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Implementation of Socio-Scientific Issues in Science Learning to Improve Argumentation Skills: A Case of Space Debris Debate

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Abstract: Implementation of Socio-Scientific Issues in Science Learning to Improve Argumentation Skills: A Case of Space Debris Debate. Objectives: This study aims to assess the impact of implementing science learning with a socio-scientific issue approach and debate on space debris on scientific argumentation skills. **Methods:** The type of research applied was a quasi-experiment using a non-equivalent control group design. In the experimental class, learning science with debate activities on space debris within the socio-scientific issue framework was applied for four lessons, while in the control class, the usual learning was carried out by the teacher. The test data was analyzed using a t-test to determine whether the treatment had an impact on argumentation skills. **Findings:** Implementation of science learning with a socio-scientific issue approach and debate activities on space debris had a significant impact on scientific argumentation skills. Students defend their argument from other rebuttals by showing scientific evidence and providing scientific explanations. **Conclusion:** Science debate about space debris in science learning with a socio-scientific issue approach can provide a dynamic learning experience, students can provide claims accompanied by scientific evidence and reasoning that connects claims with evidence.

Keywords: science debate, socio-scientific issue, space debris, argumentation skills.

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INTRODUCTION

Global development demands the possession of various thinking skills that are much needed today. One thinking skill that is important for students and needed in the 21st century is scientific argumentation skills. Scientific argumentation is a thinking skill that involves the ability to reason accompanied by scientific evidence and explanation. Argumentation skills involve evidence-based reasoning abilities and critical thinking skills (Demircioglu et al., 2023; Kabataº Memiº & Çakan Akkaº, 2020; Yýldýz-Feyzioðlu & Kýran, 2022). Aspects of scientific argumentation include the skills of making claims, providing evidence, and providing rational explanations (Hendratmoko et al., 2023; Rosliana & Suyanto, 2022). Scientific argumentation skills are of important benefit to students in learning. With good scientific argumentation skills, students can reason, think logically, and solve problems (Iwuanyanwu, 2023). Students who have good scientific argumentation skills will be able to make scientific claims accompanied by the support of scientific evidence and rational explanations.

Scientific argumentation is an important skill for students but some research results show that students still have difficulty in making evidence-based scientific claims. Students still have difficulty in making claims, providing evidence for their claims, and providing reasoning to connect the

evidence with their claims (Lieber & Graulich, 2022; Zaroh et al., 2022). Students must learn diligently to be able to change the claims that have been built to align them with new evidence found (Walker et al., 2019) and provide logical written explanations accompanied by relevant and scientific evidence (Yamamoto et al., 2022). Several factors can cause students to have difficulties in scientific argumentation. Poor logical thinking skills can cause students to have difficulties in argumentation (Al-Ajmi & Ambusaidi, 2022). Learning environments and experiences that do not support rationality and reflective processes can also have an impact on students' ability to argue scientifically (Münchow et al., 2019). Students often have difficulty in scientific argumentation due to a lack of knowledge, lack of understanding of what argumentation is, and are not familiar with proposing ideas and opinions, supporting other people's ideas, and rejecting other people's ideas and ideas (Friska et al., 2022).

The development of students' scientific argumentation skills is an important part of learning, especially science learning, as part of the development of students' science literacy. Various efforts have been made to assist students in developing scientific argumentation skills. Learning by applying innovative strategies and subject matter can improve thinking skills (Anwar & Susanti, 2019). Several studies have shown that science debate activities can create a learning environment that provides learning experiences to improve argumentation skills (Berndt et al., 2021; Iordanou et al., 2019; Özdem Yilmaz et al., 2017). In its implementation, students' willingness to debate science is still minimal (Choi et al., 2021) due to the lack of evidence ownership, which impacts the ability to build scientific claims (Muntholib et al., 2021). De La Paz et al. (2023) suggested interaction in scientific argumentation, where less proficient students learn together with other more proficient students. Hendratmoko et al. (2024) suggest the implementation of debate activities in inquiry-based learning so that students have sufficient evidence and logical reasoning when arguing. Thus it can be said that inquiry, discussion, and debate are important activities in the learning process, as part of providing opportunities for students to learn together to build scientific arguments. The debate process can produce valid arguments because they have been discussed and agreed upon in a joint forum.

