Jurnal Edutech Undiksha
Volume 12, Number 2, Tahun 2024, pp. 216-223
P-ISSN: 2614-8609 E-ISSN: 2615-2908
Open Access: https://doi.org/10.23887/jeu.v12i2.91742

Advancing Problem-Solving Competencies in Prospective Science Teachers: Comparative Insights on the Flipped Classroom and Direct Instruction Models

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ARTICLE INFO

Article history:
Received August 09, 2024
Accepted December 08, 2024
Available online December 25, 2024

Kata Kunci:
Kemampuan Pemecahan Masalah, Flipped Classroom, Direct Instruction

Keywords:
Problem-Solving Skills, Flipped Classroom, Direct Instruction

ABSTRAK

Peningkatan keterampilan pemecahan masalah merupakan tantangan utama dalam pendidikan sains. Model pembelajaran tradisional, seperti Direct Instruction (DI), cenderung membatasi keterlibatan siswa, sehingga diperlukan pendekatan inovatif, seperti Flipped Classroom (FC). Penelitian ini bertujuan untuk menganalisis perbedaan keterampilan pemecahan masalah antara siswa yang diajar menggunakan model FC dan siswa yang diajar menggunakan model DI. Penelitian ini menggunakan desain eksperimen semu dengan rancangan non-equivalent pretest-posttest control group. Sampel penelitian terdiri atas 34 mahasiswa calon guru sains semester empat yang dipilih secara acak. Kelompok eksperimen (model FC) dan kelompok kontrol (model DI) masing-masing terdiri atas 17 mahasiswa. Keterampilan pemecahan masalah diukur menggunakan tes esai pada mata kuliah biofisika dengan koefisien reliabilitas 0,717. Data dianalisis secara deskriptif dan menggunakan uji Anakova pada taraf signifikansi 5%. Hasil penelitian menunjukkan peningkatan keterampilan pemecahan masalah pada kedua kelompok dengan kategori sedang, yaitu N-gain sebesar 64,30 pada model FC dan 32,94 pada model DI. Analisis data menunjukkan terdapat perbedaan yang signifikan antara kedua kelompok (p < 0,05), di mana kelompok FC memperoleh skor keterampilan pemecahan masalah yang lebih tinggi. Kesimpulannya, model FC lebih efektif dalam meningkatkan keterampilan pemecahan masalah dibandingkan model DI. Strategi pembelajaran aktif dalam model FC mendorong keterlibatan kognitif yang lebih mendalam dan mendukung pengembangan keterampilan kognitif esensial dalam pendidikan sains.

ABSTRAK

Improving problem-solving skills is a key challenge in science education. Traditional models like Direct Instruction (DI) often limit student engagement, prompting the need for innovative approaches such as the Flipped Classroom (FC) model. This study aims to analyze differences in problem-solving skills between students taught using the FC model and those taught using the DI model. This quasi-experimental research employed a non-equivalent pretest-posttest control group design. The sample, consisting of 34 fourth-semester prospective science teachers, was selected through random sampling. The experimental group (FC model) and control group (DI model) each included 17 students. Problem-solving skills were assessed using an essay test in a biophysics course, with a reliability coefficient of 0.717. Data were analyzed descriptively and using ANCOVA at a 5% significance level. The results showed medium improvements in problem-solving skills for both groups, with N-gains of 64.30 for the FC model and 32.94 for the DI model. A significant difference was found between the groups (p < 0.05), with students in the FC group achieving higher problem-solving scores. In conclusion, the FC model is more effective in enhancing problem-solving skills compared to the DI model. Active learning strategies in the FC model foster deeper engagement, supporting the development of essential cognitive skills in science education.

