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The Effectiveness of the Socioscientific Blended Project-Based Learning (PjBL) Model in Improving Higher-Order Thinking Skills

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ABSTRACT

This research aligns with UMS RIP Theme 5 concerning the improvement of education and learning quality. Socioscientific Blended Project-Based Learning (SSI-PjBL) is a learning model that actively engages students through online and face-to-face activities, including reading, discussion, experimentation, data analysis, and problem-solving related to socioscientific issues in society. This study aimed to determine the effectiveness of the SSI-PjBL model in improving the higher-order thinking skills (HOTS) of biology education students at the Faculty of Teacher Training and Education (FKIP) UMS. This study employed a quasi-experimental design involving two groups of 40 students, consisting of an experimental group (20 students) taught using the SSI-PjBL model and a control group (20 students) taught using the conventional Project-Based Learning (PjBL) model. HOTS indicators measured in this study included critical thinking, analysis, evaluation, and problem-solving skills. Data were collected using HOTS-based pretest and posttest essay instruments. Data analysis was conducted using hypothesis testing and effect size analysis. Prior to hypothesis testing, assumption tests including normality and homogeneity tests were performed. Since the data were normally distributed, independent sample t-test was used as a parametric statistical test. The results showed a significant improvement in students' HOTS in the experimental class compared to the control class. Furthermore, the effect size was calculated using Cohen's effect size formula and produced a value of 3,190, which was categorized as high according to Cohen's criteria. These findings indicate that the SSI-PjBL model has a strong effect on improving students' higher-order thinking skills and can be considered an effective learning approach to support 21st-century biology education.

KEYWORDS

Socioscientific Project-Based Learning, Higher-Order Thinking

1. Introduction

The 21st century is the era of global computing, marked by the development of information technology. This era of global computing demands high-quality human resources. Higher education institutions must be able to produce outcomes that are high-quality and competitive. Critical thinking and problem-solving skills are among the essential skills required in modern 21st-century education. Modern education involves the development of critical thinking skills, which must be mastered to learn how to compete in the global computing era. Critical thinking skills are derived from observation, experience, reflection, reasoning, or communication, used as a guide for action (Bialik & Groff, 2017). Critical thinking is a process that includes induction, deduction, classification, and reasoning (Krulik & Rudnick, 1996). These critical thinking skills drive the ability to analyze and evaluate facts, identify questions, draw logical conclusions, and understand the impact of arguments (Friedrichsen, 2001).

According to McMurarry, Beisenherz, & Thompson, 1991, critical thinking is a crucial activity to develop in schools and universities. Furthermore, problem-solving skills are crucial for students to develop as a foundation for living in modern 21st-century society. When students possess adequate critical thinking, they will possess problem-solving skills. Critical thinking is a crucial element of inquiry, innovation, and problem-solving (Thompson, 2011). Students who possess critical thinking skills can effectively solve problems in their lives (Snyder & Snyder, 2008). Problem-solving skills are one of the fundamental competencies students must possess in the 21st century (Adeoye, 2010; Greiff et al., 2013). This aims to promote new experiences in students by seeking solutions and solving problems. Problem-solving activities are integrated into the learning process (Mauke et al., 2013), thus helping students construct new knowledge (Mukhopadhyay, 2013).

Environmental issues have become a challenging issue in today's society. Increasing environmental damage due to the large volume of waste and its incomplete management, the increasing amount of liquid waste from homes and industries polluting water bodies, and the high emissions of air polluting gases have significantly impacted the quality of human life. Several efforts have been made to address environmental issues, for example, through legal environmental education activities based on a joint decree from the Ministry of Environment and the Ministry of National Education (2010). One of the objectives of this policy is to foster and develop the knowledge, values, attitudes, behaviors, insights, and environmental awareness of students and the public. This policy is achieved through the development and implementation of environmental education across all pathways, levels, and types of education.

