. Based on this, this study aims to examine the application of the Problem Based Flipped Classroom to improve students' conceptual understanding of physics teacher candidates on crystal structure material.

2. METHOD

This study uses a quasi-experimental method with a one-group pretest-posttest research design. In this research design, students were given a pretest regarding conceptual understanding before being given treatment to research subjects to determine the initial conditions of the class of students involved. After the treatment, students were given a posttest to measure the level of students understanding of concepts related to crystal structure material. The following research design used is shown in Table 1

Table 1 Research design one group pretest-posttest design.

O	X	O
Pre-test (Concept Understanding Test)	Treatment (Problem-Based Flipped Classroom Learning Model)	Post-test (Concept Understanding Test)

In general, the implementation of the research is divided into three stages, namely the preparation stage, the implementation stage, and the final stage. Each stage is outlined in the research procedure, as shown in Figure 1.

Based on Figure 1, the initial stage of learning using the problem flipped classroom model begins with preparing lecture material that refers to the RPS for the solid matter Physics course. The prepared lecture material includes learning videos, Teaching Materials in the form of learning

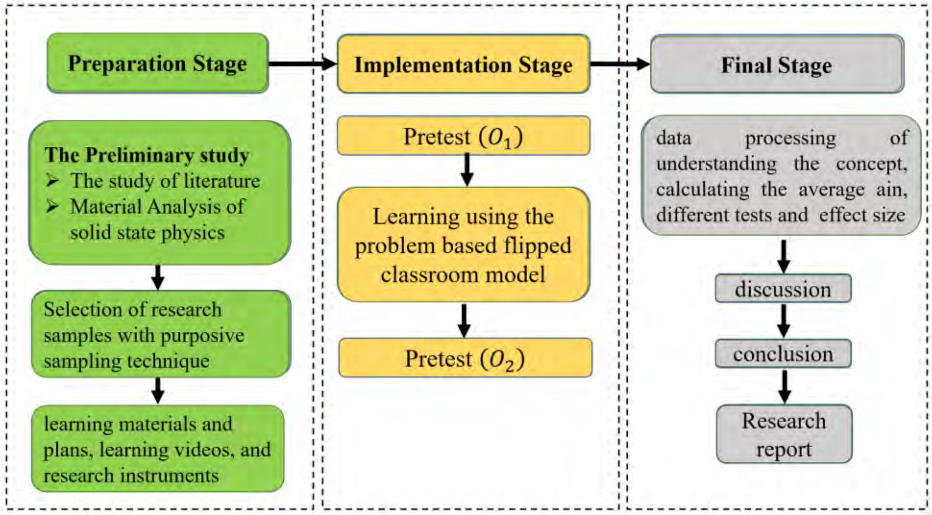

Figure 1 Research procedure

modules and Resume Slides with examples of practice questions. In the next stage, the learning tools that have been prepared are delivered to students via Whatsapp, which is uploaded before the lecture day is carried out so that students have more time to prepare material that can be discussed during lectures. An overview of the learning module and learning video material slides are shown in Figure 2 and Figure 3

The next activity carried out outside the classroom is that students carry out independent learning of the learning tools that have been distributed, with the aim of students practicing their ability to remember and understand by

Table 2 Implementation of lectures using the problem-based flipped classroom learning model

