International Journal of Evaluation and Research in Education (IJERE)
Vol. 13, No. 6, December 2024, pp. 4346~4353
ISSN: 2252-8822, DOI: 10.11591/ijere.v13i6.26935

Enhancing the scientific argumentation skills of prospective chemistry teacher using integrated chemical literacy strategy

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Article Info

Article history:

Received Feb 25, 2023
Revised Jul 31, 2024
Accepted Aug 8, 2024

Keywords:

Chemical literacy
Chemistry
Inquiry
Scientific argumentation
Socio-scientific issues

ABSTRACT

This research aims to enhance prospective chemistry teachers' scientific argumentation skills through integrated chemical literacy strategy (ICLS) learning and to examine the patterns of relationship between students' scientific argumentation skills in terms of content and socio-scientific issues (SSI). The study used mixed methods: the embedded design with embedded experimental model. The research sample was 88 students, the control and the experimental groups each consisted of 44 students. The research instrument used scientific argumentation skills test: an open and closed essay test, and interviews with 10 students as selected respondents. Data analysis used descriptive analysis, N-gain, Mann-Whitney test, effect size test, and qualitative analysis. The results showed that ICLS significantly had a great influence on enhancing students' scientific argumentation skills. The interview results show that: the level of scientific argumentation skills related to SSI is not consistently related to content-related scientific argumentation skill; students who have scientific argumentation skills related to SSI levels 4, 3, and 2 can provide the correct claim, data, warrant, backing, and rebuttal to scientific arguments related to content if guided by guiding questions; student that had higher level of scientific argumentation skills need fewer guiding questions.

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1. INTRODUCTION

Scientific argumentation is an important component in science literacy [1] Mastering scientific literacy is one of the most important things in this century [2]. Scientific argumentation by scientists is used to support theories, models, and explain natural facts [3]. In this case scientific argumentation can be used as a persuasive communication in arguing. Arguing skills are important to develop in science education because they can help learners in: i) developing skills to construct, support, evaluate, or validate a claim based on scientific evidence [4]; ii) understand cognitive and metacognitive processes, develop reasoning, and communication skills [5]; iii) understand content knowledge better and more deeply [6]; and iv) collaborative work [7].

Students' argumentation skills are still low. In general, learners of all levels of education/age still have difficulty in building arguments well [1]. Students' scientific argumentation skills are still dominated by the skill of giving true claims but have not been able to provide correct explanations and rebuttals to the evidence obtained to support the claims [8], [9]. The low scientific argumentation skills of students are caused by: i) students' lack of knowledge about nature and how to argue for good scientific arguments. Learners often argue based on personal values or experiences rather than scientific knowledge [10]; and

ii) lack of integration of scientific argumentation skills in explicit learning. Learners lack the opportunity to practice scientific argumentation in classroom learning situations [1], [11]. Only 10% of science teachers teach science as a knowledge that is tested for proof of truth through reasoning, evaluating evidence, and considering counter-argumentation [12]. Science education places more emphasis on "what to believe" than "why" to believe [3]. Lack of knowledge about scientific argumentation and their involvement in argumentation forums contributes to the inability to participate in discussions of socio-scientific issues (SSI) [13]. Learners express their arguments less if the topic is new and difficult than when discussing more familiar topics [14].

One of the factors that causes students' low scientific argumentation skills is the teacher's lack of preparation in teaching those skills in the classroom [15]. The lack of preparation is possible because the teacher lacks mastery of scientific argumentation skills. One of the responsibilities of a teacher is to guide students in developing their perspectives on the world, capacity for economic success, attitudes toward others in society, involvement in social decision-making, and interactions with the environment [16]. This highlights the significance of the role played by educators in helping their pupils acquire scientific argumentation skills. Any school reform's potential success depends heavily on teachers [17], [18]. Only when the starting knowledge, attitudes, and beliefs of teachers are taken seriously will effective educational reform take place [19], [20]. Based on this description, it is crucial to work on a prospective chemistry teacher's scientific argumentation ability.

