SMART-Problem Solving Strategy to Improve Students Scientific Argumentation Skills on "Rain and Malin Kundang Stone Issue" as Local Socio-Scientific Issues (LSSI)

Vella Aulia Illahi[1*], Sri Rahayu[1], Hayuni Retno Widarti[1], Yahmin[1]

[1] Department of Chemistry, Faculty of mathematics and science, Universitas Negeri Malang, Malang, Indonesia.

Abstract: Argumentation skills are needed to prepare the generation to face the industrial era 5.0. This research aims to find out whether the SMART-Problem Solving strategy can improve students' scientific argumentation skills in the context of LSSI "Batu Malin Kundang" which is integrated in chemistry learning to encourage students to make good scientific arguments. This research is a quasi-experimental research with Pretest Posttest Control Group design, involving 101 class XI students at one of the State High Schools in Padang City. The research sample was selected using a convenience sampling technique, namely sampling based on availability in the field or samples that have easy access to researchers. Scientific argumentation skills were measured through pretest and posttest using scientific argumentation skills test instrument in the form of an essay (N=4). The data analysis used in this research is parametric (one way ANOVA). The results of the study showed that there was a significant difference in the average students' scientific argumentation abilities between the SMART-Problem Solving class (average score of 74.09), ADI (average score of 62.94) and the control class (average score of 43. 35), where learning SMART-Problem Solving with the LSSI context can improve argumentation skills effectively

Keywords: Local socio-scientific issues (LSSI); Problem solving; Scientific argumentation skills

Introduction

Technological developments have had a big impact on the field of education, especially in preparing the generation for the era of the industrial revolution 5.0. Education in this case becomes a strategic vehicle for efforts to develop all individual potential (Asniar, 2016), where educators have the challenge of preparing students to have weapons to face this era, namely equipping students with the skills needed in the 21st century. One 21st century skills are communication skills, students must be able to communicate with the public and provide arguments in opinions which are currently often called argumentation skills.

Argumentation is basically used in presenting, supporting, refining, and evaluating science (Telenius et al., 2020). Argumentation skills are needed in learning, including in science learning. The use of argumentation in science learning can encourage students to use scientific theories, data and evidence to oppose or confirm a claim they have (Listiyani et al., 2021). There are many natural phenomena that occur, this skill is really needed in solving problems explained by scientific theory, so that the scientific argumentation skills used are important for students to have because they relate to interpreting data or scientific evidence and communication skills (Choi et al., 2011; Gräber et al., 2001).

Scientific argumentation in science learning can be defined as the process of strengthening a claim supported by evidence and logical reasons through evaluation based on scientific criteria or through theoretical studies (Jiménez-Aleixandre et al., 2007; Osborne et al., 2004; Sampson et al., 2009). Integrating

argument learning allows students to produce good learning outcomes and makes students actively motivated in learning activities (Rosyid et al., 2024). However, in reality, practices involving argumentation-based learning in the field are rarely carried out. Internationally and nationally, research shows that argumentation skills are rarely practiced in learning settings so that the majority of pupils and students face difficulties in constructing arguments, so they have simple/low level argumentation skills (Acar et al., 2010; Lubben et al., 2010; Syerliana et al., 2018). This is also supported by research by Driver et al. (2000) that students of all levels of education/age often experience difficulties in constructing their arguments well.

Other findings regarding research on students' argumentation skills in Indonesia show that students' argumentation skills are categorized as a low level of argumentation because most students still experience difficulties in constructing arguments (Putri et al., 2022). Research conducted by Nussbaum (2002) states that most students are unable to provide supporting evidence to strengthen their arguments. This is also in line with Putri et al. (2020) research which states that students' argumentation skills in the field of chemistry are still dominated at level 2 (two). At this level students can only convey their arguments using the basic structure of argumentation. One of the factors that influences students' low argumentation skills is that argumentation skills are not explicitly taught in class, especially in groups of students who are not used to learning argumentation (Putri et al., 2022). Not maximizing the involvement of argumentation in learning can also be caused by a learning environment that does not support argumentation in class, so that to develop students' argumentation skills, an environment that supports argumentation is needed, such as providing context in learning and social interaction in the classroom, which are the main components for developing argumentation skills (Osborne et al., 2004).

