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THE INFLUENCE OF PROBLEM-BASED LEARNING-FLIPPED CLASSROOM (PBL-FC) ON MATHEMATICAL ARGUMENTATION SKILLS

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ABSTRACT

This study examines the influence of the Problem-Based Learning-Flipped Classroom (PBL-FC) model combined with learning independence on students' mathematical argumentation skills. Utilizing a quasi-experimental design, the research involved 42 fourth-semester students from IAIN Kerinci, randomly selected from 66 students. The study employed tests and questionnaires to assess the students' argumentation skills and learning independence. Results indicated that the PBL-FC model significantly improved the students' argumentation skills, with an average score of 70.2 compared to 62 in the control group. Statistical tests of the between-subject effect yielded a significance of 0.003 (sig < 0.05), confirming a notable difference in argumentation skills. Furthermore, a significant interaction effect was observed between learning independence and mathematical argumentation skills. Thus, integrating the PBL-FC model with learning independence effectively enhances students' argumentation skills. Future research should investigate applying the PBL-FC model to other subjects to evaluate its effectiveness broadly.

PENGARUH MODEL *PROBLEM-BASED LEARNING-FLIPPED CLASSROOM* TERINTEGRASI KEMANDIRIAN BELAJAR TERHADAP KETERAMPILAN ARGUMENTASI MATEMATIS

Kata Kunci:

Flipped classroom
Kemandirian belajar
Kemampuan argumentasi matematis
Problem based learning

ABSTRAK

Penelitian ini mengkaji pengaruh model *problem-based learning-flipped classroom model* (PBL-FC) yang dikombinasikan dengan kemandirian belajar terhadap keterampilan argumentasi matematis siswa. Menggunakan desain kuasi-eksperimen, penelitian ini melibatkan 42 mahasiswa semester empat IAIN Kerinci yang dipilih secara acak dari total 66 mahasiswa. Studi ini menggunakan tes dan kuesioner untuk menilai keterampilan argumentasi dan kemandirian belajar siswa. Hasil menunjukkan bahwa model PBL-FC meningkatkan secara signifikan keterampilan argumentasi siswa, dengan skor rata-rata 70,2 dibandingkan dengan 62 di kelompok kontrol. Uji statistik efek antar subjek menghasilkan signifikansi 0,003 (sig < 0,05), mengonfirmasi perbedaan yang mencolok dalam keterampilan argumentasi. Selanjutnya, ditemukan efek interaksi yang signifikan antara kemandirian belajar dan keterampilan argumentasi matematis. Dengan demikian, integrasi model PBL-FC dengan kemandirian belajar efektif meningkatkan keterampilan argumentasi siswa. Penelitian selanjutnya disarankan untuk meneliti aplikasi model PBL-FC pada mata pelajaran lain untuk mengevaluasi efektivitasnya secara luas.

1. PENDAHULUAN

Education worldwide currently emphasizes argumentation as one of the most crucial objectives for students [1]. Among the 21st-century competencies needed to face modern society's challenges are critical thinking, creativity, communication, social skills [2], [3] and argumentation skills [4]. Hence, equipping prospective teachers with the necessary skills to succeed in a dynamic educational environment is increasingly recognized as vital [5]. In mathematics, argumentation is essential for students' conceptual understanding, logical explanation and decision-making in problem-solving [6]-[8].

In mathematical education, argumentation serves to understand characteristics, explain phenomena [9], [10] and provide knowledge through communication [11]. Argumentation is proposing and defending opinions or conclusions using valid evidence and strong reasoning [12]. It involves extensive stages in science and mathematics, like evaluating and making scientific claims [13] or geometric proofs [14].

Engaging students in mathematical arguments supports language development and conceptual understanding as they use spoken and written language in coordination with mathematical representations to recognize patterns, make claims, develop, build and revise explanations, and communicate their mathematical knowledge [15]-[17], as a series of statements and reasons intended to reinforce the validity of a proposition [18].

In mathematical education, "argumentation" encompasses two different concepts. First, it indicates presenting mathematical arguments by students and lecturers in a classroom setting. Second, it refers to arguments put forward by researchers in mathematical education regarding the nature of mathematical learning and the effectiveness of mathematical teaching in different contexts [19]. Mathematical argumentation involves building persuasive arguments to demonstrate or explain the validity of mathematical statements or solutions to mathematical problems [7]. The effectiveness of argumentation in the classroom depends on active student participation in constructing, listening to, and responding to arguments and collaboration to reach mutual agreement [20].

Mathematical learning activities should provide students with opportunities to express their mathematical ideas and defend their beliefs argumentatively [13], [20], [21]. Students should be given the chance to understand and use mathematical concepts, language, and methods correctly. They should no longer be merely skilled in using mathematical rules or procedures expressed and performed by their lecturers without knowing the reasons behind them.

