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The Effects of the PBL Based on the Socioscientific Issue Approach on Interdisciplinary Thinking and Argumentation Skills

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ABSTRACT

The independent curriculum directs the education sector to develop socioscientific issues (SSI)-related interdisciplinary reasoning and argumentation skills that can be applied to biology education. This study aims to investigate the effects of the PBL-SSI model on students' interdisciplinary thinking and argumentation skills. This study used a Quasi Experimental design non-equivalent control group pretest-posttest design. The participants in this investigation were 71 10th grade students. Students were separated into two groups and evaluated using distinct learning models: (1) PBL-SSI, 11 males and 24 females; (2) PBL, 12 males and 24 females. PBL-SSI enhances the students' argumentation and interdisciplinary thinking skills in compared to PBL. PBL-SSI had an effect on inter-disciplinary reasoning and argumentation skills ($p<0.05$), according to the investigation results. PBL-SSI improved interdisciplinary thinking and argumentation skills more effectively than PBL.

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1. INTRODUCTION

The learning process is a process designed by the instructor to improve students' morale, intellect, and develop their various skills, including critical thinking, creativity, knowledge construction, and problem-solving, in order for them to comprehend the learning material effectively. Improving students' skills is crucial because it enhances their ability to networking and adapt to global changes (Anggraena et al., 2021). However, in the process of improving the quality of the learning process, Indonesia experienced a learning loss during the COVID-19 pandemic. One of the efforts made to restore learning is by establishing an Independent Curriculum. The principles used in designing the Merdeka Curriculum are: (1) constancy, focus, and coherence; (2) applicable to all disciplines, interdisciplinary, competency transfer ability, and choice, required in curriculum planning; (3) flexibility, authenticity, and alignment, related to the design of curriculum policies at the macro level; (4) the principles of involvement, student independence, and teacher independence are related to the curriculum design work process (Anggraena et al., 2021). Interdisciplinary thinking skills are expected in the implementation of the independent curriculum. The significance of interdisciplinary thinking skills for students, i.e., training students to think in a complex manner beyond their existing scientific knowledge, so that they can comprehend the inter-disciplinary relationships involved in solving commonplace problems (Labov et al., 2010)

Based on the results of an interview with a biology teacher at SMAN 1 Wates conducted on September 1, 2022, it is evident that the development of interdisciplinary thinking skills in schools has not been carried out optimally, as the teacher only develops understanding in terms of content, not in a real way by confronting students with contextual problems in biology learning. Students are trained to integrate biological disciplines with chemical disciplines in biology material containing chemical bioprocesses, such as metabolism material, but this development has not been carried out optimally. The instructor has trained the students' interdisciplined reasoning skills, but the problems assigned are limited to conceptual comprehension. The results of a preliminary investigation on the interdisciplinary thinking skills and argumentation skills of students who had previously

received material on environmental change revealed that 84% of students had not attained the minimal level of mastery. Therefore, it is necessary to cultivate interdisciplinary reasoning and argumentation skills.

Low levels of interdisciplinary thinking skills can have an impact on argumentation skills (Wulandari, 2017). This can be seen through the results of observations in class X-1 SMAN 1 Wates on biodiversity, where almost 80% of students have not been able to provide scientific arguments in providing solutions to overcome the problem of decreasing biodiversity levels in Indonesia. Based on research conducted by Wulandari (2017), interdisciplinary thinking skills have a significant relationship with scientific argumentation skills, the results of his research show that 13% of students' argumentation skills are influenced by interdisciplinary thinking skills. Argumentation skills need to be developed because they can be used as a guide to carry out an action in the learning process, but it can also balance the goals of science education. With a mean score of 68.7 for inter-disciplinary reasoning, it is evident that students have not attained classical mastery. Therefore, it is necessary to carry out learning strategies that can develop interdisciplinary thinking skills and scientific argumentation skills so that students at the high school level can interpret what is learned.