The use of context in the science learning process is an effort to bridge the gap between abstract concepts and the reality of everyday life (Zeidler et al., 2009). Context-based learning, students do not only provide ideas by rote, but rather require high-level thinking by presenting dilemmas in problems. One science context that can be applied in learning is the Socioscience Issues (SSI) context.

The SSI context is the presentation of problems in learning that are dilemmatic and controversial in everyday life related to science (Rahayu, 2016; Zeidler et al., 2009). SSI involves science topics that require students to engage in dialogue, discussion, and debate (Zeidler et al., 2009), thereby improving students' argumentation skills. There have also been many studies conducted by several researchers in the field of education related to SSI learning, stating that SSI context

learning can help students reflect on their learning to apply their experiences in everyday life and can hone their thinking skills with the cases or issues given (Fadly et al., 2022; Saija et al., 2022). Based on the research results of Muntari et al. (2024) that the implementation of SSI-based learning materials is quite effective in science learning. SSI as a case deserves to be applied in active learning activities based on real life contexts (Dewi et al., 2022, 2023). SSI learning in everyday life can be made as interesting as possible, such as the "Hydrogen fuel issue" which makes students challenged to find solutions to problem solving (Putri et al., 2022), involving SSI in learning is able to reach a better level in arguing (Setyaningsih et al., 2019).

SSI as a context is found to be both global and local. The global SSI context is an issue about the global, generally presented in learning, while local SSI is an issue that is discussed about circumstances, culture, or problems in a local form that only occur in certain situations or in certain areas that have unique characteristics related to chemistry. Global SSI includes genetic engineering, environmental pollution caused by waste, global warming, green chemistry, and cloning in biotechnology. The local and global context is very closely related to chemical materials and has a large social impact on society. The local SSI used in this research is about Batu Malin Kundang, a tourist attraction in West Sumatra as a form of chemical application in everyday life which raises dilemmas for students in acid-base material. The LSSI context is designed in such a way as to combine the conditions that occur in an area by including chemical material in the discourse.

The dilemma problem in LSSI is quite difficult for students to solve, so learning strategies are needed to solve problems, practice processes, and find problems in the context of SSI. So far, many students have experienced difficulties in solving and finding solutions to everyday problems because the strategies used in learning are only to solve problems that require mathematical calculations, so that most students when solving problems do not pay attention to the steps in solving them, they are only concerned with the final results of the calculations (Ningsih et al., 2024). Problem solving is important for students to have because it can help students make decisions appropriately, carefully, systematically, logically and considering various points of view (Ayunda et al., 2024).

Based on this description, it can be indicated that there are problems in the world of education that must be provided with solutions. One of them is by designing learning strategies that suit student needs. For this problem, we offer problem solving and inquiry learning strategies that specifically use arguments in problem solving. The learning strategy used is a combination of the argument driven inquiry (ADI) strategy (Grooms et

al., 2014; Walker et al., 2011, 2016) with problem solving learning specifically for solving ill-structure problems, namely learning Ill Structure Problem Solving (ISPS) (Ge et al., 2003).

The combination of these two lessons into a SMART-Problem solving strategy is a novelty in this research, resulting in the learning steps needed by students in solving LSSI problems to improve students' scientific argumentation skills. This research contributes to the world of education that SMART-Problem solving can be used to improve students' scientific argumentation skills on dilemmatic and unstructured issues. The aim of this research is to determine the effect of the SMART-Problem solving strategy in improving students' scientific argumentation skills.