Many studies on mathematical argumentation skills do not guarantee that most people have mastered this ability [12]. Field data show that students' mastery of mathematical material is still low. According to data obtained during the course, only 32% of students received grades between A and B in the academic year 2018/2019, 38% in 2019/2020, 34% in 2020/2021, and 40% in 2021/2022. This condition indicates that most students in the Mathematics Education Study Program at the Islamic Institute of Kerinci still struggle with proving mathematical statements, the primary focus of this lecture. Indirectly, this also indicates students' lack of argumentation skills.

Additionally, students still have low learning independence. This is further emphasized by research stating that the learning culture among students in Indonesia is low, evidenced by findings that many students read books only because of tasks from lecturers, lack initiative in learning, study seriously only for exams, rarely reread taught material, ask superficial questions, submit assignments close to the deadline, not everyone contributes in group tasks, and copy or cheat from friends or the internet without reading the content first [22].

Aligned with current curricular guidelines, it's important to reflect on the use of active learning strategies, directly involving students in meaningful mathematical activities, contributing to reversing this situation [23]. Several studies have also been conducted to find suitable learning models to address these issues. Learning outcomes are influenced by many variables, such as clarifying the approach used, the setting and for what age group, and the learning outcomes to be achieved and measured [24]. Therefore, to improve students' argumentation skills in discrete mathematics, the researcher also chose learning that requires students to construct concepts through guided investigation using the PBL-FC model.

The appropriate learning model applied is the problem-based learning model constructed with the flipped classroom. Problem-based learning (PBL) and flipped classroom (FC) models are two learning approaches that have received significant attention in mathematics education literature. Research findings [25] show that PBL requires flexibility and dynamics from everyone involved and good management, including planning, implementation, monitoring, and evaluation. PBL users should be reminded that the large variation in PBL practices makes its effectiveness complex, and the current PBL still applies generally to all levels of education, so the goal of this research, mathematical argumentation skills, is not achieved [24], [26]. Therefore, the author modifies this PBL model by integrating flipped classrooms, combining both models to increase mathematical argumentation skills meaningfully.

This integration will serve as a solution to challenges in mathematical learning. The flipped classroom model is where students study lesson materials at home before class and engage in in-class activities like task completion and discussions on misunderstood concepts [27]-[29]. This is combined with the Problem-Based Learning (PBL-FC) model. This combination allows students to develop learning independence and enhance mathematical argumentation skills. On the other hand, learning independence is a crucial aspect of mathematical learning that can improve argumentation skills. Independent learners tend to have better argumentation skills, and more time allocated for independent learning in the curriculum correlates with faster student graduation rates [24]. Therefore, cultivating student independence and changing their perspective on their role in the learning process is central to the PBL-FC model.

Several studies on the PBL-FC model have been conducted, including its influence on critical thinking abilities [30], [31], its application to scientific literacy [32], and its use with ethnosciences in developing creative thinking skills [33]. However, there is a lack of research on the PBL-FC model integrated with learning independence for mathematical argumentation skills. The novelty of this research using the PBL-FC model integrated with learning independence lies in the innovative combination of two widely recognized educational approaches in mathematical education literature. By combining these strong approaches and focusing on developing mathematical argumentation skills, this study introduces fresh elements that could lead to a better understanding of how mathematical learning can be significantly improved. Moreover, combining these models offers the opportunity to leverage the strengths of each, allowing students to access materials before class and use class time for discussion, collaboration, and deepening their mathematical understanding.

Based on the problems outlined and the theoretical review, it is hypothesized that applying the PBL-FC model integrated with learning independence can address issues related to low mathematical argumentation skills in students. Specifically, this study aims to describe the improvement in students' argumentation skills after attending courses implementing the PBL-FC model integrated with learning independence in discrete mathematics subjects. The results of this study are expected to contribute to best practices in mathematics education, especially at the higher education level.

2. METHOD

This research employs a quasi-experimental approach, where treatments are not randomly assigned to participants [34]. Two student groups will be observed for their mathematical argumentation skills due to the applied learning treatment. One group will use the PBL-FC model, while the other will employ conventional teaching methods. Students are categorized into high and low levels of learning independence from each group to observe the interaction between the independent variable and the moderating variable on mathematical argumentation skills. The factorial design and obtained results are depicted as follows.

Table 1. Factorial Design

	A_1	A_2	μ
B_1	Y_{A1B1}	Y_{A2B1}	...
B_2	Y_{A1B2}	Y_{A2B2}	...
μ	...	...	X

Description:
A_1 : PBL-FC model
A_2 : Conventional model
B_1 : High learning independence
B_2 : Low learning independence
X : Interaction symbol

The population in this study comprised all fourth-semester students, totalling 66. Using a random sampling technique, the experimental group consisted of fourth-semester students from class IVa and the control group from class IVb, totalling 42 students. This research employed the test of between-subject effect to examine the interaction between the model and learning independence in influencing mathematical argumentation skills.