Learners' scientific argumentation skills can develop, if they are involved in the experience of acquiring knowledge in a real (authentic) way [21]–[23]. One of the lessons that has these characteristics is inquiry-based learning. Inquiry-based learning involves learners in the process of authentically discovering scientific knowledge through a series of inquiry processes [24], [25]. The presentation of learning with authentic inquiry can provide an opportunity for learners to evaluate information, develop conclusions and engage in evidence-based arguments, which is a competence of science literacy. Several studies [21], [26], [27] stated that inquiry-based learning is better when linked to social issues. Learning that aims to involve students to use their knowledge in understanding social issues that are happening is SSI [9]. Through SSI, learners' ability to make decisions increases [28], [29], making learning more meaningful [30], and enhancing epistemic knowledge (the nature of science) [31]. However, inquiry-based learning that explicit scientific argumentation skills and uses the SSI context is still rare. Integrated chemical literacy strategy (ICLS) learning is an inquiry-based learning strategy that provides authentic science experiences, develops literacy skills, promotes curiosity, uses a contextual approach that contains contextual content and SSI, and explicit scientific argumentation. ICLS learning is based on cognitive learning theory and is a modification, fusion and adjustment of the ISLS model developed by Leonard [32] and Argument Driven Inquiry (ADI) developed by Walker *et al*. [33].

Based on these problems, the research question was: how to improve scientific argumentation skills using ICLS? This research focuses on the influence of ICLS on the scientific argumentation skills of prospective chemistry teacher that aims to: i) improve the scientific argumentation skills of prospective chemistry teacher using ICLS learning; and ii) examine the patterns of relationship between students' scientific argumentation skills in terms of content and SSI.

2. METHOD

The study used mixed methods, the embedded design with embedded experimental model according to Creswell and Clark [34]. In the first stage, the research begins with the collection of quantitative data, conducting a pre-test of scientific argumentation skills. The second stage was to provide treatment through a quantitative approach using quasi-experimental designs with nonequivalent (pre-test and post-test) control-group design as shown in Table 1.

Table 1. Quasi-experimental nonequivalent (pre-test and post-test) control-group design1

Class	Pre-test	Treatment	Post-test
Experiment	O	X	O
Control	O	-	O

Students of prospective chemistry teachers in the experimental class were given treatment (X) which was taught by ICLS and students in the control class were taught by conventional strategies. The ICLS step consists of: i) stimuli; ii) problem statement; iii) inquiry investigation; iv) argumentation and presentation; and v) line of learning. The conventional strategy step consists of material delivery, inquiry phase, and presentation and discussion. The third stage, carried out by collecting quantitative data and qualitative data after the treatment process. Quantitative data were collected from the scores of post-test students' scientific argumentation skills. Qualitative data were collected from the results of interviews of scientific argumentation skills. The fourth stage, an analysis of the findings was carried out. The findings obtained were in the form of quantitative and qualitative data.

The research sample used the entire student population of prospective chemistry teachers who took part in the Basic Chemistry course at one of the state universities in the city of Malang, Indonesia. The 88 students were distributed in four offerings, based on the existing offerings randomly selected two offerings as an experimental group (44 students), and 2 offerings (44 students) as a control group. The minimum sample size in quantitative research is 30 samples [35]. Before treatment, students in the experimental and the control groups were given a pre-test of scientific argumentation skills to determine their initial abilities. Pre-test is one way to control confounding variables [36]. Pre-test result showed that both the experimental class and the control class have the same initial ability based on the Mann-Whitney (U) test with significance value=0.707. Other ways to control confounding variables were making constant variables between experiment and control group to eliminate the possible effects [37]. In this study controlled confounding variables, e.g., number of class meetings, lecturers' teaching experiences, and curriculum.