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1. INTRODUCTION

The demands of modern education highlight the importance of equipping students with essential problem-solving skills (Antara et al., 2020; Kim et al., 2022; Yalcin & Erden, 2021). As one of the core competencies in 21st-century education, problem-solving enables individuals to address complex issues through critical analysis and effective decision-making (Hussin et al., 2018; Sierra, 2020). For prospective teachers, these skills are fundamental in navigating classroom challenges and preparing students to become adaptive, lifelong learners (Candas et al., 2022; Phan et al., 2022). Problem-solving is a necessary cognitive strategy for success in both academic settings and real-life situations (Isatunada & Haryani, 2021; Koray et al., 2023). For prospective teachers, possessing strong problem-solving skills is vital to navigating the complexities of teaching and preparing students to be critical thinkers in a rapidly changing world (Pahrudin et al., 2019; Phan et al., 2022). However, facts in the field indicate that many students still exhibit low problem-solving skills, which significantly impacts their learning outcomes. The lack of problem-solving abilities among students leads to poor academic performance. Despite various educational reforms, such as curriculum improvements initiated by the government, efforts to enhance problem-solving skills have been less effective. This issue largely stems from the prevalent use of traditional, teacher-centered instructional models like Direct Instruction (DI) (Dignath & Veenman, 2021; Ibrahim et al., 2014). In DI classrooms, teachers dominate the learning process, and students are expected to absorb knowledge passively through memorization (Dewi et al., 2019; Setyono, 2014). This teaching approach limits students' opportunities to engage in active learning and develop their problem-solving skills, resulting in superficial understanding and increased frustration (Pimdee et al., 2024; Schallert et al., 2020).

The over-reliance on the DI model creates a rigid learning environment that overlooks students' diverse backgrounds and prior knowledge. DI typically follows a structured five-stage process: explaining goals, demonstrating knowledge, guiding practice, providing feedback, and facilitating independent practice (Dignath & Veenman, 2021). While effective for certain purposes, this model fails to acknowledge the individual differences among students. Each student comes to the classroom with unique prior knowledge and experiences, which are crucial for bridging the gap between existing knowledge and new concepts (Alkhawaldeh & Khasawneh, 2023; Doğan et al., 2023). Learning that activates students' prior knowledge not only improves their comprehension but also enhances the clarity and retention of new material (Fidan & Fidan, 2024; Gao & Hew, 2022). Therefore, shifting from a teacher-centered model to more active, student-centered approaches is essential to fostering better problem-solving skills and preparing prospective teachers to meet the demands of modern education.

To address the issue of low problem-solving skills among students, innovative learning models are needed to move away from traditional, teacher-centered approaches toward more student-centered environments. One such promising approach is the Flipped Classroom (FC) model, which integrates e-learning and caters to the demands of the Industrial Revolution 4.0 and 21st-century education (Karaismailoglu & Yildirim, 2024; Khasawneh, 2023). The FC model enables students to access learning materials, such as videos and quizzes, outside the classroom, allowing them to learn at their own pace and time (Koray et al., 2023; Maulyda et al., 2024). This flexibility encourages greater engagement and enhances motivation to solve problems, while class time can be used for active problem-solving and clarification of misconceptions (Kızkapan, 2024; Liou, 2021). Although previous research has established the effectiveness of the FC model in improving problem-solving skills and learning outcomes, there remains a gap in understanding its application in specific fields like biophysics. Previous studies have shown the FC model's effectiveness in enhancing writing-related problem-solving (Mudlofir, 2021; Pimdee et al., 2024), motivation and performance (Campillo-Ferrer & Miralles-Martínez, 2021; Tsai et al., 2020). However, the impact of the FC model in natural science subjects like biophysics, compared to traditional teaching models like Direct Instruction (DI), has not been adequately explored. This presents a novelty in the current research, aiming to directly compare these models in fostering problem-solving skills in biophysics education.

This study was conducted with the aim to analyze the difference in problem-solving skills between students taught using the FC learning model and those taught using the DI model in biophysics courses. By comparing the effectiveness of these two teaching methods, this research seeks to provide insights into which model better supports the development of critical thinking and problem-solving skills in a scientific context. The findings will contribute to the existing literature on innovative teaching strategies in science education, offering valuable implications for enhancing student engagement and cognitive skills in biophysics.