The instruments used in this study were questionnaires and tests. The questionnaire was administered to respondents to collect information about students' learning independence before and after the treatment. It consisted of 30 questions adopted from LASSI. Test questions aimed to measure mathematical argumentation skills consisted of 4 items using mathematical argumentation indicators, as listed in Table 2.

Table 2. Indicators of Mathematical Argumentation Skills

Indicator	Description
Claim	Students can provide reasons orally or in writing for deciding to solve a problem.
Grounds	Students can provide authentic data supporting the reasons stated in their claims.
Warrants	Students can make statements and connect reasons for claims supported by data.
Backing	Students can solve problems using existing theorems
Rebuttal	Students refute others based on theories they believe in

3. RESULT AND DISCUSSIONS

This section presents the research data. Analysis is conducted on whether there is an interaction between the teaching model used and students' learning independence in mathematical argumentation skills. The following hypothesis is formulated to test the presence or absence of interaction between the Teaching Model (X1) and Learning Independence (X2) on Mathematical Argumentation (Y). H1: There is an interaction between the teaching model (X1) and learning independence (X2) in influencing mathematical argumentation (Y). Here's an overview of the interaction between the model and learning independence in influencing mathematical argumentation. The interaction test results are presented in Table 3 below.

Table 3. Interaction between Teaching Model (X1) and Learning Independence (X2) on Mathematical Argumentation

	PBL-FC Model	**Direct Teaching Model**	**μ**
High Learning Independence	66,4	63,6	65
Low Learning Independence	72,4	60,9	66,65
μ	70,2	62	X

Based on the above table, there are differences in scores obtained from the two research groups. The argumentation scores achieved by students in the experimental group are higher than those in the control group. To understand the differences between the two groups, statistical tests are needed to determine the statistical significance of the data obtained. The statistical test aims to determine if there is an interaction between the teaching model and learning independence in influencing mathematical argumentation.

Testing the interaction between the teaching model and learning independence in influencing mathematical argumentation begins with a normality test of both groups' data. Based on the previous normality test, the data distribution is normal. Then, a homogeneity test of both research samples is conducted. Levene's test for homogeneity of variance used a significance level of $\alpha = 0.05$. The homogeneity test results for the experimental and control groups are shown in Table 4.

Table 4. Homogeneity Test of Teaching Model (X1) and Learning Independence (X2) on Mathematical Argumentation (Y) in Experimental and Control Classes

F	**df_1**	**df_2**	**Sig**
.034	3	38	.992

Based on the above table, it can be concluded that both experimental and control classes have homogenous variance. Next, to gain a deeper understanding of the impact of the different treatments in the study and their achievements on the observed aspects, an analysis of the difference test is conducted based on two categories of high and low learning independence.

Testing the impact of the interaction between the PBL-FC Model and direct teaching and learning independence (X2) on mathematical argumentation (Y) is presented in Figure 1 and Table 5 below. Based on the interaction shown in Figure 1, it can be concluded that the increase in argumentation from students with low to high learning independence experiences a greater change in the experimental class compared to the control class (not equal). This implies that learning independence responds differently in both models in influencing argumentation. In other words, there is an interaction between the Model and Learning Independence in influencing mathematical argumentation. Subsequently, a test of the interaction model between the model and learning independence on mathematical argumentation skills was conducted using the test of between-subject effects. The test of between-subject effects yielded results, as shown in Table 5.

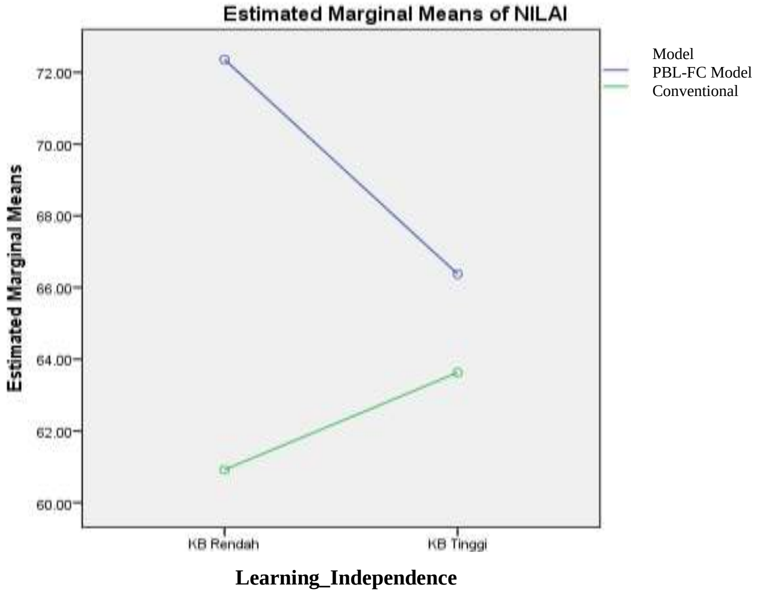

Figure 1. Interaction of the Model with Learning Independence in Influencing Mathematical Argumentation