The results of pre- and post-tests testing scientific argumentation skills were converted into quantitative data. The scientific argumentation skills test instruments were in the form of an open and closed essay test, each with 1 valid question and has high reliability (Cronbach's alpha=0.689). The instrument was prepared to refer to the Toulmin argument framework which has six categories of aspects, namely claim, data, warrant, backing, qualifier, and rebuttal [38]. The assessment of the quality of scientific argumentation refers to Osborne *et al*. [39]. Initially, the pre-test and post-test data were qualitative data, then they were converted into interval data. The data on scientific argumentation skills were assessed by a two-person assessment team, then the results of the assessment were tested by Cohen's kappa. Pre-test and post-test data were analyzed descriptively to determine the highest score, lowest value, mean and N-gain to see whether there is an improvement in students' scientific argumentation skills; post-test data tested by Mann-Whitney to see whether there were differences in treatment for enhancing students' scientific argumentation skills, and effect size to see how much learning affects scientific argumentation skills. Effect size classification using Cohen's standard [40].

The findings of ten students' semi-structured interviews, which were recorded, served as the source of qualitative data. To ensure the validity of the interview data, it was carried out by checking the transcripts again by matching the interview results that have been made with the recorded results. The data was used to explain the results of quantitative data and to examine the patterns of relationship between students' scientific argumentation skills in terms of content and SSI.

3. RESULTS AND DISCUSSION

3.1. Students' scientific argumentation skills

Students' scientific argumentation skills data were obtained from pre-test scores and post-tests of scientific argumentation skills. Based on Cohen's kappa test, measurement data from two scientific argumentation skill assessors obtained a Kappa measure of agreement value of 0.870 (having a very high degree of equality). A description of the student's scientific argumentation skills data was presented in Table 2. N-gain data showed that the improvement of students' scientific argumentation skills in the ICLS (experiment) class was higher than in the conventional (control) class. The category of improvement in the ICLS class was medium and in the conventional class was low.

Table 2. Description of student scientific argumentation skills data

Group	Pre-test	Post-test	N-gain
Experiment	0	4	0.33
Control	0	3	0.21

Mann-Whitney's test results showed a significance value of 0.002/2=0.001<0.050, which means that there was an average difference in scientific argumentation skills between students who were taught with ICLS learning and conventional strategies. Students who were taught with ICLS have higher scientific argumentation skills (sum of ranks=2304) than students who were taught with conventional strategies (sum of ranks=1612). The results of the calculation of eta and eta squared obtained eta (r) values of 0.33 and eta squared (r2) of 0.109, which means that ICLS had a great influence on students' scientific argumentation skills.

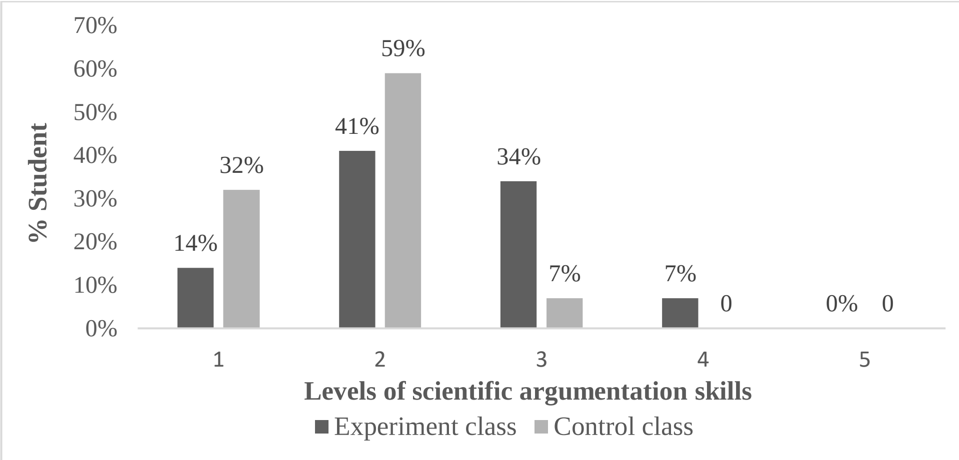
Before being taught with ICLS, experimental class students who were selected as respondents were interviewed regarding their knowledge of scientific argumentation. The results showed that students' knowledge of scientific argumentation was still low: i) most students stated that scientific argumentation was the result of their own thinking; ii) a small number of them stated that scientific argumentation was an opinion supported by evidence; and iii) scientific argumentation was a pro- counter opinion. After studying ICLS, these students were again interviewed with the same topic. The results showed that most of the students' scientific argumentation knowledge increased. The following is an excerpt of the interview transcript of the researcher (Q) with the respondent (R).