2. METHOD

This research adopts a quasi-experimental design (Creswell, 2014), specifically utilizing a non-equivalent pretest-posttest control group design to assess the impact of different instructional models on students' problem-solving skills. The population in this study consists of all students enrolled in the fourth semester of the Science Education program. These students are divided into two distinct classes, namely Class A and Class B. To determine which group will serve as the experimental group and which will act as the control group, a random selection process is employed, assigning one class to each group. In the experimental group, the Flipped Classroom (FC) model is implemented, where students are provided with learning materials such as videos and online quizzes prior to classroom sessions. This approach allows students to engage in active learning during face-to-face interactions and apply critical thinking to problem-solving tasks. In contrast, the control group follows the Direct Instruction (DI) model, where traditional teacher-centered methods are applied. The DI model emphasizes direct teaching, where the instructor primarily delivers content, and students passively absorb the material.

The data in this study is focused on assessing students' problem-solving skills, which are measured using an essay-type test designed to evaluate their ability to analyze, evaluate, and solve complex problems (Schoenfeld, 1987; Shirali, 2014). The test, with a reliability coefficient of 0.717, is considered to have high reliability, ensuring that it accurately captures the students' problem-solving abilities. The variables examined in this study are categorized into three types: independent variables, dependent variables, and covariate variables. The independent variables in this study are the Flipped Classroom (FC) learning model and the Direct Instruction (DI) model, as the study seeks to compare the effectiveness of these two instructional approaches in enhancing problem-solving skills. The dependent variable is the students' problem-solving skills, which are directly influenced by the instructional methods applied. Finally, the covariate variable is the pre-existing problem-solving skills of the students, measured before the experimental treatment, in order to control for any initial differences between the groups. Table 1 presents the instrument grid used to assess students' problem-solving skills, including the indicators and dimensions measured.

Table 1. Problem Solving Instrument Grid

Aspect/Indicators	Description	Type of Item
Problem Identification	Ability to recognize and define the problem at hand	Essay-type question
Information Gathering	Skills in collecting relevant data or facts to address the problem	Essay-type question
Solution Strategy	Ability to formulate effective strategies or approaches to solve the problem	Essay-type question
Evaluation of Solutions	Ability to assess the outcomes and consequences of potential solutions	Essay-type question
Reflection and Learning	Ability to reflect on the process and learn from mistakes	Essay-type question

(Schoenfeld, 1987; Shirali, 2014)

The data on students' problem-solving skills were analyzed using descriptive statistics to summarize the characteristics and performance of the students in both the experimental and control groups. Subsequently, to assess whether the differences between the two groups were statistically significant, the data were tested using one-way Ancova (Analysis of Covariance). Prior to conducting the Ancova, several prerequisite tests were performed to ensure the validity of the analysis. These included the normality test to check if the data followed a normal distribution, the homogeneity test to determine if the variances between the groups were equal, and the linearity test to verify that the relationship between the covariate and dependent variable was linear. Once the data met all the assumptions required for Ancova, the analysis was conducted to compare the problem-solving skills between the two groups. If the significance value (p-value) of the Ancova test is less than 0.05, it would indicate that there is a statistically significant difference in the problem-solving skills of students between the two classes, thereby confirming the impact of the learning models applied.

3. RESULT AND DISCUSSION

Results

Initial knowledge profiles and understanding of students' concepts in each class are analyzed to look for grade point averages, standard deviations and N-gains. The results of the analysis are descriptively presented in Table 2.

Table 2. Student Problem Solving Skills Profile

Statistical Parameters	Experimental Group		Control Group	
	Pretest	**Post-test**	**Pretest**	**Post-test**
Mean	39.85	78.68	38.68	71.62
Std. Deviation	5.32	1.85	4.18	1.45
<g>	64.30		32.94	

Table 2 shows that the pretest score in the experimental class is 1.17 points higher than in the control class. This difference indicates that the initial knowledge of students in both classes is relatively similar. The pretest and posttest scores in both classes indicated improvements; however, the class using the Flipped Classroom (FC) learning model demonstrated a greater level of improvement compared to the class using the Direct Instruction (DI) model. This is evident from the increase in scores from pretest to posttest, as well as the higher average scores achieved by students in the experimental class. These findings suggest that the experimental class experienced a more significant improvement than the control class. The results of the prerequisite tests indicated that the data were normally distributed ($p > 0.05$) and homogeneous ($p > 0.05$). Additionally, the regression analysis revealed a meaningful direction with linear relationships (p linearity < 0.05 and p deviation from linearity > 0.05). Based on these results, with all p-values being less than 0.05, it can be concluded that the data met the necessary assumptions to proceed with one-way Ancova testing.