Table 5. Test of Between Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	918.690[a]	3	306.230	6.068	.002
Intercept	171244.126	1	171244.126	3392.951	.000
Model	497.501	1	497.501	9.857	.003
Learning_Independence	26.479	1	26.479	.525	.473
Model * Learning Independence	186.590	1	186.590	3.697	.062
Error	1917.881	38	50.471		
Total	187376.000	42			
Corrected Total	2836.571	41			

The table above shows that the achievement of mathematical argumentation skills in students receiving the PBL-FC model is generally higher than those using conventional learning models. The experimental class showed better performance in students with low learning independence, while in the control class, high argumentation skills were achieved by students with high learning independence. The table shows the significance value of the Model = 0.003, Sig < 0.05, meaning there is a difference in skills between those using the PBL-FC Model and those using direct learning models.

The research findings generally indicate that the PBL-FC model is more effective than conventional models in enhancing students' mathematical argumentation skills. Moreover, independence also affects learning outcomes, as reinforced by previous studies showing that students with high learning independence tend to monitor, evaluate, and effectively regulate their learning patterns; save time in completing tasks; and achieve high scores in science [21], [35], [36]. Other research confirms that students with learning independence show capabilities in using cognitive strategies to process information, possess metacognition to plan and direct their mental processes, exhibit adaptive motivational beliefs and emotions such as a sense of high academic ability, and plan and control time and effort for tasks by creating an enjoyable learning environment [37]. From the statements above, it is evident that independence also influences mathematical argumentation skills besides the learning model.

The primary objective of the PBL-FC model is to educate students to be independent. In every syntax of the PBL-FC model, students are expected to be self-reliant in performing the steps. Here, independence means students initiate their learning, not just receiving information from lecturers but actively seeking information and preparing for lectures. Learning independence allows one to regulate one's behaviour, emotions, and actions towards success in the campus environment, work, and life [38]-[40]. Student-oriented teaching enables more participation in learning and helps them achieve their learning goals [41].

Learning independence becomes crucial when students in a class face an environment that requires active interaction among all components. However, students may struggle to manage thoughts and control behaviour and emotions without high learning independence. Students with high learning independence demonstrate better argumentation skills when using the PBL-FC model. The average argumentation skill score for those using the PBL-FC model with high independence is 66.4, while 63.6 for those using conventional models with high independence. In contrast, the average score for the PBL-FC model with low learning independence is 72.4, and for conventional models with low independence, it is 60.9.

The difference in argumentation skills among students is also influenced by learning independence. This is supported by research stating that learning independence is crucial in achieving learning objectives, as evidenced by learning outcomes [42].

The interaction between the learning model and learning independence through essay tests explains that this process affects mathematical argumentation in MATDIS lectures. Research findings confirm that learning independence influences student learning outcomes in mathematics education, contributing 15% to student learning outcomes [43].

Based on the analysis of the second hypothesis test, it can be concluded that there is an interaction between the learning model (X1) and learning independence (X2) in influencing mathematical argumentation (Y). This means learning independence responds to the model in influencing mathematical argumentation. The results of this research provide a strong scientific foundation and practical guidance for educators to improve students' mathematical education. It also allows for developing more effective teaching methods to enhance mathematical argumentation skills, a crucial competency for a deep understanding of mathematics.

The PBL-FC model can be used as an alternative learning method to improve students' mathematical argumentation skills in discrete mathematics courses. Furthermore, the PBL-FC model should be tested in other subjects, especially those requiring analysis and critical thinking skills. Regarding limitations in this study, improvements to the learning tools are needed, particularly adding problems that can train mathematical argumentation skills.

4. CONCLUSION

The analysis concludes that there is an interaction effect between the teaching model and learning independence on mathematical argumentation skills. With a significance value of the model = 0.03, sig < 0.005. The achievement of students' mathematical argumentation skills who received learning with the PBL-FC model is higher than that of direct teaching models, with an average score of 70.2 for PBL-FC and 62 for direct teaching.

Some recommendations based on these findings include the following: First, the PBL-FC model should be routinely used by lecturers for teaching discrete mathematics courses. Second, future researchers are encouraged to test this model on students of different levels or at different universities. Researchers applying the PBL-FC model should investigate aspects of mathematics learning outcomes beyond mathematical argumentation.

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