Environmental learning programs have been widely implemented in universities to improve students' understanding of environmental issues and sustainability. Previous studies have shown that contextual and issue-based learning can improve students' critical thinking, scientific literacy, and problem-solving abilities because environmental problems are closely related to real social life and require interdisciplinary understanding. In addition, project-based and socioscientific approaches have been reported to encourage students to actively engage in analyzing environmental problems and proposing solutions based on scientific evidence.

However, previous studies still have several limitations. Most research has focused only on conceptual understanding or scientific literacy, while studies specifically examining the integration of socioscientific issues with blended Project-Based Learning (SSI-PjBL) to improve Higher Order Thinking Skills (HOTS) in higher education remain limited. Furthermore, the implementation of blended learning environments that combine online and face-to-face learning activities in environmental education contexts has not been widely explored, particularly in biology education programs.

Therefore, this study seeks to address these gaps by investigating the effectiveness of the Socioscientific Blended Project-Based Learning (SSI-PjBL) model in improving students' HOTS, especially critical thinking and problem-solving skills. Through the integration of socioscientific issues, project-based activities, and blended learning environments, this study is expected to provide empirical evidence regarding the potential of SSI-PjBL as an innovative learning approach to support 21st-century environmental and biology education.

Facing the challenges outlined, it is necessary to implement an appropriate learning model or approach. One solution to address these issues is the application of a model that emphasizes students' critical thinking and problem-solving skills during the pandemic. This learning can be implemented using the socioscientific Blended Project-Based Learning (PjBL) model. Blended PjBL learning helps students become independent learners, both online and offline, in the era of global computing. Students will make strong connections between the concepts and facts they learn, enabling them to actively seek information and produce learning products, rather than simply passively receiving information. This study differs from previous studies because it integrates socioscientific issues, blended learning, and project-based learning simultaneously in biology education

Learning using the socioscientific blended project-based learning model (PjBL) applies real-world problems to the learning process. The contextual problems applied to learning are social problems in society related to science. The development of the socioscientific blended project-based learning model aligns with the research theme of the Biology Education Study Program, namely improving the quality and innovation of biology learning to create superior professional teachers in the 21st century. One of the curriculum criteria for 21st-century learning is motivating students to apply learning materials to their communities (Solomon, 2001). Socioscientific learning facilitates real-world learning conditions that provide opportunities to develop scientific argumentation skills, explore moral issues, develop moral reasoning, and understand reflective judgment (Zeidler, 2009). Students will be able to make decisions regarding problems in the social environment in a scientific and socially beneficial manner.

Learning using the socioscientific blended project-based learning model enables a learning process that actively engages students, both online and offline, in reading, writing, conducting experiments, analyzing, and seeking solutions to socioscientific problems in society. The application of the socioscientific blended project-based learning model can train and accustom students to be sensitive to their surroundings and to relate the theories or concepts they learn to the social conditions of their communities. Students' ability to connect scientific theory to social problems can train them to find solutions to those problems.

One skill that can be developed through SSI learning is reflective critical thinking, which allows students to draw conclusions and solve problems based on specific arguments (reflective judgment).

This skill leads to a person's level of literacy development in gathering and analyzing information from various data sets and forming decisions based on facts or concrete evidence (Callahan, 2009; Zeidler, et al., 2009). Although still limited, studies on the potential of SSI in science learning have also been conducted in Indonesia. Regarding teaching materials, Subiantoro and Fatkhurohman (2009) identified the emergence of students' critical thinking skills through biology learning utilizing newspapers, focusing on the issues of ozone depletion and building a greenhouse gas-free environment. Research by Herlanti, et al. (2012) revealed that students achieved the highest level of argumentation through discussions on the polemic issue of E. sakazakii bacteria via social media, although individual achievement was moderate. Based on these gaps, this study aims to examine the effectiveness of the socioscientific blended Project-Based Learning (SSI-PjBL) model in improving students' higher-order thinking skills.