One learning strategy that can improve interdisciplinary thinking skills and argumentation skills is to use the Problem Based Learning (PBL) model with a socioscientific issue (SSI) approach (Fang et al., 2019). Based on observations, the teacher has implemented the PBL model but has not implemented it optimally, the implementation of the PBL model syntax has not been fully achieved. The problems used in the PBL model already involve SSI, but the method of solving these problems only focuses on one point of view of the biological disciplines, does not yet involve points of view from different disciplines, for example, economics, social sciences, and the environment. It is possible to improve interdisciplinary thinking skills and argumentation skills through the PBL model with the SSI approach because the PBL-SSI model has several components, namely authentic problems, interdisciplinary focus, authentic investigation, collaboration, and communication (Astuti, R & Junaedi, 2013). An example of the application of an interdisciplinary approach in learning biology is the problem of environmental change. This problem can be seen from the point of view of polluting chemicals, their effects on health, and changes in social and economic conditions that exist in society (Mirjam & Jan, 2017).

Problems related to social, economic, and scientific life in society are called socioscientific issues (SSI). One of the SSI problems found in society is water pollution. This problem can train students to improve interdisciplinary thinking skills by understanding the problem of water pollution from government systems, economic systems, physical systems, life, and the earth (Ewing & Sadler, 2020). The PBL model with the SSI approach can train interdisciplinary thinking skills and scientific argumentation skills. This is evidenced by the results of previous research, which stated that the problem-based learning model with the SSI approach affected the high-level thinking skills of class X MAN 1 Samarinda in the 2018–2019 academic year (Sismawarni et al., 2020). As a result, SMAN 1 Wates has never conducted research on the effects of PBL-SSI, so it is necessary to implement PBL-SSI to strengthen interdisciplinary thinking and argumentation skills.

2. RESEARCH METHOD

This study used a quasi-experimental, non-equivalent control group pretest-posttest design approach. The independent variable used in this study is the learning model, while the dependent variable is interdisciplinary thinking and argumentation skills. In contrast, the independent variables are problem-based learning with the SSI approach (PBL-SSI) and problem-based learning (PBL). The concentration on quantitative data is more suitable for use in this research, because this study aims to measure the effects of the independent variables on the dependent variable (Ariel et al., 2022).

Participants

Participants were 71 students of first years in SMAN 1 Wates. The number of participants in this study were as follows: (1) PBL-SSI, 11 male and 24 female students; (2) PBL, 12 male and 24 female students.

Teaching Procedures

Each of the two research groups was assigned the task of studying the same biological material. Students participate in a module teaching the biology of environmental change. The module is completed in four meetings within four weeks. Before and after being taught the module, the two research groups completed pretest and post-test questions on interdisciplinary thinking skills and argumentation skills in the form of essays.

The PBL model was used to assist students in solving problems related to biology. Two research groups participated in 135 minutes of learning in each meeting but were treated to different PBL models, namely PBL-SSI and PBL. Students in PBL-SSI research groups collaborated to visualize data and solved specific problems. The stages of the PBL-SSI model, namely: (1) orientation of students to the basic concept of the material from a problem, where students could identify problems, formulate problems, and formulate hypotheses (2) after reasoning and understanding the material through the selected problem formulation, students chose a focus question that, according to them, was the most contextual and the most complex based on the problem formulation. (3) organizing students to study: students were asked to form groups; four groups were formed randomly and

variously. (4) to guide group investigations to obtain joint decisions, students conducted literature reviews from various sources to support the hypotheses that have been written. Students wrote down a list of references and the results of a literature review. (5) by developing and presenting works in the form of arguments, students could provide solutions in the form of arguments related to the problems that have been given. (6) after analyzing, evaluating, and reflecting on problem-solving ideas and life experiences gained, students presented the results of discussions in front of the class to standardize understanding.

The teacher provided reinforcement regarding solutions to environmental change problems. Students could formulate a conclusion based on the formulation of the problem and the data collection activities that had been carried out. Students were also trained to be able to describe reflections so as to gain meaningful life experiences after studying environmental change material. The second research group used the PBL model. Students in these groups collaborated to answer certain questions. The steps of the PBL model were: (1) orientation of students to problems; (2) focusing questions; (3) organizing students for learning; (4) guiding group investigations; (5) developing and presenting work; and (6) analyzing and evaluating problem-solving ideas. The PBL group answered questions by reading textbooks and participating in peer discussions.

