The Effect of Scientific Reading Based Inquiry-STEM to Stimulate Scientific Argumentation Skills

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Abstract. Scientific argumentation is one of the 21st-century skills that must be mastered, but there are still many facts that most teachers do not know and have been unable to stimulate learning. This study aims to determine the effect of the integrated Scientific Reading Based Inquiry (SRbI) learning model in Science, Technology, Engineering, and Mathematics (STEM) on improving the scientific argumentation skills of junior high school students. The method used in this research is quasi-experimental. The design used is the Noneequivalent Control Group Design. This research was conducted on 63 students as a sample of all eighth-grade students in one of the public junior high schools in Surakarta as a population. The essay test instrument is used to measure argument individually, and a performance-based assessment instrument is used to measure argumentation skills in groups. The data analysis technique used is the t-test and the Mann-Whitney test. SRbI-STEM model improves students' scientific argumentation skills more effectively than conventional models. The average N-gain score of scientific argumentation skills in the experimental class is 0.24 and in the control class is 0.07. While the average value of N-gain scientific argumentation skills individually in the experimental class is 0.32, and the control class is 0.13. The t-test and Mann-Whitney test results showed differences in the ability of scientific argumentation, both individually and in groups, between the experimental and control classes. The results of this study then become the basis for developing argumentation skills through STEM-based multi-model learning using innovative media.

Keywords: Scientific Argumentation Skills, Scientific Reading Based Inquiry, Science Technology Engineering, and Mathematics

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1 Introduction

The learning process in the 21st century leads to various knowledge, skills, habits, and characters considered essential for success in today's world [1]. Critical Thinking and problem solving, Creativity, Collaboration, and Communication (4C) are essential skills that become solutions to global challenges, shaping students into human beings who can contribute creative ideas and solve problems [2]. 4C skills are related to scientific argumentation, especially critical thinking and communication skills. Scientific argumentation has a big enough role in improving students' critical thinking and communication skills [3], [4]. Scientific argumentation is a student's skill in expressing an opinion structured and supported by scientifically strong evidence and reasons, which aims to defend his opinion [5]. Scientific argumentation skills are also fundamental for students to think, communicate, and act like scientists [6]. Scientific arguments are also beneficial for students, such as increasing understanding of concepts and student learning outcomes and developing reasoning abilities, and writing reciprocal ideas [7] [8].

Approximately three months of observations and interviews were done at one of Surakarta's public junior high schools, indicating that students' scientific reasoning skills are still lacking. Student learning actions during the learning process are pretty passive. In a class of around 30 students, just two or three are willing to ask questions, provide answers, and lead discussions during the learning process. This occurrence continues to occur in nearly all classrooms and subjects. Only seven out of a total of 37 students were able to make claims [9]. Based on a preliminary study conducted, more than fifty percent of students' daily test responses contained just assertions without supporting evidence or reasoning.

Numerous factors contribute to students' lack of scientific argumentation abilities, including a lack of habituation from teachers to make arguments, a lack of bravery to express viewpoints, and a lack of basic information from the preliminary reading. According to the results of interviews with instructors at one junior high school in Surakarta, the teacher had facilitated discussion activities but could not develop students' reasoning skills. Based on the observations and interviews, these findings concur with the research findings that elementary and middle school students' scientific reasoning skills are still lacking [10]–[12]. The majority of students lacked the courage to voice their opinion. Others dare to speak their thoughts, but the quality of their arguments, which consist of unsubstantiated assertions, is still relatively low [13].

An alternate solution to overcome the weakness of argumentation skills is the implementation of learning models that can assist teachers in carrying out student-centered learning and stimulate students' scientific argumentation skills. There are many studies on learning models that can stimulate and improve scientific argumentation skills, such as class discussion learning models [14], project-based learning [15], problem-based learning [16], inquiry learning [17], Argument-Driven Inquiry (ADI) [18] with their respective advantages and disadvantages. Based on existing research, the inquiry learning model is more capable of stimulating and developing students' scientific argumentation skills [19]. The inquiry learning model can lead students to construct an argument from the knowledge they build themselves

through experiments in proving a phenomenon. However, one weakness of inquiry learning is the lack of prior knowledge of students during the learning process. Students can obtain initial knowledge through reading activities before learning, but in fact, students' interest in reading is still low. Based on the results of PISA, Indonesia ranks 72 out of 77 countries that take the PISA test [20].