2. Method

This study employed a quantitative approach using a quasi-experimental design. Two groups of 40 students were involved, consisting of an experimental group (20 students) taught using the Socioscientific Blended Project-Based Learning (SSI-PjBL) model and a control group (20 students) taught using the conventional Project-Based Learning (PjBL) model. The research was conducted in the Biology Education Study Program at UMS from September to December 2022 during the odd semester of the 2022/2023 academic year.

The population of this study included all fifth-semester Biology Education students at UMS in the 2022/2023 academic year. The sample consisted of students from classes D and E selected through purposive sampling. Class D was assigned as the experimental class, while class E served as the control class.

The implementation of the SSI-PjBL model was conducted over eight meetings during one semester. Each meeting lasted approximately 100 minutes and consisted of both online and face-to-face learning activities. The project theme focused on environmental issues and socioscientific problems related to waste management, water pollution, and environmental sustainability in the surrounding community. The blended learning process utilized several online platforms, including Google Classroom for distributing learning materials and assignments, Zoom Meeting for online discussions and presentations, and WhatsApp groups for communication and project coordination among students. Face-to-face sessions were used for project planning, experiments, group discussions, and presentation of project outcomes.

The learning activities in the experimental class followed the stages of the SSI-PjBL model, including identification of socioscientific issues, project planning, information gathering, data analysis, development of project solutions, and presentation of project results. Students worked collaboratively in groups to investigate real environmental problems and propose scientific solutions based on evidence and literature review. Meanwhile, the control class implemented general project-based learning activities without explicit integration of socioscientific issues.

Assessment procedures were carried out through pretests and posttests to measure students' higher-order thinking skills. In addition, project assessment rubrics were used to evaluate students' critical thinking, problem-solving, collaboration, and presentation skills. Student participation during discussions and project activities was also observed and documented throughout the learning process.

The data analysis technique used in this study was the Two Independent Sample Test. Prior to hypothesis testing, assumption tests were conducted, including normality and homogeneity tests. The normality test was performed to determine whether the data were normally distributed, while the homogeneity test was conducted to examine the equality of variances between groups. The results of the assumption tests indicated that the data were normally distributed; therefore, parametric analysis using the independent sample t-test could be applied (Nurcahyanto, 2018). This test was used to determine whether there were significant differences between the experimental and control groups after treatment. The hypothesis testing procedure was conducted to identify differences in the average scores between groups resulting from the applied learning model (Widiyanto, 2017). Furthermore, after significant differences were identified, the effect size analysis was performed to determine the effectiveness of the implemented learning model.

The effectiveness of the learning model was further analyzed using effect size (ES) analysis to determine the magnitude of the treatment effect. The interpretation of effect size values referred to Cohen's criteria (Cohen, 1988), where an ES value of less than 0.20 was categorized as low, values between 0.20 and 0.80 were categorized as moderate, and values greater than 0.80 were categorized as high effect size. This categorization was used to determine the level of effectiveness of the Socioscientific Blended Project-Based Learning (SSI-PjBL) model in improving students' higher-order thinking skills.

3. Results and Discussion

The results of the high-level thinking skills tests in cycles I and II were then t-tested to determine the differences in these skills in the experimental and control classes. The results of the t-test can be seen in Table 1.

Table 1. Results of the independent sample t-test for high-level thinking skills in Cycles I and II

Cycle	*Test Type*	*Sig.*	*Conclusion*
I	Independent Sample T-test	0,042	There is a difference
II	Independent Sample T-test	0,034	There is a difference

Based on Table 1, the SPSS analysis results showed a significance level of 0.042 <0.05 in Cycle I, indicating a difference in the mean scores of higher-order thinking skills between the experimental and control classes. In Cycle II, the significance level was 0.034 <0.05, indicating a difference in the mean scores of higher-order thinking skills between the experimental and control classes.

After identifying the differences between the experimental and control classes, the effectiveness of the Socioscientific Blended Project-Based Learning model can be assessed by conducting an effectiveness test using effect size. The effect size results from Cycles I and II are shown in Table 2.