Instrument

The instrument used in this research is an essay question to assess interdisciplinary thinking and argumentation skills. The researcher collaborated with a biology teacher at SMAN 1 Wates and a biologist from Malang State University in the process of preparing the questions. The interdisciplinary thinking skills test consists of seven items related to the three dimensions of interdisciplinary thinking skills according to Golding: a) disciplinary grounding (3 items), b) advancement through integration (1 item), and c) critical awareness (3 items). Interdisciplinary thinking skills are assessed based on the skill assessment rubric. Argumentation skills had several dimensions based on Toulmin that are used to evaluate students' argumentation skill levels, including claims, data, warrants, backing, qualifiers, and rebuttals. Students' argumentation skills were assessed based on a rubric developed based on the dimensions of argumentation skills. Test validity of the research instrument conducted was its logical and empirical. Logical validation consisted of content and construct validity, which was carried out by biologists at the State University of Malang and biology teachers at SMAN 1 Wates. Empirical validity is used to determine the level of validity obtained in accordance with the test results in the field. Empirical validity was obtained from the results of trials through pretest-posttest questions on respondents, namely in class XII, which consisted of 36 students. Empirical validity was carried out by testing questions on interdisciplinary thinking and argumentation skills. Then analyzed with Pearson's correlation coefficient (Pearson's R). Pearson's r values for interdisciplinary thinking skills ranged from 0.329–0.536 (p>r table (0.329)), while for argumentation skills they ranged from 0.489–0.561 (p>r table (0.329)), so it could be seen that the items used in data collection are valid. The results of the reliability test using Cronbach's Alpha showed that interdisciplinary thinking skills have a correlation coefficient of 0.606 and argumentation skills had a correlation coefficient of 0.633, so it could be stated that the research instruments for these two skills were reliable and included in the high category.

Data Collection and Analyze

In collecting data for this study, we used test scores for interdisciplinary thinking skills and argumentation skills. Data obtained from the pretest and post-test scores that have been done. The pretest and post-test scores were carefully corrected based on the scoring rubric before being entered into Microsoft Excel. Scores of students' interdisciplinary thinking skills ranged from 0-28, while argumentation skills ranged from 0-27.The answers and scores obtained from the two research groups for interdisciplinary thinking skills are in Table 1. and argumentation skills are in table 2. Interdisciplinary questions: Global warming is currently a very controversial topic of discussion regarding environmental changes that are occurring. Global warming is often associated with human activities and many other factors. Analyze the causes of global warming and how to solve the problem by considering various disciplinary perspectives. Argumentation question: One of the causes of global warming is increasing industrial activity. The solution that can be found is to stop all industrial activities so that survival is maintained in the future. What are your arguments for accepting or rejecting this solution?

Table 1. Answers and scores of students' interdisciplinary thinking skills based on the rubric

Group	Answer
PBL-SSI	Global heating is caused by the depletion and even holes in the ozone layer, which cause ultraviolet radiation rays to be reflected and blocked by the presence of CO2 gases in the air. Excessive CO2 gas emissions in the air are generated through the use of motorized vehicles, forest burning, plastic waste, and organic waste, which also contain other gas emissions such as sulfur dioxide (SO2), which can cause acid rain. Carbon dioxide, carbon monoxide, sulfur, and even lead can be found in manufacturing and industrial waste. Industry is the world's largest emitter of greenhouse gases. In addition, greenhouse gas emissions that should be absorbed by plants have been disrupted due to the behavior of some individuals who converted the forest for development purposes [Disciplinary