Debate topics are an important part of teaching argumentation skills. One of the science debate topics that is currently widely applied to teach scientific argumentation is scientific social issues commonly referred to as socio-scientific issues. Socio-scientific issue learning is effective for teaching scientific argumentation (Dewi et al., 2023; Owens & Sadler, 2024). Socio-scientific issues in learning can have an impact on students' ability to argue, students can provide claims accompanied by adequate scientific evidence and explanations (Ivani & Dutilh Novaes, 2022; Lin & Wei, 2024; Nurtamara & Widyastuti, 2023). Socio-scientific issue learning that combines debate activities and reflective thinking can improve students' ability in scientific argumentation (Bächtold et al., 2023). Some socio-scientific issues that have been implemented are climate change (Dawson & Carson, 2020), scientific testing using animals (Garrecht et al., 2021), air pollution (Macalalag Jr et al., 2020), energy (Martín-Gámez & Erduran, 2018). These socio-scientific issue approaches have been shown to help students provide scientific explanations that link scientific claims and evidence when they argue.

Some science topics covered by socio-scientific issues have been used to teach scientific argumentation and not many have integrated the topic of space exploration. On the other hand, debate activities and inquiry-based learning can be implemented to teach scientific argumentation.

For this reason, in this study, science learning by integrating socio-scientific issues and inclusive learning focused on the debate about space debris as a result of the increasingly intense space exploration program. For this reason, the problems raised in this research are as follows.

How are students' argumentation skills after the implementation of science learning that integrates socio-scientific issue debate activities on space debris?

What is the effect of science learning that integrates socio-scientific issue debate activities about space debris on students' argumentation skills?

METHOD

Research Design

The type of research applied is a quasi-experiment using a non-equivalent control group design. This design is used because students are already in a class that has been determined by the school but between classes have similar characteristics and include comparable classes (Fraenkel et al., 2023). In this research design, two classes were used where one class received treatment in the form of science learning by applying the socio-scientific issue approach accompanied by debate activities about space junk and the other class as a control class that applied the usual learning applied by the teacher.

Population and Sample

The population used in this study were all seventh-grade students of SMPN 2 Lumajang East Java, which were 8 classes. The samples used in this study were students in two classes, namely class VIIA students as the experimental class and class VII D students as the control class. The number of experimental class students was 28 students with details of 16 female students and 12 male students. The number of control class students was 28 students with details of 15 female students and 13 male students.

Treatment

Science learning on solar system material was conducted for 4 meetings in both experimental and control classes. In the experimental class, learning with the socio-scientific issue approach was applied and in the control class, learning was applied as usual by the teacher. In the experimental class, learning began with a general explanation of the subject matter and learning activities carried out by students. Furthermore, students learn in groups using learning media in the form of electronic modules in which there are material descriptions, social problems about space debris, instructions for conducting investigations, instructions for discussions and debates about scientific solutions to space debris problems. During the investigation process, students can explore cyberspace to obtain information and scientific data related to space exploration and, the positive and negative impacts of space exploration. The information and scientific data obtained by students are used to support claims during the debate. In the control class, learning was conducted as usually done by the teacher. Learning begins with a general explanation of the material and learning activities that will be carried out by students. Students listened to the teacher's explanation of solar system material and space exploration. Furthermore, the teacher gave problems about space debris, and students were assigned to determine various alternative solutions to these problems by discussing them in groups. After learning for four meetings, a posttest was conducted in two classes to measure the final argumentation skills.

Instrument

The research instrument used to measure scientific argumentation skills was a written test in the form of an essay test adapted from (Acar & Patton, 2016). The essay test is 2 items, and each item consists of 3 questions that ask about

aspects of scientific claims, evidence, and explanations. The test results from students were scored and graded by referring to the scoring guidelines that had been made by the researcher. Before being used to measure argumentation skills, the instrument was logically validated by three validators who are experts in the field of science learning. The validated test was then used to measure argumentation skills after the students followed the lesson.