Method

Research design and method should be clearly define. This study used quasi experiment with pretest postest Control Group designs. The research sample was selected using *convenience sampling* technique, which is sampling based on availability in the field or samples that have easy access to researchers (Cohen et al., 2018). The sample in this study was 101 people divided into 3 class groups. The pseudo-experimental design was used to determine differences in the results of students' scientific argumentation skills taught with the SMART-Problem solving learning strategy, Argument-Driven Inquiry (ADI) strategy and conventional strategy.

The pseudo-experimental research design used in this study can be described in Table 1.

Table 1. Quasi-Experimental Pretest-Postest Control Group Design

Group	Prettest	Treatment	Posttest
Experimen I	O1	X1	O1′
Experimen II	O1	X2	O1′
Control	O1	X3	O1′

Description:
O1   : Pretest of Argumentation skills
O1′ : Postest of Argumentation skills
X1   : Learning uses the SMART-Problem Solving strategy in the LSSI context
X2   : ADI Learning
X3   : Conventional Learning

Students in the experimental class were given treatment (X1), namely learning using SMART-Problem solving in the SSI context, students in experimental class II were given treatment (X2) with ADI learning strategies and the control class were taught using conventional learning (X3), namely direct instruction learning. The data collection method used an essay test on argumentation skills, then analyzed using the One-way ANOVA parametric test. Before the ANOVA test,

prerequisite tests were carried out, namely the normality test and homogeneity test. If there were differences between the 3 treatments, then they were analyzed using the Post Hoc Tukey test.

Result and Discussion

Results

Data on students' argumentation skills was obtained through learning outcomes in the three classes, each of which had studied the SMART-Problem Solving learning strategy in experimental class I, the ADI learning strategy in experimental class II, and conventional learning in the control class. Before looking at the extent of the differences in the argumentation skills of the three classes, a prerequisite test was first carried out to determine the distribution of the data. This is what determines the use of statistical analysis that will be used in hypothesis testing. Data regarding students' argumentation skills was obtained through a written test in the form of 4 essay question numbers.

Data analysis of students' argumentation skills test results includes prerequisite tests in the form of Normality and Homogeneity tests. The explanation is as follows.

Normalitas Test

The normality test was carried out to determine whether students' scientific argumentation skills in the three classes were normally distributed or not. Analysis of the normality test data on students' argumentation skills was measured using the Kolmogorov-Smirnove Test at a confidence level of 95% or a value of $\alpha = 0.05$ with the help of the IBM SPSS Statistics 22 for Windows program as shown in Table 2.

Table 2. Normality Test Data for Students' Argumentation Skills

Group	A	Sig	Criteria	Conclusion
Experimen I	0.05	0.200	$\alpha < sig$	Normality
Experimen II	0.05	0.200	$\alpha < sig$	Normality
Control	0.05	0.142	$\alpha < sig$	Normality

Table 2 shows that the results of the normality test of students' scientific argumentation skills in the experimental class have a significance value of 0.200 in experimental class I, 0.200 in experimental class II and 0.142 in the control class, which means that the data for the three research classes is normally distributed because the significance value is greater from 0.05.

Homogeneity Test

Another test to determine the similarity of variants in the sample is the homogeneity test. This test uses Levene's Test at a confidence level of 95% or a value of $\alpha = 0.05$ with the help of SPSS Statistics 22 for Windows as shown in Table 3.

Table 3. Homogeneity Test Data for Students' Scientific Argumentation Skills.

Group	A	Sig	Criteria	Conclusion
Argumentation skill	0.05	0.46	α < sig	Homogeny

In Table 3, a significance value of 0.46 is obtained, which is greater than 0.05, so it can be concluded that the three classes have students' scientific argumentation skills that are almost the same or homogeneous.

Hypothesis Testing

The results of prerequisite testing show that the data resulting from argumentation skills are normally distributed and homogeneous, so hypothesis testing can be carried out. Data descriptions of students' argumentation skills for experimental class I, experimental class II, and control class are presented in Table 4.