The results of the one-way Ancova test revealed that there was a significant difference in problem-solving skills between students taught using the Flipped Classroom (FC) model and those taught using the Direct Instruction (DI) model, with a p-value < 0.05. After controlling for initial knowledge, the learning model was found to significantly influence problem-solving skills, leading to the rejection of the null hypothesis (Ho), confirming a difference in problem-solving skills between the FC and DI groups, with a p-value < 0.05. The R-squared value indicated that the learning model accounted for only 0.82% of the variance in problem-solving skills between the experimental and control groups, suggesting a relatively small contribution of the learning model to the differences in students' concept understanding.

Discussion

The results of the covariance analysis revealed significant differences in problem-solving skills between students taught using the Flipped Classroom (FC) model and those taught with the Direct Instruction (DI) model, with the FC group outperforming the DI group. During the pre-class phase, students worked on tasks at home, using Learning Activity Sheets (LKM), videos, and biophysical materials, which allowed them to engage in critical problem-solving processes such as analyzing problems, formulating hypotheses, collecting and analyzing data, and drawing conclusions. These findings are consistent with previous studies which demonstrated that the FC model enhances problem-solving skills by fostering a more interactive, student-centered learning environment (Necor, 2021; Phan et al., 2022). The ability of students in the FC model to independently engage in problem-solving activities reflects the principles of constructivist learning, which have been widely supported in educational research.

Learning activities in the classroom include presenting the results of students' work and implementing practical activities in the experimental classes. In these activities, students, in groups, engage in discussions to identify problems, formulate hypotheses, plan solutions, and select appropriate strategies for solving the problems. During in-class activities, students present their findings, and lecturers provide guidance and emphasis on the concepts and problem-solving approaches. The goal is to help students understand the underlying concepts and strategies that can be applied to address the problems they encounter. Both pre-class and in-class activities contribute significantly to students' problem-solving skills, as students share their proposed solutions and the results of their problem-solving efforts. This collaborative process encourages students to seek input from their peers, facilitating discussions that lead to more accurate and effective solutions. When students encounter challenging new experiences and attempt to resolve problems with their own abilities, they undergo technological development, spurring cognitive growth and the formation of new ideas (Hwang et al., 2022; Muslim et al., 2024).

On the other hand, the Direct Instruction (DI) model proves less effective in improving students' problem-solving skills. This is primarily because the DI model emphasizes the direct transmission of knowledge from the lecturer to the students, with less opportunity for students to actively engage in problem identification and solution formulation. During the provision of Learning Activity Sheets (LKM), students work in groups to complete tasks according to pre-established guidelines, which limits their ability to think critically and creatively. As a result, the learning process becomes less effective, and discussions among students are prolonged because many students struggle to understand the design of the solutions outlined in the LKM. Moreover, less engaged students tend to rely on their peers who have better problem-solving skills, reducing the overall contribution of all group members to the task. When comparing the effectiveness of both learning models, it becomes clear that the Flipped Classroom (FC) model outperforms the DI model in fostering problem-solving abilities. This aligns with previous studies which demonstrated that the FC approach significantly enhances students' problem-solving skills, particularly in areas such as writing, by encouraging active engagement and self-directed learning (Nantha et al., 2022; Oudbier et al., 2022).