Stages	Flipped classroom learning model	Lecturer Activity	Student Activity
OUT-OF-CLASS PRACTICE (Students)	Before class	Lecturers prepare 1) material in the form of PPT and video, 2) practice questions, and 3) make assignments.	Prepare learning devices in the form of gadgets or laptops
	Inform students of the problem-based flipped classroom learning model.	Lecturers inform students via Whatsapp about flipped classroom learning. At this stage, the lecturer provides an overview of the learning that students must carry out	Students listen to online information submitted by lecturers regarding implementing the learning system using a flipped classroom.
	Explain to students how to access learning materials and learning videos.	1. The lecturer informs students that learning materials and learning videos can be accessed via a link sent via the WhatsApp group. 2. Lecturers give assignments to students to understand the material that is listened to through learning videos and provide solutions to the problems that have been presented	Students listen to, and study learning material delivered via PPT and video, then analyze problems related to crystal structure material provided by lecturers delivered via video and look for alternative solutions.
CLASSROOM PRACTICE (teacher and students)	Lecturers explore the initial knowledge that students have acquired during the learning stages outside the classroom	The lecturer collects and directs various questions from students without giving comments first.	Students explain the concepts they have learned during learning outside the classroom
	Group discussion tosolve on the problem given in the video.	The lecturer acts as a facilitator and does not provide explanations. Lecturers guide so that students understand what their friends convey. Lecturers interact with students actively to analyze, evaluate and construct the concepts learned.	Students ask each other questions between groups and within groups and respond to the questions asked. Students must also verify the discussion results through presentations in their respective groups.
	Create a learning outcomes assessment system	Lecturers conduct student assessments through post-test activities related to understanding concepts.	Students work on the posttest.

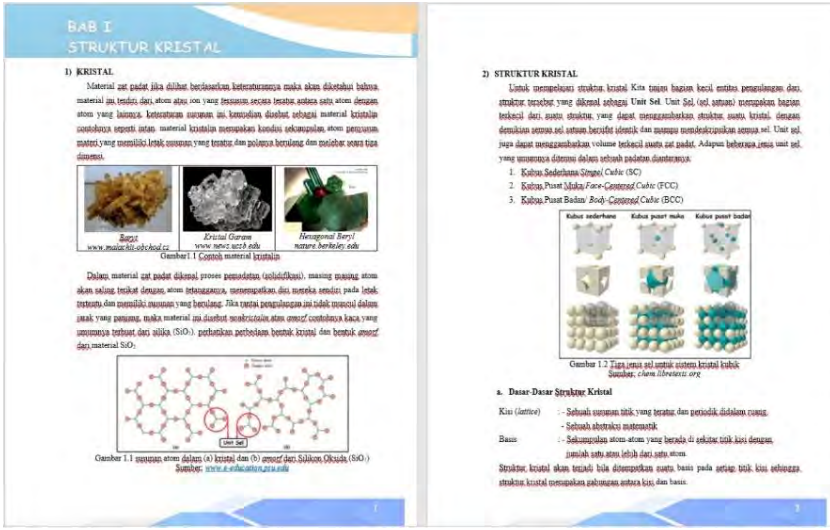

Figure 2 Crystal structure learning module

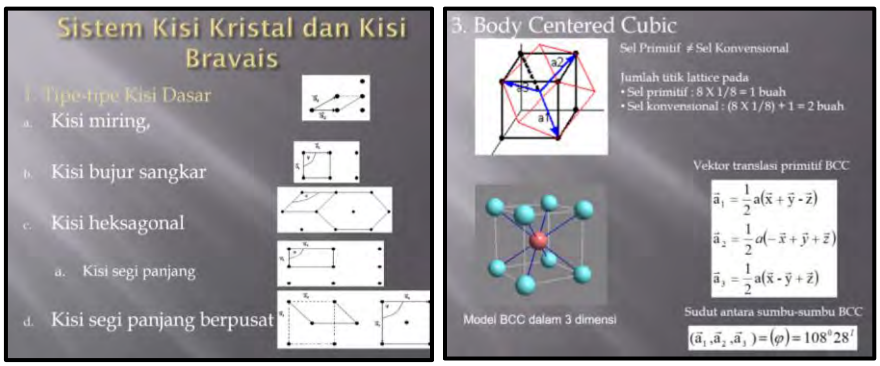

Figure 3 material in the video for the flipped classroom

1. What is lattice, base, and crystal structure?
2. What is meant by conventional cells and primitive cells?
3. Draw primitive cells using Weigner Seist!
4. Determine the number of lattice points of conventional cells and primitive cells for hexagonal body-centered cubic (BCC) and face-centered cubic (FCC) crystals.
5. Two fields using primitive axes in the FCC cube have indexes $(1\ 1\ 2)_p$ and $(1\ 2\ 1)_p$ Show the two fields using two different pictures, and if the conventional axis is used, what are the indexes of the two fields