Scientific Reading-based Inquiry (SRbI) is an inquiry learning methodology based on scientific reading since it combines inquiry with reading activities [19]. Students can build quality arguments using the SRbI. If the use of the model is combined with a learning strategy that aligns with the learning objectives, performance will be enhanced. The Science Technology Engineering and Mathematics (STEM) methodology [21]–[23] emphasizes students' scientific argumentation skills. Through the STEM stages, students can explore their ideas and creativity. STEM can enhance student success in science, mathematics, reading comprehension, and academic accomplishment [24]. Some research demonstrated that this approach improves students' critical thinking [25], problem-solving, achievement, and creativity [26]. STEM also helps enhance students' scientific argumentation skills [27].

Alternative actions to overcome the problem of students' low scientific argumentation skills include presenting a meaningful learning process that allows students to communicate actively about a problem from various points of view of each. So far, even though the teacher has conditioned the discussion of interactions in learning, students are not given much space to express their opinions. This fact gives the impression that scientific communication in learning takes place in one direction, even though the diversity of experience and knowledge built by students is one of the capitals for ongoing scientific communication in the classroom, both in discussions between students and teachers [28]. If this continues, how can students acquire and build their thinking skills, especially higher-order thinking skills.

Several inquiry-learning models and strategies have been proven to improve argumentation skills. However, in reality, the selection of learning models cannot be made haphazardly because the teacher must accommodate the student's character, especially regarding the level of knowledge, group dynamics, and perceived values. This study applies the SRbI model because it has the advantage of positively impacting students' scientific argumentation skills compared to other models [19], as well as providing a multidisciplinary science learning experience through a STEM approach. This reason makes this research necessary, especially to find out how much impact SRbI integrated STEM has on students' scientific argumentation skills. The results of this study are helpful for future researchers and education practitioners to apply and develop appropriate learning processes to improve students' argumentation skills. Based on the described issues, there is a need to study learning models that address the issue of inadequate scientific arguentation skills. Consequently, this study aimed to investigate the impact of the SRbI-STEM model on improving students' scientific argumentation skills.

2 Research Method

This research is experimental quantitative research. The type of research used is a quasi-experimental design with a Nonequivalent Control Group Design. The population was all class VIII students in one of the public junior high schools in Surakarta, totaling 256, and divided into eight classes from class A to class H, each category containing 32 students. The sample used is two classes with a total of 64 students, one as the experimental class and one as the control class.

The instruments used are essay test questions, performance-based assessments, observation sheets, interview sheets, and documentation. The test contained five questions about light and optical instruments to collect data on individual scientific argumentation skills. Meanwhile, performance-based assessment collects data on scientific argumentation skills in groups. The results of students' writing, both in groups and individually, were analyzed using the argumentation aspect of [29], which includes statements, evidence, and reasons. The study begins with observing students' scientific argumentation skills before being given treatment. Then the two classes were offered unequal treatment, the control class was treated with the conventional model with the presentation method, and the experimental type was treated with the STEM integrated SRbI model. After the treatment, the students were given a presentation task to measure the improvement of scientific argumentation skills in groups. Then do an essay test to measure the progress of scientific argumentation skills individually.

The data analysis used is the prerequisite test and hypothesis test. Prerequisite tests are in the form of normality and homogeneity tests. Hypothesis testing using independent sample t-test and Mann-Whitney test. Normally distributed data will be analyzed using the t-test, while data that are not normal will be tested using the Mann-Whitney test with a significance level of both tests of 5%. The normality test results show that the average score of individual scientific arguments has a significance score of more than 0.05, so it is known that the data is normally distributed. Meanwhile, the average score of scientific argumentation data in groups gets a significance score of less than 0.05, so it is known that the data was not normally distributed. The results of the two data's homogeneity test showed more than 0.05, so it was known that the data came from a homogeneous population. Data with normal distribution were analyzed using a t-test, while data that were not normal were analyzed using the Mann-Whitney test.