Table 4. Description of Student Argumentation Skills Data

Group	The number of students	Highest score	Lowest score	Average
Experimen 1	33	95	45	74.09
Experimen 2	34	85	35	62.94
Control	34	65	15	43.35

Table 4 it is known that the average answers to the students' written argumentation skills test for experimental class I, experimental II and control class were 74.09, 62.94 and 43.35 respectively. These data show that the argumentation skills of the Experiment I class are higher than those of the Experiment II class and the control class. Next, a parametric statistical hypothesis test was carried out, namely a one-way ANOVA test assisted by IBM SPSS 22 for Windows at a confidence level of 95% or a value of α=0.05. The results of hypothesis testing on students' scientific argumentation skills are presented in Table 5.

Tabel 5. One Way ANOVA Test Results of Students' Argumentation Skills

	Sum of Squares	Df	Mean Square	F	Sig
Between Group	16268.62	2	8134.30	42.13	.00
Within Groups	18922.37	98	193.08		
Total	35190.99	100			

Table 5 shows that the argumentation skills of experimental class and control class students meet the criteria of Sig < 0.05, so H0 is rejected. Therefore, it can be concluded that there are significant differences in the three research classes. However, the results of the one-way ANOVA test do not fully provide information regarding what could cause differences between research class groups. To find out what factors influence the differences in the three research classes, a post hoc test, namely the LSD test, was carried out. The following are the results of the LSD further test on students' argumentation skills, presented in Table 6.

Table 6. LSD Test Results for Students' Argumentation Skills

	(J) Group	Mean Difference (I-J)	Std. Error	Sig
SMART	ADI	11.15*	3.40	.001
	Control	30.74*	3.40	.000
ADI	SMART	-11.15*	3.40	.001
	Control	19.59*	3.37	.000
Control	SMART	-30.74*	3.40	.000
	ADI	-19.59*	3.37	.000

*. The mean difference is significant at the 0.05 level.

Table 6 shows that the data that has been presented shows that the data on the argumentation skills of SMART class, ADI class and conventional class students meet the criteria with a sig value <0.05 so that H0 is rejected. Thus it can be concluded that: (1) there are differences in students' argumentation skills taught by SMART classes and ADI learning; (2) there are differences in students' argumentation skills taught by ADI learning and conventional learning; (3) there are differences in the argumentation skills of students who are taught SMART learning and control class.

The argumentation skills data used is strengthened by interrater reliability which is indicated by the kappa coefficient (Cohen's kappa) value. Cohen's kappa analysis was chosen by researchers because the correction factor for observational bias is very good so that the research results are not subjective. The kappa coefficient value was determined using SPSS 22 for Windows, namely 0.94. Based on the kappa coefficient value, the reliability of the argument skill data is very high.

Discussion

Based on the research results that have been described, the designed SMART-Problem Solving Learning has an influence in improving students' argumentation skills. This is because the SMART-Problem Solving strategy contains explicit problem solving steps, where problem solving in science education is a student activity using scientific methods to solve problems with the theory they have studied (Saenab et al., 2024). The implementation of SMART-Problem Solving in the SSI context was implemented in experimental group I including five student-centered activities, namely Strengthening, Making, Argumentation, Reflecting, and Testing. In "strengthening" activities, students in class are ensured to understand the learning objectives along with what concepts must be mastered in the learning. The teacher's role in facilitating learning and providing motivation is also considered to be an important aspect related to the

success of learning strategies. Therefore, to support learning outcomes, teachers must be able to facilitate students in developing their abilities (Amirahma et al., 2024).

At the "strengthening" activity stage, students are ensured to be ready and motivated to carry out chemistry learning through "making" activities in which context relevant to the topic has been integrated, because an important component in the learning process is the existence of meaningful learning contained in learning for students (Komalasari et al., 2019). The context used is socio scientific Issues (SSI), namely multidisciplinary dilemmatic problems based on social and scientific dimensions (Sadler et al., 2006) which are presented in the form of articles or readings on Student Worksheets. Teachers can use problems faced by everyday citizens, for example personal health and environmental quality, various contexts that underlie science. The unique characteristic of SSI is that it always involves dilemmas and the pros and cons of a problem is expected to help improve students' scientific argumentation skills.