Group	Answer
	Grounding (7)]. There are various perspectives in scientific disciplines that can overcome the problem of global warming, namely economic and politic social, and environment. 1. Discipline of economics, Indonesia is included in an agrarian country where the economic system is still supported by the agricultural sector. The existence of global warming can affect the food sector. Every 1°c increase in average temperature reduces about 10% of rice yields. Drastic climate change causes unpredictable weather. If many farmers experience crop failure due to drought, there will be a lot of spikes in commodity prices that will reduce people's purchasing power. This causes poverty, the solution that can be offered from an economic perspective is to suppress inflation and apply the concept of climate-smart agriculture. 2. Social science discipline, in the current climate issue, humans are not only victims, but also the cause of global warming. Based on this, a mass understanding of humans is needed to be able to commit to overcoming global warming in a compact way together. 3. Discipline in political science, the government has made efforts to overcome global warming by enacting forest protection laws and limiting the use of motorized vehicles on weekends (Car Free Day). 4. The environment, according to environmental science disciplines, the existence of global warming can cause changes in behavior and even the population of living things in it. The solution to this problem is reforestation, saving energy, reducing the use of motorized vehicles, implementing 3R, etc. [Advancement through integration (8)] Another alternative solution that can be given is to clean up the pollutants so as to minimize the factors that cause global warming. If people work together consistently to deal with global warming, then the quality of the environment will definitely improve. This solution is feasible and sustainable if there is support, permits, and participation from the village, sub-district, district, and even state-level governments. In addition, a budget is also needed to carry out remediation [Critical Awareness (10)].
PBL	Global warming is caused by the greenhouse effect, forest fires, illegal logging of tropical forests, industrialization, and increased fuel burning [Disciplinary Grounding (6)]. Various perspectives of scientific disciplines that can solve the problem of global warming, namely: 1. Biology: Studying the impact and interaction of greenhouse gases on living things. For example, the ability of plants to absorb CO22. 2. Physics: studies the interaction of solar radiation with greenhouse gases as well as an increase in atmospheric temperature due to the absorption of radiant heat. 3. Chemistry: studying the chemical compounds of greenhouse gases as well as the nature of these compounds and ways to control them.4. Geography: studying the interaction of global warming with the earth's layers [Advancement through integration (8)]. An alternative solution that can be given is reforestation, because it can reduce global warming by absorbing CO2 gas by plants. The solution is feasible if it starts from our own environment and includes efforts that are easy to do. What is most needed is self-awareness and community awareness as well as tools that support these efforts [Critical awareness (4)].

Note: problem-based learning with the SSI approach (PBL-SSI) and problem-based learning (PBL)

Table 2. Answers and scores of students' argumentation skills based on the rubric

Group	Answer
PBL-SSI	I do not accept the solution [Claim (3)]. Industry is a pillar of the global economy. The survival of society depends on the industrial sector. Industry in Indonesia itself is able to increase productivity, reduce unemployment, innovate, and optimally increase resources [Data (3)]. If industrial activities are stopped completely and simultaneously, it will have an impact on the economy in Indonesia. Indonesia will experience state debt inflation, poverty, and hunger. In my opinion, industrial activities can continue to be balanced with an attitude of care for the environment that must be carried out by everyone [Warrant (3)]. Based on a press release (Number: SP.227/HUMAS/PP/HMS.3/7/2021), which was carried out by the Ministry of Environment and Forestry of the Republic of Indonesia on July 26, 2021, it stated that realizing a good order of life (sustainable and environmentally friendly development) requires significant changes in human attitudes and behavior, including changing consumption and production patterns in a sustainable and environmentally friendly way [Backing (3)]. Based on this, it can be concluded that industrial activities must also continue, but using environmentally friendly methods. If only industrial activities continue, then the lives of living things, especially humans, will increasingly become extinct because of global warming, which

Group	Answer
	reduces a decent place to live for many living things. However, if you only focus on tackling global warming, then humans will also experience extinction due to hunger. Both industrial activities and countermeasures against global warming must run in balance [Rebuttal (3)].
PBL	I do not agree with this solution [Claim (3)], because if you want to overcome global warming, you don't have to stop all industrial activities in the world because this could be detrimental to the economy [Data (2)]. To reduce and overcome global warming, many efforts can be made, depending on each individual [Warrant (1)].

Note: problem-based learning with the SSI approach (PBL-SSI), and problem-based learning (PBL) With a 95% level of confidence, the average pre and post-test scores of the two models were compared using analysis of covariance (ANCOVA) to determine a significant difference in the increase in test scores. If a significance value of less than 0.05 was obtained, there is a significant difference, if a significance value of more than 0.05 was obtained, there is no significant difference.

3. RESULT

Implementation of Learning Model Syntax

Based on the observation results, the implementation of the PBL-SSI and PBL model syntax can be implemented well, as can be seen in Table 4. Based on this table, it can be seen that the implementation of the PBL-SSI model at 90.63% is included in the very well implemented category. The implementation of the PBL model syntax of 83.54% was included in the well implemented category. The criteria for implementing the PBL learning model syntax using the SSI approach can be seen in Table 3.