Based on the t-test, the score of sig. (2-tailed) was obtained on the score of individual scientific arguments of 0.000. The score of sig. (2-tailed) shows an effect of the STEM integrated SRbI on personal scientific argumentation skills in students. Based on the Mann-Whitney test, the score of sig. (2-tailed) was obtained in the argumentation score as a group of 0.000. The score of sig. (2-tailed) shows the effect of the STEM integrated SRbI on students' scientific argumentation skills in groups. Based on the N-Gain test, the experimental class scored higher than the control class. On the scientific argumentation, the experimental class got a score of 0.32, and the group got a score of 0.24. The control class on scientific argumentation individually got a score of 0.13 and, as a group, a score of 0.07.

3 Findings

Based on the results of research and data analysis, the discussion will focus on the formulation of the problem, namely the influence of the STEM integrated Scientific Reading Based Inquiry model on students' scientific argumentation skills in groups and individually.

3.1 The Effect of The STEM Integrated Scientific Reading Based Inquiry (SRbI) on Argumentation Skill in Group

Scientific arguments in groups get a lower score than the score of individual arguments. The mean score of students in the control class increased by 6.7 points, while the experimental class increased by 21.0 points. The score of each aspect of scientific argumentation in groups in control and experimental classes is in Figure 1.

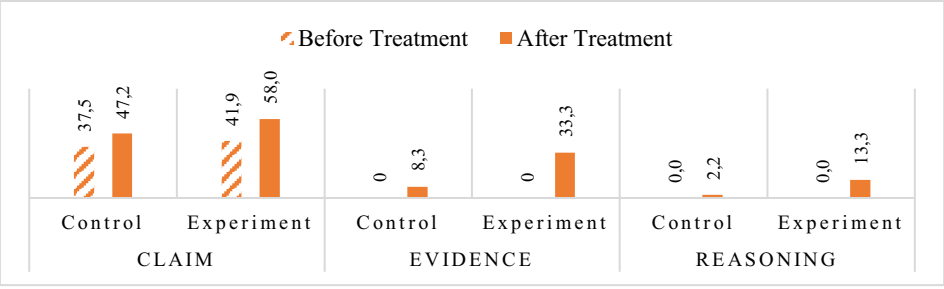

Fig. 1. The score of each aspect of scientific argumentation as a group

Figure 1 shows an increase in all aspects of students' scientific arguments. The mean score of the statement aspect in the control class increased by 9.7 points, while it increased by 16.1 points in the experimental class. The average score of scientific argumentation on the evidence aspect in the control class increased by 8.3 points. The experimental class increased by 33.3 points. The average score of scientific argumentation on the aspect of reasoning in the control class increased by 2.2 points, and in the experimental class increased by 13.3 points. The differences in the answers of the control and experimental class students are in Table 1.

Table 1. Comparison of Students' Argument Answers in Groups

	Comparison of Students' Arguments in Groups After Treatment
Control Class	Questions from group 4: Explain solar cookers' disadvantages and negative impacts! Answers from group 2: Cannot be used at night, longer cooking time, very dependent on the weather, not all types of dishes can be cooked
Experiment Class	Question from group 1: What temperature does the solar cooker produce? Answers from group 2: The solar cooker in the design made the temperature reaches 82oC, and food can usually be cooked until cooked at a temperature of 82-135 oC (harivedca.wordpress.com)

Examples of students' responses indicate that the responses of students in the control group, both before and after therapy, tend to contain statements without proof or justification. Students in the experimental class added evidence, reasoning, and sources to their statements after receiving the treatment. Although the level of experimentation has grown, the level of discussion between the two classes remains the same. The study results indicate that the scientific argumentation skills of groups of students are inferior to those of individuals. Before group and individual treatment, there is a substantial disparity between students' scientific argumentation skills in their early conditions. Based on this disparity, there must be a reason why most students prefer to work individually over in groups. This fact follows previous research, which indicates that the score of reasoning in groups is not greater than the score of argumentation alone; nonetheless, working together in groups will lead to collaborative abilities that improve conceptual understanding and information sharing [30] . However, contrary to another findings, the score of argumentation in groups is greater than that of argumentation individually because students can discuss ideas and concepts in groups [31].