Table 2. Results of the t-test for Hots in Cycles I and II

Cycle	*Socio-scientific Pjbl*			*Pjbl*			*Effect Size*	*Category*
	Mean	*SD*	*N*	*Mean*	*SD*	*N*	*Cohen's d*	
I	19,46	3,342	20	16,44	3,149	20	2,395	High
II	26,44	3,124	20	22,1	3,383	20	3,190	High

Based on Table 2, the effect size calculation for Cycle I yielded a value of 2.395, making it categorized as high. In Cycle II, the value was 3.190, also categorized as high. This indicates that the Socioscientific Blended Project-Based Learning model is effective and highly effective in improving higher-order thinking skills.

Based on the t-test results, it can be concluded that there is a difference and an increase in the application of the Socioscientific Blended Project-Based Learning model on higher-order thinking skills between Cycles I and II. The greatest impact occurred in Cycle II, as students felt comfortable and enjoyed the learning process using the Socioscientific Blended Project-Based Learning model. In addition to the increasing t-test scores and percentage increase in each cycle, another evidence of improved higher-order thinking skills is the effect size. Using effect size can determine the extent of the effect or influence of Socioscientific Blended Project-Based Learning on students' higher-order thinking skills. In Cycle I, the effect size was 2.395, and in Cycle II, the effect size was 3.190. The effect size results for Cycles I and II fall into the high category.

Learning is an interactive process involving lecturers, students, and various learning components that collectively influence the quality of education. In the context of 21st-century education, higher education institutions are required to adapt to the demands of the industrial revolution 4.0 and society 5.0, which emphasize critical thinking, creativity, collaboration, communication, and problem-solving skills (Ratih et al., 2021). Therefore, learning approaches that actively engage students in authentic problem-solving activities are increasingly needed to support the development of Higher Order Thinking Skills (HOTS).

The findings of this study indicate that the implementation of the Socioscientific Blended Project-Based Learning (SSI-PjBL) model contributes positively to the improvement of students' HOTS. This result is consistent with previous international studies showing that blended PjBL encourages students to become more active, independent, and collaborative learners. In blended learning environments, students are provided with opportunities to explore learning materials both online and offline, engage in inquiry activities, and develop solutions to real-world problems. Research by Kivunja (2015) and Anazifa & Djukri (2017) reported that project-based and blended learning environments improve students' critical thinking and problem-solving abilities because students are directly involved in meaningful and contextual learning activities.

Furthermore, the integration of socioscientific issues (SSI) into project-based learning provides contextual learning experiences that connect scientific concepts with social and environmental problems. SSI-based learning enables students to analyze controversial issues, evaluate evidence, construct scientific arguments, and make reasoned decisions. International studies conducted by Sadler (2011) and Zeidler

et al. (2019) emphasized that SSI instruction plays an important role in developing scientific literacy, reflective thinking, argumentation, and decision-making skills. Through discussions and investigations of real societal issues, students are encouraged to think critically and consider scientific, ethical, and social perspectives simultaneously.

In biology education, the development of HOTS is particularly important because biology learning does not only focus on conceptual understanding but also involves scientific inquiry, problem-solving, and the relationship between science, technology, and society. Inquiry-based activities integrated into SSI-PjBL facilitate students in identifying problems, analyzing information, and proposing solutions based on scientific evidence. These findings are in line with studies by Heong et al. (2012), Osman et al. (2013), and Turiman et al. (2012), which reported that inquiry-oriented learning significantly supports the development of higher-order thinking skills. Therefore, the implementation of SSI-PjBL can be considered an effective approach to support 21st-century biology learning and improve students' HOTS in higher education contexts.

Higher-order thinking skills are the development of mental skills derived from a person's fundamental abilities. Higher-order thinking skills encourage students to discover facts and concepts for themselves, as well as foster the attitudes and values required (Afandi, Sajidan, Akhyar, & Suryani, 2019). This allows students to develop their own knowledge without relying on lecturers as a source of information. The knowledge gained is not merely the memorization of concepts, facts, or principles required for higher-order thinking skills, but rather provides students with direct experience with the objects being studied.