Q: *Did you practice argumentation in lectures?*
R: *Yes, we did.*
Q: *Did you still remember what components of scientific argumentation are?*
R: *Yeah. claim, data, warrant, backing, rebuttal*
Q: *Did you know the difference? Please explain?*
R: *Claim is a statement. Data are the facts or evidence that supports the claim. Warrants are explanations about the data obtained. Backings are the theories, laws and principles that uphold warrants. Whereas rebuttal is an exception.*
Q: *Tell me the positive things that you got after practicing scientific argumentation?*
R: *With this learning, I have a better understanding of how to express a good and correct opinion, starting with claims, data, warrants, backing, then rebuttal. So, I can learn how to put forward a good and correct scientific argumentation. For example, at the time of the debate about is it better to use Pertamax or Pertalite as transportation fuel. Three student groups stated they were pro Pertamax and two student groups stated they were pro Pertalite. The two pro-contra groups each defend their arguments. We are a pro Pertalite student group. Through the data, backing, warrants and rebuttals that we submit, we can convince all groups to agree with our argument, the use of Pertalite is more profitable in terms of costs and environmental health than Pertamax if people prefer to use public transportation rather than using private vehicles.*

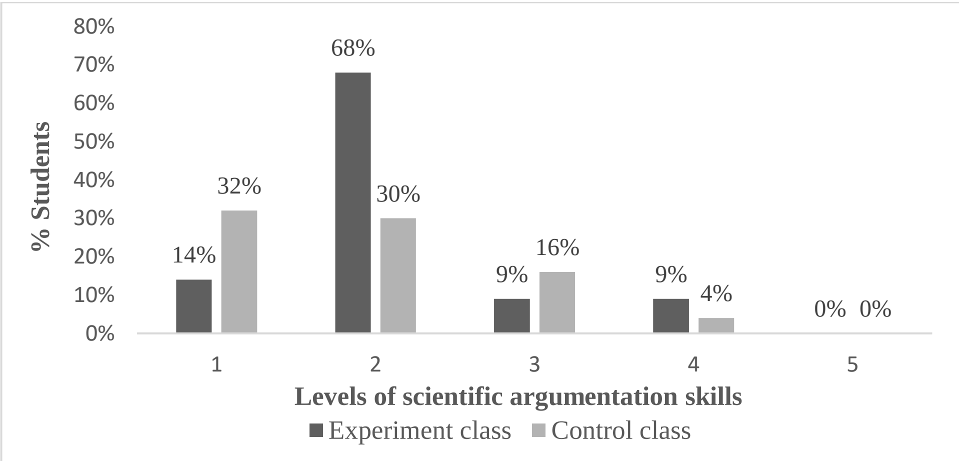
Based on the results of the test and interview, it was concluded that ICLS had a higher influence on scientific argumentation skills than conventional strategies. These results can be strengthened by analyzing students' skills in answering scientific argumentation tests on closed-type questions and open-type questions. In closed-type questions, students are given the help of statements both supportive and outwitting statements that can lead them to make arguments. In open-type questions, students compile their arguments independently. The results of the analysis are presented in Figure 1. Figure 1 (a) and (b) showed that in both open and closed type argumentation questions, students who are taught with ICLS achieve more levels 3 and 4 scientific argumentation skills compared to students who are taught with conventional strategy. Students who have reached levels 3 and 4, have been able to provide rebuttal. Rebuttal is an indicator of high-quality, and arguments that include rebuttal are more persuasive arguments [6], [39].

The difference in scientific argumentation skills of ICLS class students and conventional classes is since ICLS classes train students to make scientific arguments explicitly, while conventional classes are implicit. These findings are in line with the results of the previous research [41]–[43]. Activities to explicit scientific argumentation skills are carried out at the stage of investigation inquiry stage, the argumentation and presentation, and the line of learning. At the investigative inquiry stage students are trained to state their scientific arguments in their collaborative groups, through tentative argument production activities. In this activity, students do not directly state their arguments independently, but students are given scaffolding to be able to compile their scientific arguments properly. Scaffolding is given gradually until finally students can be released to express their scientific arguments independently.