Figure 4 Research instrument for understanding the concept of crystal structure material

increasing their interaction with teaching materials. While the activities are carried out in the class that the lecturer only acts as a facilitator in the lecture process, the lecturer also provides topics of discussion that can be discussed with the whole class on each concept. The following is an overview of the activities in the lecture process with the Flipped Classroom model. The implementation of this lecture is carried out based on the syntax of the Flipped classroom learning model, which is based on the theory of Bergmann & Sams (2012), except that the lecturer directs it to solve problems related to crystal structure material as shown in Table 2

Sampling in this study uses a purposive sampling technique. Meanwhile, the research subjects involved were 16 students in the seventh semester of the Physics education program who took the Solid Substance Physics course in the 2021/2022 academic year. The research instrument used was in the form of tests of students' mastery of the concept of Solids Physics material in the Crystal Structure chapter with several concepts including lattice, basis, crystal structure, conventional cells, primitive cells, describing primitive cells using Weigner Seist, Number of lattice points of conventional and primitive cells for Hexagonal crystals, Body Center Cube (BCC) and Face Center Cube (FCC) and determined the index between the two planes. The instrument used is shown in Figure 4

Based on Figure 4. The question consists of 5 numbers, but for number 1, it consists of 3 questions, namely explaining the concepts of lattice, basis, and crystal structure; for number 2, there are two questions, namely explaining the concept of conventional cells and primitive

Table 3 Recapitulation of validity and reliability test results

No	Question	Topic	r_{count}	r_{table}	Information	Reliability
1	(1)	lattice	0.901	0.497	Valid	
	(2)	base	0.674	0.497	Valid	
	(3)	Crystal structure	0.746	0.497	Valid	
2	(4)	Conventional cell	0.616	0.497	Valid	
	(5)	Primitive cell	0.752	0.497	Valid	0,830
3	(6)	Describe primitive cells using Weigner Seist	0.352	0.497	Invalid	(Reliable)
4	(7)	Determine the number of conventional cell lattice points	0.498	0.497	Valid	
	(8)	Determine the number of primitive cell lattice points.	0.610	0.497	Valid	
5	(9)	field index on the FCC cube	0.733	0.497	Valid	

cells, number 3 only has 1 question is describing primitive cells using Weigner Seist, number 4 has two questions, namely determining the number of lattice points of conventional cells and primitive cells and for number 5 there is 1 question, namely regarding the field index on the FCC cube. Based on this, it was concluded that this instrument consisted of 5 numbers with nine questions.

Before using this instrument, a content validity and reliability test were carried out, where the validity test used the product-moment correlation coefficient. In contrast, the reliability test used the Cronbach Alpha formula to obtain a valid and reliable instrument. The results of calculating the validity and reliability tests can be seen in Table 3.

Based on table 3, from the nine questions tested, it can be concluded that eight questions are valid. In contrast, 1 question is not valid, but overall the instrument used has a reliability value of 0.830 with a reference value of 0.79, so Cronbach's Alpha value> 0.70, which concluded that this instrument is reliable.

Based on the pre-test and post-test results, it can be analyzed whether there is an increase in students' conceptual understanding by comparing the average achievement of pre-test and post-test scores. At the same time, the data analysis technique uses the Kolmogorov-Smirnov test for the normality test and the Levene test for the test. Homogeneity. Given the relatively small number of samples of 16 students, the Kolmogorov-Smirnov test was carried out using the Exact method to determine if the data obtained were normally distributed (Mehta & Patel, 2013). Once it is known that the research data are normally distributed, then a hypothesis test is carried out using the paired sample t-test. The research hypothesis is formulated as follows:

Ho: There is no increase in understanding of concepts through problem-based flipped classrooms

Ha: There is an increased understanding of the concept through a problem based flipped classroom.