In the "making" activity, in SMART Problem Solving learning, students identify problems, formulate problems, look for solutions and choose solutions as a form of justification that requires arguments to solve the problem given in the SSI context.

Figure 1. Example of LSSI

SMART-Problem Solving learning in the SSI context requires students to make arguments both in writing and convey their opinions in front of the class through "argumentation" activities. The "argumentation" activity is designed so that students can explicitly practice how to argue based on a good argumentation structure, so that arguing means building sociocultural activities through presentation, interpretation, criticism and revision of arguments carried out in a discussion. Students who have finished making and delivering final arguments then enter the "reflecting" activity to reconfirm the solutions they have made along with important chemical concepts. One SMART-Problem Solving cycle in the SSI context then ends with a "testing" activity where students work on questions that have been prepared by the teacher. This activity supports the problem solving process which is important to ensure students' conceptual understanding of the topic being studied.

The SMART-Problem Solving stages in the SSI context that have been carried out by students have been proven to have a significant effect on students' scientific argumentation skills through a series of statistical tests. Argumentation skills are students' skills in expressing their knowledge both orally and in writing (Skuomios, 2009) which can reflect students' thinking skills in solving a dilemmatic problem (Kilinc et al., 2017). Through the pretest, the initial argumentation skills of students in the three groups of students were the same, namely that most students in each class were only able to produce simple arguments (lower level). Argumentation that is classified at the simple level is shown by students who are only able to choose a claim from the statements that are available but are unable to provide data or evidence, explanation and rebuttal. This finding is in line with previous research which shows that without explicit treatment to practice scientific argumentation skills, students are only able to make simple arguments or just explanations (Lee et al., 2017; Mason et al., 2006; Syerliana et al., 2018).

Good quality argumentation skills can be seen in terms of the completeness of the arguments (Claim, Data, Warrant, Backing, and Rebuttal) and the correctness of the content of the argument which does not contain misunderstandings of concepts and information. After being given learning strategy treatment, there were differences in the results of scientific argumentation skills in the three groups of students. The results of the student argumentation test on the percentage of student argumentation skill achievements can be seen in Table 7.

Table 7. Percentage of Students' Argumentation Skills Level Achievement

Level achievements	Pre-test			Posttest		
	SMART	ADI	Conventional	SMART	ADI	Conventional
0	53.03%	54.41 %	55.88 %	-	-	5.15%
1	45.45 %	42.65 %	40.44 %	2.27 %	2.94 %	17.65%
2	1.52 %	2.94 %	3.68 %	8.33 %	17.64 %	34.56%
3	-	-	-	28.79 %	45.59 %	42.65%
4	-	-	-	40.15 %	27.21 %	-
5	-	-	-	20.45%	6.62 %	-

Based on Table 7, percentage achievement of students' argumentation skills, as many as 40.15% of students have been able to present their arguments in the SMART-problem solving class with good rebuttals and as many as 20.45% of students have been able to provide more than one rebuttal (rebuttal) and that is level 5 level of argumentation. The percentage achievement in the SMART-Problem Solving learning strategy in the SSI level 4 and 5 context is higher than in the ADI class and control class. The fundamental difference in the achievement of argumentation skills of students in the SMART-Problem Solving class and students in the ADI class lies in the application of the context of socio scientific issues related to chemical material and the stages of problem solving in the SMART-Problem Solving class. The existence of an SSI context in learning will encourage students to get used to thinking from the perspective of solving problems, so that students are better trained in presenting complete and strong arguments. Apart from that, the stages of problem solving also influence students' arguments because the more students are trained to solve problems, the more they can make arguments and learn independently. This is in line with research by Suryadi et al. (2023), the score of students' problem solving abilities in the experimental class is higher than the scores of students in the control class because students who have good problem solving skills will be able to provide arguments and make good decisions. Further research conducted by Mahdi et al. (2023) that problem solving by discovery is proven to be much better than learning using conventional methods in terms of independence in learning.