Data Analysis

Data analysis was conducted to determine whether the socio-scientific issue learning approach involving a debate activity on space debris had an impact on scientific argumentation skills. The statistical analysis used was an independent sample t-test that began with a normality test (Denny et al., 2017). Statistical tests were carried out on all data on students' argumentation skills, both in experimental and control classes. Based on the results of the statistical test, the impact of socio-scientific issue learning that integrates debate activities on argumentation skills can be analyzed. The t-test analysis can only describe whether there is a difference due to the treatment. An effect size analysis is needed to determine how strong the impact of the treatment is on scientific argumentation skills. The effect size is done by calculating using the Cohen formula as this calculation has been done by Khairunnisa & Faradillah (2023). The strength of the impact of the treatment on scientific argumentation skills is determined based on the criteria determined by Cohen (1992). Based on these criteria, it can be determined how strong the impact of science learning with socio-scientific issues and debate activities is on scientific argumentation skills.

RESULT AND DISCUSSION

This study was conducted to examine science learning by applying the socio-scientific issue approach accompanied by debate activities about space junk and analyzing its impact on scientific argumentation skills. Science learning is carried out on solar system material by integrating inquiry activities so that students can conduct investigations to obtain scientific information and data used to support the proposed sentence. The investigation process is carried out by exploring the virtual world and visiting websites that present information about space exploration. Students also conduct scientific debates about space debris in terms of its causes, impacts, and solutions. Arguments proposed by students must be supported by scientific information and data obtained through inquiry activities. After learning for 4 meetings, the results of students' scientific argumentation tests in the experimental and control classes were obtained as shown in Table 1.

Table 1. Descriptive analysis of argumentation skills

No	Data	Experiment Class	Control Class
1	Number of Students	28	28
2	Minimum Score	56	11
3	Maximum Score	94	78
4	Average	76.93	34.43
5	Standard Deviation	10.859	15.262

Based on the data, it can be seen that students' argumentation skills in the two classes varied. In the experimental class, the argumentation skills were in the range of the minimum score of 56 to reach the maximum score of 94. Likewise, in the control class, the range of argumentation skills was very wide, from a minimum value of 11 to a maximum value of 78. However, the lowest value in the control class was very small, which was 11 on a value scale of

0 to 100. The width of the range of values from the minimum value to the maximum value can also be seen based on the standard deviation number, where both classes show a fairly large price. The average scientific argumentation skill in the experimental class is relatively much greater than the control class. This shows that the classical ability of the experimental class is better than the ability of the control class. Learning by integrating socio-scientific issue debate on space debris has a positive impact on students' argumentation skills.

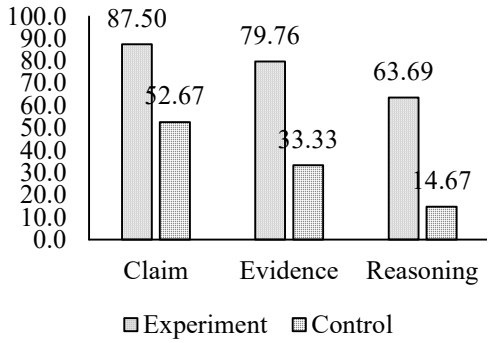

Figure 1. Argumentation skills for each aspect

Analyses were also conducted on each aspect of argumentation skills. The three main aspects analyzed based on the argumentation test results include claims, evidence, and reasoning. The results of the analysis of each aspect of argumentation skills in the experimental and control classes are shown in Figure 2. Based on the data, it can be seen that the skill in providing claims for students in both classes is relatively higher than other skills. The skill of providing logical reasoning gave the lowest result compared to the other two skills. In general, students' skills in providing claims, evidence, and reasoning in the experimental class were better than students in the control class. However, the skill of providing logical reasoning for experimental class students is still in the poor category. This is indicated by the average achievement of skills to provide logical reasoning only reached 63.9 on a scale of 0-100. The results of this study indicate that learning science by applying the socio-scientific issue approach and science debate activities on space junk can develop students' skills in providing scientific claims and evidence but still not optimally in developing logical reasoning skills. Although students have been able to make claims with the support of scientific evidence, students still have difficulty connecting the two through logical scientific reasoning.