Guidelines for decision-making in the paired sample t-test based on the significance value (Sig.) proposed by Santoso (2014), namely 1) if the value of Sig. (2-tailed) <0.05, then Ho is rejected and Ha is accepted; 2) If the Sig. (2-tailed)> 0.05, then Ho is accepted, and Ha is rejected.

To see how much an increase in conceptual understanding using the problem based flipped classroom learning model is obtained based on the N-gain test (Hake, 1999) from the pretest and posttest scores using the following equation:

$$\langle g \rangle = \frac{\langle S_{post} \rangle - \langle S_{pre} \rangle}{100\% - \langle S_{pre} \rangle} \quad (1)$$

The information for the above formula is $\langle g \rangle$ = normalized gain score, S_{post} = post-test score, S_{pre} = pretest score. Meanwhile, the magnitude of the g factor can be interpreted as shown in Table 4

Table 4 Interpretation of the average N-gain score

Score	Criteria Interpretation
N-gain > 0,7	High
0,3 ≤ *N-gain* ≤ 0,7	Medium
N-gain < 0,3	Low

The effect size test is used to see how much the effectiveness of learning is using the Problem Based Flipped Classroom model. This test is used to measure the scale of the effectiveness of the learning model that has been carried out (Lakens, 2013).

$$d = \frac{\bar{x}_t - \bar{x}_c}{S_{pooled}} \quad (2)$$

with,

$$S_{pooled} = \sqrt{\frac{(n_t - 1)s_t^2 + (n_c - 1)s_c^2}{n_t + n_c}} \quad (3)$$

The explanation for the formula above is d = Cohen's effect size; $\bar{x}$= mean; s_t= posttest standard deviation; s_c= pretest standard deviation; n = number of samples. From the acquisition of the effect size test score, it can be interpreted based on the adaptation of Cohen (1988), as shown in Table 5. After the statistical test draws,

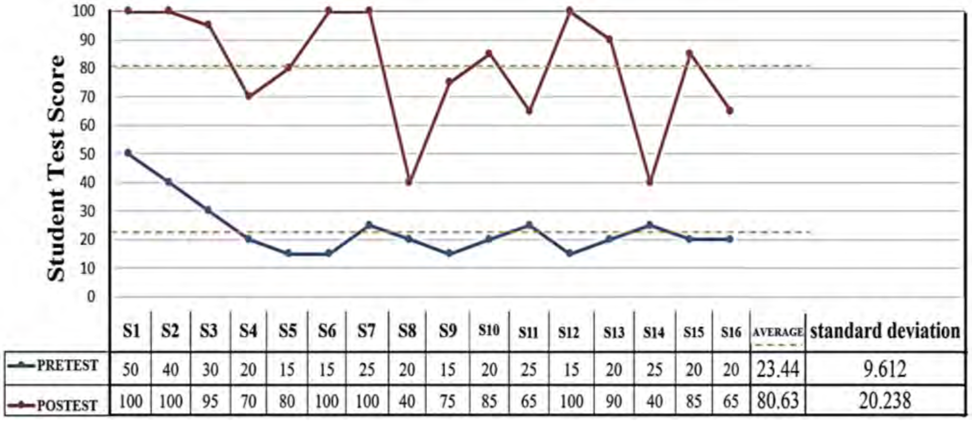

Figure 5 Student pre-test and post-test scores

Table 5 Interpretation of effect size scores

Score	Criteria Interpretation
0 – 0,20	Very weak effect
0.,21 – 0,50	Weak effect
0,51 – 1,00	Moderate effect
>1,00	Strong effect

conclusions are based on the problems and research objectives.