The advantage of the Flipped Classroom (FC) model lies in its ability to create a dynamic and engaging learning atmosphere by blending face-to-face and virtual learning experiences (Koray et al., 2023; Oudbier et al., 2022). This model divides the learning environment into two parts: in-person sessions and online learning conducted through platforms like Google Meets and Google Classroom, which precede the face-to-face sessions. The FC model is inherently student-centered, allowing students to take charge of their learning process by engaging with learning materials, such as instructional videos, provided by lecturers before attending in-person classes. However, during the face-to-face sessions, whether in the classroom or online, lecturers retain the role of guiding and facilitating students' learning by transforming knowledge. Technology used for learning outside the classroom provides students with ample opportunities to explore and access a wide range of relevant information, which is a core benefit of the FC approach (Nantha et al., 2022; Yu et al., 2023). The key distinction between the FC and the Direct Instruction (DI) model is the incorporation of online learning prior to the face-to-face classroom sessions in the FC model. From the perspective of improving student learning outcomes, the FC model demonstrates greater effectiveness compared to the DI model, as it fosters more active and independent learning (Alkhawaldeh & Khasawneh, 2023; Candas et al., 2022).

Empirically, the Flipped Classroom (FC) learning model has shown better outcomes in improving students' problem-solving skills compared to the Direct Instruction (DI) model. However, there are several obstacles that have prevented the maximization of students' problem-solving skill development. First, the relatively short duration of the treatment period in which students were exposed to the FC model has resulted in insufficient time for students to become fully accustomed to meaningful learning. Without ample time for adaptation, students may not be able to develop a deeper understanding of the learning materials and problem-solving strategies (Muslim et al., 2024; Wright & Park, 2022). Second, problem-solving skills are complex and require consistent practice to refine. These skills, classified as higher-order thinking, cannot be significantly improved in a short period, as they necessitate regular and sustained practice to become ingrained habits (Shirali, 2014; Yapatang & Polyiem, 2022). Third, the reliance on technology and internet access within the FC model presents a challenge, particularly for students with inadequate access to these resources (Koray et al., 2023; Wikanda et al., 2021). The lack of stable internet connections or technological tools at home can hinder students' ability to fully engage with the online components of the learning process, thus affecting their overall learning experience. These barriers highlight the need for a more comprehensive approach and additional support to ensure that all students can benefit from the advantages of the FC model.

Efforts to overcome the obstacles encountered in implementing the Flipped Classroom (FC) learning model are essential for enhancing its effectiveness in Biophysics courses. First, continuing the application of the FC learning model over an extended period will allow both lecturers and students to become more accustomed to this approach. As familiarity with the model grows, it is expected that the learning experience will become more meaningful and engaging, enabling students to better internalize the content and improve their problem-solving skills. Second, lecturers and researchers can implement a team-teaching system, where both individual and group sessions are facilitated. This system can provide students with more personalized guidance, ensuring that those who require additional support are adequately assisted during training sessions, whether on an individual basis or within smaller groups. Third, to optimize the online learning components, students can be encouraged to study in groups. Collaborative learning will help ensure that no student is left behind, particularly in accessing educational materials such as videos and quizzes.

The findings of this study have significant implications for the development of educational practices, particularly in enhancing problem-solving skills. The results indicate that students taught using the Flipped Classroom (FC) learning model demonstrated higher problem-solving abilities compared to those taught with the Direct Instruction (DI) model. This highlights the effectiveness of the FC model, which encourages active learning, critical thinking, and collaboration, thus optimizing the development of students' problem-solving skills. The study suggests that the structure of the FC model, which combines online learning with in-class activities, supports a more student-centered approach, fostering deeper engagement and better problem-solving outcomes. These findings encourage further exploration of blended learning models in education, as they offer a promising approach to improving higher-order cognitive skills, ultimately benefiting students' academic performance and future career readiness.

4. CONCLUSION

The findings of this research emphasize the positive impact of the Flipped Classroom (FC) learning model on students' problem-solving skills, revealing a significant difference between the groups that used the FC model and those who used the Direct Instruction (DI) model. Students in the FC group demonstrated relatively higher problem-solving abilities, suggesting that the FC model fosters a more engaging and effective learning environment for enhancing critical thinking and problem-solving skills. This research highlights the importance of integrating innovative learning models like FC, especially in the context of online education. It also underscores the necessity for sustained implementation of such models to further improve educational quality, as developing problem-solving skills is a gradual process that requires ongoing practice and support. Moreover, ensuring that students have access to collaborative learning opportunities and adequate resources can mitigate challenges such as limited internet access, enhancing the overall learning experience.

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