Scientific reasoning is an important part of argumentation skills. The results of this study show that students' ability to provide logical reasoning is still not optimal. Students have not optimally developed their reasoning skills. Science debates conducted in learning are more dominated by discussions about claims and scientific evidence that support claims. The reasoning provided by students is shown by less detailed explanations and restating scientific evidence as part of the reasoning provided by students. The results of this study are in line with previous research that some students had difficulty in providing reasoning that included incompleteness, imprecision, and confusion between claims and scientific evidence (Yamamoto et al., 2022). Students have difficulty providing scientific arguments based on the claims given (Lieber & Graulich, 2022; Zaroh et al., 2022). This is because the problem being discussed is quite complex and students have difficulty in obtaining important information that can be used to provide scientific explanations. Some students provided reasoning by showing scientific evidence and scientific claims. For this reason, the results of this study still need to be followed up to determine what are the factors that cause students to still not be optimal in providing scientific reasoning.

Table 2. Test of normality

Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig
Control	.144	28	.140	.930	28	.062
Experiment	.141	28	.162	.940	28	.113

The test data in the experimental and control classes were then statistically analyzed to determine the impact of the treatment on scientific argumentation skills. Statistical analysis begins with a data normality test to determine whether the data obtained based on the scientific argumentation test is normally distributed. This test was conducted as a condition for conducting hypothesis testing. The results of the data normality test are shown in Table 2. Based on the Shapiro-Wilk test results, data is normally distributed if the significance value is above 0.05. Based on the test results, the significance value is 0.06 for scientific argumentation data in the control class and 0.113 for scientific argumentation data in the experimental class. Thus it can be stated that the scientific argumentation data in both classes are normally distributed and declared suitable for further statistical tests.

Table 3. Test of homogeneity of variance

	Levene Statistic	df1	df2	Sig.
Based on Mean	1.609	1	54	.210
Based on Median	1.287	1	54	.262
Based on Median and with adjusted df	1.287	1	44.426	.263
Based on trimmed mean	1.327	1	54	.254

The next data analysis is the homogeneity test using the Levene test. This test is conducted to determine whether the experimental class and control class have the same variance and ensure whether the data is uniform between the two classes. The results of the homogeneity analysis of variance using the Levene test are shown in Table 3. Based on these results, it can be seen that the significance value of the argumentation test data is 0.210. This value is above the probability value of 0.05 so it can be stated that the sample variance is homogeneous.

Based on the results of the analysis, it was found that the data on scientific argumentation skills were normally distributed and the variance in the population was uniform. Thus, the statistical analysis can proceed to the independent sample t-test. The t-test was conducted to determine whether the students' scientific argumentation skills in the experimental and control classes were significantly different. The conclusion is based on the significance value, if the significance value is smaller than 0.005, it can be concluded that there is a difference in the average scientific argumentation skills between the experimental class and the control class. The results of the t-test are shown in Table 4. Based on these results, it can be seen that the significance value of 0.000 is smaller than the significance limit of 0.050. Thus it can be stated that there is a difference in scientific argumentation skills between experimental class students and control class students. Classically, the average argumentation skills of experimental class students were better than the control class.