3. RESULT AND DISCUSSION

In this study, problem-based flipped classroom learning was used, divided into two stages, namely the stages outside and in the classroom, carried out on different days. Prior to the implementation of learning, a pretest is carried out. At the stage outside the classroom, the lecturer arranges the material in the form of PPT, modules, and learning videos which are then given to students online to be listened to simultaneously by informing them of the implementation of problem-based flipped classroom learning activities, which will be carried out at the next meeting in class. Meanwhile, during the stages in the class, the lecturer directs students to ask as many questions as possible related to crystal structure material. When learning in the classroom, the lecturer only facilitates student discussions and directs various questions that arise to find answers together. The answers formed in the discussions can build on each concept learned. After learning, the lecturer creates a scoring system, including conducting a pretest on crystal structure material. The activity pattern, which is divided into two learning stages, is based on the theory of Bergman & Sams (2012), Reidsema, Kavanagh, Hadgraft, & Smith (2017), and Baytiyeh (2017) only in every implementation of learning directed to solve problems. Based on the acquisition of data, the results of the pretest and posttest are shown in Figure 5

Figure 5 illustrates that the results of the pretest scores of 16 students on crystal structure material have the lowest score of 15 and the highest score of 50. No student achieves a minimum understanding ability with a score of 70. While the post-test results show that the lowest student score is 40 and the highest score is 100, it can be said that the number of students who achieve the standard of comprehension ability is 14 people while two others are still below the minimum standard.

Based on the student test scores obtained, a normality test was carried out using the Kolmogorov-Smirnov test using IBM SPSS 25. Given the relatively small number of samples, the Kolmogorov-Smirnov test was carried out using the Exact method to determine whether the data obtained was normally distributed. (Mehta & Patel, 2013). Based on this, the normality test results obtained in this study are shown in Table 6.

Table 6 Kolmogorov-Smirnov One Sample Normality Test

N	Sig.Pre-test	Sig. Post-test	Significance	Description
16	0.177	0.688	0.05	Normal

Table 6 shows that the sig. The exact pretest was 0.177, while the posttest score was 0.688. Both values were known to be greater than 0.05, meaning that at a significance level of 5%, the normalized gain pretest and posttest scores of learning outcomes in crystal structure material come from normally distributed populations. Under normal conditions, the number of research subjects described is limited to the Kolmogorov-Smirnov test with the Exact or Monte Carlo method due to the relatively small number of samples that affect the variance condition. The Homogeneity test is carried out using the Levene test. Furthermore, the homogeneity test in this study is shown in Table 7

Table 7 Levene's test homogeneity

Levene statistic	df1	df2	Sig
1.696	1	0,7544	0,197

Table 7 shows that the significance of homogeneity is 0.197, which means that at a significance level of 5%, the research subject data obtained has a homogeneous condition with a statistical level of 1.696. By knowing that the samples obtained are normally distributed and have homogeneous conditions. Then a different test or hypothesis testing can be carried out. The researcher tested the hypothesis using the Paired Sample t Test. This result test was used to find out whether there was a difference in the average of two paired samples. The results of the t-test are described in the following three output tables

Table 8 Paired sample t-test results (Output 1)

Paired Samples Correlation					
		Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	Pretest	23.438	16	9.61228	2.40307
	Postest	80.625	16	20.23817	5.05954

Table 8 or output one above summarizes descriptive statistics based on pre-test and post-test data. It was found that the average pre-test value was 23.4375 while the post-test average value was 80.6250. with a total of 16 students (N). The Std. The deviation score on the pre-test was 9.61228, and the post-test was 20.23817. As for the value of Std. The mean error for the pre-test is 2.40307, and for the post-test, it is 5.0595. The results of output 1 show the average value of students' understanding of crystal structure concepts at pre-test 23.4375 < Post-test 80.6250, meaning that descriptively there is a difference in average students' understanding of concepts between pre-test and post-test.

Table 9 Paired sample t test results (Output 2)

Paired Samples Correlation				
		N	**Correlation**	**Sig.**
Pair 1	PRETEST POSTEST	16	0.262	0.326

Table 9 or output two above is the result of the Paired Sample T-test (paired t-test) is the result of the correlation or relationship between the two data, namely the pre-test, and post-test. The correlation referred to in this case is the Pearson product-moment. Based on the table above, the correlation coefficient (Correlation) is 0.262 with a sig. 0.326 because of the value of Sig. 0.326> 0.05, it can be concluded that there is no relationship between the pre-test and post-test.