Table 3. Learning Implementation Criteria

Assessment (%)	Quality Level
85-100	Very Good
80-84	Good
75-79	Enough
70-74	Less
0-69	Failed

Source: Cahyati (2016, 28)

Table 4. Implementation of the learning model syntax

Model	Learning Implementation (%)	Qualification
PBL-SSI	90.63%	Very Good
PBL	83.54%	Good

Interdisciplinary Thinking Skills

The results of the prerequisite test for normality, homogeneity, and linearity of the data show their respective significance values, namely 0.372; 0.08; 0.258, where the value of $p > 0.05$, so it can be concluded that the data is normally distributed, homogeneous, and linear. Based on this, it can be continued with the ANCOVA test, which is used to analyze the statistically significant effect between the pre- and post-PBL-SSI and PBL tests on interdisciplinary thinking skills, which can be seen in Table 5. There is a significant difference between the results of the pretest and posttest on both methods. The significance value of all indicators of interdisciplinary skills is less than 0.05, so it can be said that the PBL-SSI model applied in biology learning has an effect on increasing students' interdisciplinary thinking skills. Students in the PBL-SSI group had better interdisciplinary thinking skills than the PBL group in the Disciplinary Grounding, Advancement through integration, and Rebuttal components.

Table 5. The interdisciplinary thinking skills of PBL-SSI and PBL students

Indicator	Group	Pretest	Posttest	P-value (ANCOVA)
Disciplinary Grounding	PBLSSI	7.16	7,68	0.000
	PBL	4.69	6,13	
Advancement through integration	PBL-SSI	5.06	7,31	0.000
	PBL	5.78	5,14	
Critical awareness	PBL-SSI	8.04	10.54	0.000
	PBL	9.44	8.72	
Total of indicators	PBL-SSI	20.3	25.5	0.000
	PBL	19.9	20.1	

Argumentation Skills

The results of the statistical tests of argumentation skills before and after the test can be seen in Table 4. The results of the prerequisite tests for normality, homogeneity, and linearity of the data show their respective significance values, namely 0.244; 0.937; 0.428 where the value of p> 0.05, so it can be concluded that the data is normally distributed, homogeneous, and linear. Based on this, it can be continued with the ANCOVA test which is used to analyze the statistically significant effect between the pre- and post-PBL-SSI and PBL tests on argumentation skills, which can be seen in Table 6. There is a significant difference between the results of the pretest and posttest on both methods. The significance value of all indicators of argumentation skills is less than 0.05, so it can be said that the PBL-SSI model applied in biology learning has an effect on increasing students' argumentation skills. The PBL-SSI group students had better argumentation skills than the PBL student group in the Claim, Data, Warrant, Backing, Qualifier, and Rebuttal components.

Table 6. Interdisciplinary thinking skills of PBL-SSI and PBL students

Indicator	Group	Pretest	Posttest	P-value (ANCOVA)
Claim	PBLSSI	2.03	2.73	0.000
	PBL	1.76	1.81	
Data	PBL-SSI	1.90	2.35	0.001
	PBL	2.17	1.93	
Warrant	PBL-SSI	1.57	2.67	0.000
	PBL	1.59	1.81	
Backing	PBL-SSI	1.68	2.32	0.000
	PBL	1.96	1.38	
Qualifier	PBL-SSI	1.98	2.47	0.000
	PBL	1.83	2.04	
Rebuttal	PBL-SSI	2.01	2.56	0.000
	PBL	2.36	2.18	
Total of indicators	PBL-SSI	11.2	12.6	0.000
	PBL	11.7	11.1	

4. DISCUSSION

PBL-SSI and Interdisciplinary Thinking Skills

In comparison to the PBL class group, PBL-SSI has an important effect on the development of inter-disciplinary thinking abilities, as evidenced by data collection results. PBL-SSI presents complex scientific and social problems that necessitate interdisciplinary thinking, i.e., knowledge from multiple perspectives, in order to generate alternative solutions. Environmental change content is one of the essential socioscientific issues that should be discussed in order to cultivate the inter-disciplinary reasoning skills of students. Environmental change is an important topic in cross-disciplinary studies aimed at sustainable development (Widiyawati, 2020). Relevant research states that knowledge of climate change and global warming influences students' decision-making, which is based on the perspectives of farmers, the government, and society in general (Freije et al., 2017). Through PBL-SSI students get more opportunities to use their interdisciplinary knowledge in dealing with problems that arise by considering alternative mitigation strategies, starting from regional, national and even global contexts.