According to the interviews, the lack of reasoning abilities in groups makes students feel uncomfortable when working with their peers in groups. Because of the pandemic, they had not met in person for two years. After the pandemic lockdown, this research was undertaken in the school for the first time face-to-face. Even though these eighth-graders have been required to participate in online education since they were freshmen in junior high, student relationships have not been altered. In addition, students never received group assignments during the pandemic, despite having only online chats. Therefore, they are accustomed to learning alone. The lack of collaboration skills among students due to the epidemic should be remedied by teachers through classroom management and developing a learning process that improves collaboration abilities [32].

Through the STEM-based SRBI learning approach, students can hone their scientific argumentation and collaboration skills. The syntax of the SRBI learning model enables students to voice their thoughts. All stages of SRBI , including reading orientation, recapturing, processing, communicating, and reviewing, promote students' ability to construct and deliver arguments [19]. The STEM approach is beneficial for developing scientific reasoning skills in groups since a collaborative project fosters student camaraderie. This proximity will foster productive collaboration among students [33]. Consequently, students' group arguing skills improved in the experimental class.

3.2 The Effect of The Integrated SRbI-STEM on Individual Argumentation Skills in Science Subjects

Individual scientific arguments get a higher score than the score of group arguments. The mean score of individual students in the control class increased by 10.0 points, while it increased by 24.0 points in the experimental class. The score of each aspect of scientific argumentation individually can be seen in Figure 2.

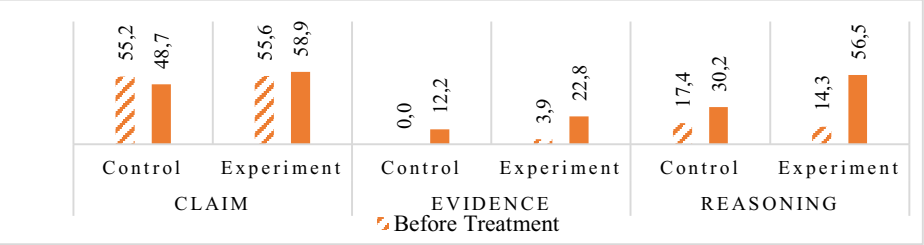

Fig. 2. The Score of Each Aspect Scientific Argument Individually

Figure 2 shows an increase in all aspects of students' scientific arguments. The mean score of the statement aspect in the control class decreased by 6.0 points, while in the experimental class, it increased by 3.0 points. The mean score of scientific argumentation in the aspect of evidence in the control class increased by 12.0 points, while in the experimental class, it increased by 19.0 points. The average score of scientific argumentation on the aspect of reasoning in the control class increased by 13.0 points, while it increased by 42.0 points in the experimental class. The question given to number one is, "Among the energy sources that exist on this earth, which energy is the largest?, Explain your reasons and provide supporting evidence!". The difference in the answers to this question in the control and experimental class students is shown in Table 2.

Table 2. Comparison of Individual Students' Argument Answers

	Comparison of Students' Arguments Individually After Treatment
Control Class	The sun, because the sun can illuminate the earth and help living things, for example, drying fish in the sun, drying clothes, making salt.
Experiment Class	The sun is the largest energy source on earth because it provides enormous heat energy. The sun releases considerable heat energy through its fusion reactions and keeps it warm. In addition, the sun is the most significant source because it is the primary light source for the earth. The sun's surface emits about 63 million energy per square meter (kompas.com).