Table 10 or output three above is data regarding whether there is a difference or an increase in student's conceptual understanding of crystal structure material before and after lectures with the problem based flipped classroom model. Based on the Paired Samples Test table, the sig is known. (2-tailed) is 0.000 <0.005, then H_o is rejected, and H_a is accepted. So there are differences in the average understanding of concepts, or other words, there is an increase in students' conceptual understanding skills through problem based flipped classroom learning.

Table 10 also explains information regarding the Mean Paired Difference value of -57,187. This value indicates the difference in the average understanding of students' concepts in the pre-test with the average post-test understanding or 23.438-80.625 = -57.18 and between -67.843 to -46.531 (95% Confidence Interval of the Difference Lower and Upper). Furthermore, it is known that the t count is negative, namely -11,439. This negative sign is because the average value of students' understanding of crystal structure concepts at the pre-test is lower than the average students' understanding of the concept of the crystal structure at the time of the post-test. In cases like this, a negative t-count value can have a positive meaning so that the t-count value becomes 11.439.

After carrying out statistical tests, based on the pretest and posttest value data shown in Figure 5, it can be analyzed to increase understanding of the concept of crystal structure material which is determined by N-Gain analysis of the understanding of the concept. By using SPSS, the N-Gain score is obtained as follows.

Table 11 Improved understanding of the concept reviewed through N-Gain

Maximum N-Gain	Minimum N-Gain	Average N Gain	Category
1.00	0.20	0,7544	High

Table 11 shows increased student conceptual understanding of crystal structure material using the problem based flipped classroom model. The table shows that the N-Gain Score results are obtained with an average value of 0.75 which is in the high category, meaning that there is an increase in conceptual understanding through the learning model Problem Based Flipped Classroom. Meanwhile, to determine the effectiveness of the problem-based flipped classroom model, it can be seen from the learning outcomes in crystal structure material by conducting a statistical effect size (d) test. The result of the effect size test in this study was 2.86. If viewed based on the category of effective magnitude, the score d = 2.86 can be interpreted as a strong effect. This means that the

Table 10 Paired Sample T Test Results (Output 3)

		Paired Differences			*95% Confidence Interval of the Difference*				
		Mean	**Std. Deviation**	**Std.Error Mean**	**Lower**	**Upper**	**t**	**df**	**Sig.(2-tailed)**
Pair 1	PRETEST &POSTEST	-57.187	19,997	4.999	-67.843	-46.531	-11.439	15	.000

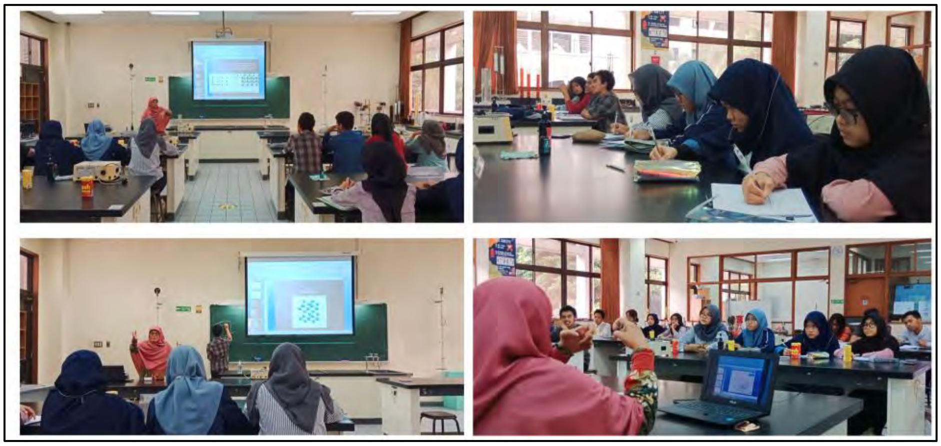

Figure 6. Learning in the classroom

problem-based flipped classroom model strongly affects student learning outcomes in crystal structure material.