Table 4. Independent sample t-test

	F	Sig.	t	Df	Sig. (2-tailed)
Equal variances assumed	1.609	.210	12.006	54	.000
Equal variances not assumed			12.006	48.761	.000

The results showed that there were differences in scientific argumentation skills between the experimental class and the control class. The implementation of science learning in the experimental class by applying the socio-scientific issue approach and debate activities on space debris had an impact on developing scientific argumentation skills. Classically, students' argumentation skills reached an average of 76.93, and in the control class reached an average of 34.43. This means that students' scientific argumentation skills in the experimental class were better than in the control class. Students were able to provide claims accompanied by scientific evidence well. Students were able to provide detailed and logical scientific explanations to link claims with evidence. The result of the effect size calculation obtained a value of 3.21, which means that science learning with socio-scientific issues and debate activities has a very strong impact on scientific argumentation skills. Inquiry, discussion, and debate activities can help students build argumentation skills. Debates provide students with experience on how to defend their claims compared to other claims. Students try to position ideas and concepts in a strong position because of the support of scientific and rational evidence and explanations.

The results showed that the socio-scientific issue approach to space debris is efficient in teaching scientific argumentation skills. The results of this study support previous studies which state that socio-scientific issues can be used in science learning to develop argumentation (Capkinoglu et al., 2020). Students can learn to make claims based on phenomena offered by the teacher. Students make claims that space exploration has positive and negative impacts on humans. Some of the claims made by students are that space exploration provides benefits to humans, especially in the field of telecommunications. Long-distance communication that many humans do today can be done with the help of signals transmitted by satellites in space. Students are also able to make other claims that space exploration has a positive impact on human knowledge of the universe. In addition to making claims about positive impacts, students also make claims about the negative impacts of space exploration, namely the high cost required and the large amount of garbage in space that can endanger humans on Earth.

Claims made by students are always supported by scientific evidence. Students can conduct exploration and inquiry to obtain information and scientific evidence to support their claims. Group learning activities assist students in conducting an inquiry to obtain scientific evidence. Students search for articles on the internet to obtain scientific evidence about the positive and negative impacts of space exploration. During the learning process, students discuss with other students to discuss whether the scientific evidence obtained can be used to support the sentence. This is done as an effort to ensure that the scientific evidence obtained can provide an objective basis in supporting the claim. To agree on the scientific evidence used to support the claim, students debated. The results of this study follow previous research that the debate process accompanied by inquiry activities can help students develop their ability to make claims and provide scientific evidence that supports claims (Martini et al., 2021; Guo et al., 2023). Some students have to debate other students to defend their ideas and ideas so that the scientific evidence submitted can be agreed upon in the group.

In general, it can be stated that debate activities on scientific social phenomena can be used as a medium for student teachers to develop scientific argumentation skills. The results of this study follow previous research where debate activities and reflective thinking in science learning can provide learning experiences for scientific argumentation (Bächtold et al., 2023).

Contradictory scientific social phenomena, on the one hand providing positive impacts and on the other hand, providing negative impacts, have the potential to become debate material for students. Claims must be supported by scientific evidence and logical reasoning that links the claim to the evidence presented. In daily life, many social phenomena are scientific and can be used to support interactive science learning. Controversial science phenomena can be used by teachers in science learning to encourage debate between students. Students can propose different arguments with other students which will trigger debate between the two contradictory arguments (Khishfe, 2021). Teachers should be able to create innovative science learning by integrating science phenomena into learning. Scientific evidence used to support claims can be obtained by students through inquiry activities, which can be hands-on activities or mind-on activities. In this study, mind-on activity through discussion and internet exploration by reading articles about space exploration can help students provide scientific evidence. The evidence obtained can be used to support their claims. Students discuss in groups to agree on claims, scientific evidence, and reasoning.

CONCLUSION

Science learning by applying the socio-scientific issue approach and debate activities is proven to develop scientific argumentation skills. Students learn to make claims supported by scientific evidence and logical reasoning obtained through the inquiry process. The debate process between arguments leads students to an agreement on a valid argument. Thus, the science learning process that requires students to submit claims and scientific evidence provides opportunities for discussion and debate activities. In this study, students had to make claims about the positive and negative impacts of space exploration on humans accompanied by scientific evidence and logical explanations. The implemented learning can develop students' skills in making claims and scientific evidence but has not optimally developed students' ability to provide reasoning that connects claims with scientific evidence. The results of the study can be used as a guide for teachers in implementing interactive science learning that leads students to the achievement of various thinking skills.

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