SSI in learning can encourage students' active participation in making decisions or actions, thus having the potential to develop students' argumentation skills (Rahayu, 2016; Rundgren et al., 2010). This is in line with research by Grooms et al. (2014) which shows that learning with an SSI context can produce better student arguments. Then the low achievement of students' argumentation skills in the control class shows that students have difficulty in developing claims and providing data, warrants, backing and rebuttal. Apart from that, students are not familiar with Socio-Scientific Issues related to chemistry material, which causes students' ability to argue in the SSI context to be very limited.

Students in the control class are accustomed to acquiring chemical concepts given by the teacher through a verification process, lectures, and writing them down in front of the class, so that most students are only able to solve chemistry problems taught by the teacher. The effect of this problem is that students are unable to make claims and submit answers to questions with data or evidence as support. This is proven by the highest level achievement of only reaching level 3 in argumentation. Most students dominate level 1 and level 2 in the control class, where students have not been able to submit relevant evidence, rebuttal or rebuttal regarding the claims they choose or submit.

Several strong factors that cause these results include: (1) in SMART-Problem solving and ADI classes, students explicitly practice being able to make strong and logical justifications for the problem solutions they have prepared and practice evaluating the advantages and disadvantages of each problem solution. which is a strong determinant of the emergence of qualifiers and rebuttals (Anisa et al., 2023; Aziz et al., 2023; Lin et al., 2016); (2) in the SMART-Problem solving class, students are trained in thinking skills using dilemmatic and complex SSI contexts so that they are trained to think practically (Atabey et al., 2017; Christenson et al., 2014; Evagorou et al., 2011); and (3) in direct instruction classes, learning is dominated by the process of presenting facts or knowledge by the teacher so that students' problem solving skills are more limited (Peine et al., 2016).

The experimental class I which is taught with SMART-Problem Solving and the experimental class II which is taught with the ADI class actually both teach students' argumentation skills explicitly, but differ in several phases. Activities in experimental class I where the SMART-Problem solving learning strategy was taught focused more on practicing argumentation through SSI issues. In LKS activities that are facilitated in the SSI context as learning media that can make students active, because learning media is an intermediary in the learning process that can function to raise student motivation in learning activities (Safarati et al., 2023). Having this context helps students develop better argumentation skills. This is supported by Rundgren et al. (2010) that the existence of an SSI context in learning will encourage students' active participation so that they can develop students' argumentation skills.

Apart from that, the SSI context also provides a contextual learning space to develop argumentation and moral reasoning skills (Sadler et al., 2006; Sadler, 2004).

Furthermore, the SMART Problem Solving learning steps in the LKS are arranged in such a way that they can practice students' scientific argumentation and can be used to see the development of students' argumentation skills. Based on the posttest results described above, there is an influence of SMART-Problem solving learning in improving students' scientific argumentation skills, where experimental class I students obtained high results from the ADI class and control class (see the average score for each class). This is also supported by the results of the worksheet students worked on during the learning process, showing that students experienced an increase in their written argumentation skills from the initial meeting to the final meeting. This written argumentation is carried out by students by answering the questions in the worksheet after they read local SSI articles, where the worksheet students do on these questions is related to the dilemma faced in the given article.

Conclusion

There is a significant difference in the average students' scientific argumentation abilities between students taught using the SMART-Problem Solving learning strategy in the LSSI "Malin Kundang" context and those taught using the ADI learning strategy and conventional learning on acid-base material. The scientific argumentation skills of students who were taught the SMART-Problem Solving learning strategy in the LSSI context were higher (average value of 74.09) than students who were taught the ADI learning strategy (average value of 62.94) and conventional learning (average value of 43.35), so it can be concluded that the SMART-Problem solving strategy in the context of LSSI can improve students' scientific argumentation skills effectively.

Author Contributions
For research articles all authors contributed to writing this article.

Conflicts of Interest
The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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