The results showed that PBL-SSI had an effect on students' critical awareness of environmental problems. This is in line with the literature, namely that students' sensitivity and critical awareness can be increased through PBL-SSI so that it can indirectly shape students' character and open-mindedness (Nida et al., 2020). The process of developing student competencies in integrating scientific disciplines (Advancement through integration) can be carried out through the PBL-SSI syntax. In addition to considering the skills acquired by students, the PBL-SSI syntax also develops the competencies of teachers, namely developing teaching skills, designing contextual and innovative learning, utilizing varied learning resources, acquiring interdisciplinary knowledge, developing critical thinking skills, making authentic assessments, and being able to motivate students (Nida et al., 2020).

The same research was also conducted by Wu & Tsai (2013) with the result that the reasoning done by class X students about the issue of the use of nuclear energy shows that these students are able to reason about problems from various perspectives. Climate change material in PBL-SSI can help students be more prepared when making decisions and integrating disciplines to obtain alternative solutions (Dana L et al., 2019). Based on research conducted by Abbonizio & Ho (2020), in the PBL-SSI learning process, students have a better level of reasoning and tend to integrate more diverse perspectives in taking alternative solutions.

PBL-SSI and Interdisciplinary Thinking and Argumentation Skills

PBL-SSI proved to be significantly better at improving students' argumentation skills than the PBL group. PBL-SSI can improve interdisciplinary thinking skills as well as argumentation skills. The process of compiling an interdisciplinary framework can contribute to developing and evaluating students' argumentation skills about a problem. PBL-SSI presents the latest controversial issues by linking various scientific, ethical, economic, and political-social dimensions. The problems used in PBL-SSI are scientific problems, but solving these problems does not only rely on scientific considerations but also uses the perspectives of various other disciplines (Eggert et al., 2019). The socioscientific nature of issues in the PBL model can challenge students to find interdisciplinary solutions by contemplating problems, seeking relevant information, being involved in giving arguments, applying reasoning skills, and integrating various perspectives to obtain joint decisions (Fang et al., 2019). Indirect argumentation skills will also increase because, through PBL-SSI, students can compare and consider the pros and cons of different options and integrate various disciplines to choose a decision-making strategy so that the best alternative solutions are obtained (Fang et al., 2019). PBL-SSI provides contemporary problems that combine social and scientific knowledge, so as to involve students in independent science learning, moral reasoning and argumentation (Marthaliakirana et al., 2022).

PBL-SSI allows students to obtain solutions by integrating various disciplines. In this process, students will present their arguments by providing evidence or refute arguments with claims based on conflicting evidence and examples. When students do their analysis, they must look for supporting data; this will affect the level of someone's argument when expressing opinions based on evidence (Marthaliakirana et al., 2022). The skills needed to solve problems in the PBL-SSI model are to produce correct actions and coherent arguments in creating interdisciplinary solutions. This is in accordance with the opinion of Istianaa & Herawatia (2019), the PBL-SSI model provides unstructured problems involving various disciplines and requires more arguments because it is used to generate and support alternative solutions in indicators of interdisciplinary thinking skills. Opinion of Nida et al. (2020) stated that one of the characteristics of PBL-SSI has social scientific problems which involve students to discuss, dialogue, debate, and argue. This proves that the PBL-SSI model besides being able to improve interdisciplinary thinking skills can also influence the improvement of argumentation skills. Relevant research results state that students' argumentation skills can be improved in interdisciplinary contexts, such as socioscientific issues (Guilfoyle et al., 2023). The interdisciplinary socioscientific issue approach in the PBL model can train students to create solutions and make decisions that are supported by evidence-based arguments.

5. CONCLUSION

PBL-SSI has been demonstrated that the application of the PBL-SSI model substantially improves the inter-disciplinary thinking and argumentation skills of class X students at SMAN 1 Wates. PBL-SSI improves inter-disciplinary thinking and argumentation skills more effectively than PBL.

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