Learning is an interactive process involving lecturers, students, and various learning components that collectively influence the quality of education. In the era of the industrial revolution 4.0 and society 5.0, higher education is required to develop 21st-century competencies, particularly Higher Order Thinking Skills (HOTS), including critical thinking, analysis, evaluation, and problem-solving skills (Ratih et al., 2021). The findings of this study indicate that the implementation of the Socioscientific Blended Project-Based Learning (SSI-PjBL) model effectively improved students' HOTS compared to conventional learning approaches.

The improvement in HOTS can be explained by several learning mechanisms embedded within the SSI-PjBL model. First, the integration of socioscientific issues encourages students to analyze authentic environmental and social problems that are often complex and controversial. Through this process, students are required to evaluate scientific evidence, construct arguments, and make reasoned decisions. These activities stimulate critical and reflective thinking, which are important components of HOTS. Second, the project-based learning component actively engages students in inquiry, collaboration, investigation, and problem-solving activities. Students are not only expected to understand concepts theoretically but also to apply scientific knowledge to real-world situations. Third, the blended learning environment supports flexible learning interactions through online and face-to-face activities, enabling students to access broader learning resources, conduct independent learning, and participate in collaborative discussions more effectively.

These findings are consistent with previous empirical studies reporting that SSI-based learning and project-based learning positively influence students' HOTS and scientific literacy. Sadler (2011) and Zeidler et al. (2019) explained that socioscientific issue instruction enhances students' reflective judgment, argumentation, and decision-making skills because students are challenged to consider scientific and social perspectives simultaneously. Similarly, studies by Anazifa and Djukri (2017) demonstrated that project-based learning improves critical thinking and problem-solving skills through active investigation and collaborative learning experiences. The present findings also support the studies of Heong et al. (2012), Osman et al. (2013), and Turiman et al. (2012), which emphasized that inquiry-oriented learning activities contribute significantly to the development of higher-order thinking skills.

However, this study also extends previous research by integrating socioscientific issues, blended learning environments, and project-based learning simultaneously in biology education contexts. Previous studies generally focused only on SSI instruction or project-based learning separately, whereas this study demonstrates that combining these approaches creates more contextual and interactive learning experiences. The integration of online and offline learning activities enables students to engage more deeply in collaborative inquiry and problem-solving processes, which may explain the high effectiveness category found in this study. Therefore, SSI-PjBL can be considered a promising instructional model for supporting HOTS development in 21st-century higher education learning.

These findings are also supported by studies published in the Journal of Biology Learning, which reported that contextual and inquiry-based biology learning can improve students' learning activities, independence, and higher-order thinking processes through active and collaborative learning experiences (Purwanto, 2019). Furthermore, contextual biology learning was found to enhance students' engagement and learning outcomes because students were directly involved in meaningful scientific activities related to real-life situations (Dwinaeni et al., 2024).

4. Conclusion

The results of this study demonstrate that the implementation of the Socioscientific Blended Project-Based Learning (SSI-PjBL) model is effective in improving students' higher-order thinking skills (HOTS). Statistical analysis showed significant differences between the experimental and control groups, indicating that students who learned through the SSI-PjBL model achieved better HOTS performance. Furthermore, the effect size analysis revealed a high category of effectiveness, suggesting that the SSI-PjBL model has a strong impact on the development of students' critical thinking and problem-solving abilities. These findings indicate that integrating socioscientific issues into blended project-based learning can create meaningful and contextual learning experiences that encourage students to actively analyze real-world problems, evaluate scientific evidence, and construct appropriate solutions. The combination of online and face-to-face learning activities also supports more flexible, collaborative, and student-centered learning environments aligned with the demands of 21st-century education.

Therefore, the SSI-PjBL model has important implications for higher education practice, particularly in biology and environmental learning, as an innovative approach to fostering HOTS and scientific literacy. The model can be considered a relevant instructional strategy to prepare students to address complex scientific and social challenges in contemporary society.

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