In terms of the individuality of each student (S), there were 16 students. It was found that student 1 (S1) had difficulty with question number 3 (Q3) related to the concept of crystal structure, question number 4 (Q4) related to the conventional cell concept and problem number 7 (Q7) related to how to determine the number of conventional cell lattice points, even this difficulty is also experienced by other students which can be seen based on the acquisition score of each question that no student can answer perfectly for these three questions. Efforts to overcome these problems include providing more practice questions and discussing the practice questions carried out within the scope of each student discussion group. Based on this, it is known that by increasing the intensity of the discussion related to the problem of students' understanding difficulties within the scope of their study group, students become more active in showing good responses related to questions or responses from other students.

As for S9 and S14 students who seemed to have difficulty studying crystal structure, grouping efforts were made by placing them in the most active discussion group so that the two students got the greater motivation to understand the concepts they considered difficult. The amount of intensity of discussion that is carried out is one of the factors in increasing the understanding of concepts in each student in this lesson. This finding is related to research findings by Basal (2015), Herlindayana et al. (2017), and Kozikoğlu (2019), which explain that flipped classrooms can make students more active through discussions in building an understanding of the concept. As for some descriptions of learning that are carried out while in class, as shown in Figure 6

This improvement in learning outcomes is, of course, inseparable from the role of learning activities carried out with the problem-based flipped classroom model, which begins with giving orientation to students on a problem contained in crystal structure material, where students will study the problem to find a solution. In their learning, the lecturer displays the problems and concepts contained in the crystal structure material through a video that is watched before the lecture begins. Various interesting phenomena shown in the video will motivate students to learn more deeply about the various concepts contained in the video (Arends, 2008).

Based on the implementation of learning using the problem-based flipped classroom model, the findings of the factors that led to an increase in conceptual understanding in this study were a more flexible allocation of student learning time. Students are required to interact with longer learning material. Besides that, knowledge when learning in class is built by discussing a posed problem. This was also found in Meilantari's research (2021), Nouri (2016), and Yulianti et al. (2021), who explained that learning with a flipped classroom has flexibility in time and learning space. The relationship between time allocation and the potential for increased opportunities for students to learn the material also follows the research results of Havwini & Wu (2019) and Låg & Sæle (2019).

Other findings in this study are related to student discussion activities which are another factor that causes an increase in student understanding. However, based on the data shown in Figure 6, one student still needs help, or the result of understanding the concept of the crystal structure still needs to be below the minimum score. Activities in class can happen because students need to get used to the learning being done, while 14 other students get scores above the average. This is considering that the discussion is carried out as a process between students exchanging ideas. At the same time, the lecturer provides direction in the discussion process so that all students get maximum understanding. This discussion process is an alternative that can be carried out in developing students' conceptual understanding, especially in the field of science (Erduran, 2004). In addition, the discussion process in solving problems will also bring up various alternative solutions to problems so that students' conceptual understanding can be formed in more depth (Newton, 2010)

From the advantages of the flexibility aspect of time allocation and discussion processes that occur in class, a student's conceptual understanding of crystal structure material can be obtained using the Problem-based Flipped Classroom model. Thus this model can provide changes in student thinking that can be seen during the lecture process. Students become more active in conducting discussions because before lectures begin, students focus on studying the material first as initial preparation for lecture activities in class, either in the form of interactive conceptual discussions that occur in groups or between students and lecturers or in solving problems on crystal structure material.

4. CONCLUSION

The use of Problem-Based Flipped Classrooms in solid matter physics learning, especially in crystal structure material, has succeeded in increasing student learning outcomes, as indicated by an increase in the value of understanding the concept of crystal structure. This research provides an alternative to active and cooperative contextual learning compared to conventional learning, which tends to be informative. The problem-based Flipped Classroom, which focuses on aspects of understanding concepts, plays a significant role in encouraging students to prepare themselves before attending lectures. The impact is that when students learn in class with prior knowledge that has been prepared, and even students can bring up many problems related to crystal structure material, learning in class can fully become a place for discussion in solving these problems. Understanding that is built through the process of discussion and problem solving with the preparation of prior knowledge will be formed in depth compared to understanding that is formed through information processes only.

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