According to Table 2, the claims and evidence offered by students in the control group are less pertinent to the question's intent. After receiving treatment, students in the experimental class were able to provide evidence and reasoning and cite their reading sources, which significantly improved the quality of their replies. Even while

the sources are news articles, the level of credibility may still be poor. However, this is a significant beginning step for junior high school students who have never been trained to give scientific reasoning. The examination of data indicates that the integrated STEM-SRBI - model affects the scientific reasoning skills of eighth-grade students. The independent sample t-test indicates that the score of individual arguments after treatment is less than or equal to 0.05. Consequently, following treatment, there is a distinction between the control and experimental groups. In addition, the N-gain test demonstrates that individual scientific reasoning skills increase slightly in the control group and rise in the experimental group. This result demonstrates that the SRBI methodology helps individually strengthen students' scientific argumentation skills.

Individually, students' scientific argumentation skills remain inadequate, as evidenced by the average individual score being only 49.0. Based on the results of interviews with teachers and students as well as observations of the learning process, the low level of scientific argumentation skills among students is caused by several factors, including teachers who do not allow students to express their opinions, a learning process that is still teacher-centered, and the presence of a pandemic that causes the learning process to be suboptimal [34]. Based on a three-month study conducted at a public junior high school in Surakarta, most teachers solely used WhatsApp and Google Classroom throughout the pandemic to facilitate learning. Teachers utilize interactive media like zoom and google infrequently meet when instructing. Many students complain about bandwidth and signal limitations when utilizing zoom or google meet for education. Consequently, teachers typically merely assign material and provide no conversation. In online discussions, only a small number of students are willing to answer questions or respond to their friends' opinions, so online discussions are considered significantly less effective in activating students to argue.

Due to the clarity of the SRbI's stages, the SRBI model facilitates students' ability to construct valid and persuasive arguments. This model promotes students to use reading as the basis for argumentation, so they can present evidence and justifications based on reading sources. The STEM method has a good impact on scientific reasoning skills as well. Through STEM, kids learn to make decisions that they believe are optimal for problem-solving [35]. In the experimental class, scientific argumentation skills have improved significantly. Before and after treatment, several students exhibited only a minor improvement. This fact is due to numerous factors that researchers cannot control. These aspects include lesson schedules, students' physical and psychological conditions, and student activities outside the classroom, which might influence students' circumstances in class. The experimental and control classes have morning and afternoon hours on their weekly schedules. Morning hours are from 7.30 to 9.40, and afternoon hours are from 10 to 12. This time difference impacts the kids' physical and mental health and motivation to learn. Morning kids are typically more engaged and excited about learning. However, by midday, kids begin to feel fatigued and lose concentration due to engaging in strenuous play activities with their peers during breaks [36]. The short investigation period, which consisted of only eight meetings, contributed to the modest growth in reasoning abilities shown in this study. Even though the teacher has attempted to establish a suitable argumentation environment by arranging

the classroom space and providing learning resources, the frequency and duration of sessions have not allowed students to acquire used to argumentation. The "habit" component can influence the argument culture, so it is vital to familiarize students with a learning environment that supports scientific argumentation abilities, particularly from the outset of their science education. The main focus in argumentation is proper reasoning and the complexity of the fallacies that occur, especially in using ambiguous words [37]. In practice, argumentation is often considered the same as an explanation when it is not [38]. These are some of the things that teachers who want to provide an argumentative experience in their learning need to be clarified.

4 Conclusion

Based on research and data analysis, it is possible to infer that the SRbI-STEM model has a good impact on students' argumentation skills, both individually and in groups. Using the independent sample t-test and the Mann-Whitney test to analyze the data, the significant score for students' scientific skills in groups and individually is less than 0.05, indicating a difference between the control and experimental courses. Additionally, the STEM-based SRBI approach is more influential than the conventional paradigm. The experimental class has a bigger N-gain than the control class. Regarding group argumentation skills, the experimental class has an N-Gain score of 0.24, while the control class has only 0.07. For individual reasoning skills, the experimental class has an N-Gain score of 0.32, while the control class has just 0.13. These results provide new insights for efforts to develop and empower argumentation skills at the junior high school level and as a basis for further research. Furthermore, it is necessary to carry out another applied research that shoots how students sort and filter all facts during the massive information rate to become strong individuals capable of literacy and numeracy and skilled in scientific argumentation.

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