At the argumentation and presentation stage, the development of scientific argumentation skills is explicit through argumentation session activities. In this activity, students presented their group arguments in a class discussion forum. To ascertain which assertions are the most credible and acceptable, or to improve the claims to make them more credible and acceptable, students discuss arguments and critiques made both orally and in writing. In the line of learning stage, students' scientific argumentation skills are developed in concept application activities through SSI. In this activity, students are given a dilemma or socio-science issue related to thermochemistry content, then students are asked to have a scientific argument on the given issue. Students in their collaborative groups compile scientific arguments to make decisions related to the issues presented, the arguments compiled are still tentative arguments. Then continued the argumentation session, which was delivered orally, namely students sharing arguments with each other and conveying criticism to determine which claims are the most valid and acceptable or to refine claims to make them more valid and acceptable.



(a)



(b)

Figure 1. Level of students' scientific argumentation in answering (a) closed-type questions and (b) open-type questions

3.2. The patterns of relationship between students' scientific argumentation skills in terms of content and socio-scientific issues

The scientific argumentation skills data measured in the post-test were scientific arguments related to SSI. To illustrate whether students who have a high level of scientific argumentation skills related to SSI can also have high scientific argumentation skills related to content, students are given questions in interviews to express scientific arguments related to content issues. The results showed that students who have scientific argumentation skills related to SSI levels 4, 3, and 2 can provide the correct claims, data, warrants, backing, and rebuttal on scientific arguments related to content if guided by guiding questions. The higher the level of their scientific argumentation skills, the fewer guiding questions given. However, the level of scientific argumentation skills related to SSI was not consistently related to students' scientific argumentation skills related to content. The results of the analysis of interview data show that: i) level 4-SSI students are able to provide the right claims, data, backing warrants, and rebuttal but must be assisted with guiding questions; ii) level 3-SSI students are able to provide appropriate claims and warrants, but data, backing and rebuttal must be assisted with guiding questions; iii) level 2-SSI students are able to provide the right claims, data, warrants, and backing, but must be assisted with guiding questions; and iv) level 1-SSI students can provide the right claim, the right rebuttal, but have not been able to provide the right warrant and backing. This finding is in line with the results of Nussbaum and Asterhan research [44]. They found that students experienced some difficulties in transferring arguments from one context to another, in this case from contexts related to SSI to contexts related to content. Students have difficulty developing different understandings about the need for evidence in arguments and lack of expertise or knowledge in unfamiliar contexts may limit the ability to utilize or adjudicate evidence.

Initially respondents were given context about the phenomenon of SO_3 gas resulting from volcanic eruptions. The gas easily reacts with water and can cause acid rain. SO_3 gas is difficult to duplicate in the laboratory through the sulfur combustion reaction. Then a question was given with the aim of exploring their scientific argumentation skills regarding the content, "do you agree with the statement of the enthalpy of the formation of SO_3 gas from sulfur combustion cannot be determined?" The following was a snippet of interviews from students who have level 4 scientific argumentation skills related to SSI (can provide claims, data, warrants, backing, and rebuttal), but to make scientific arguments related to content they must give a guiding question to disclose rebuttal.

R-level 4-SSI: *I disagree (claim). I think the reaction of SO_3 gas formation from sulfur combustion can be determined ΔH through Hess's Law (backing). We can calculate ΔH_f of SO_3 gas from the reaction data of (1) sulfur with oxygen gas fixing SO_2 gas with ΔH =-297 kJ; and (2) SO_2 gas with oxygen gas forms gas SO_3 with ΔH =-198 kJ. How to calculate it by multiplying the equation of the first reaction by the second then the same and opposite ones crossed out and then summing up the ΔH (data, warrant). Because ΔH is a function of state, so I think this can already explain about ΔH SO_3 (backing).*

Are all the unknown reactions ΔH of it determined through Hess's Law? (guiding question).

R-level 4-SSI: *I don't think so. The problem is that in Hess's Law, we still need data, data on other related reaction equations. So, if for example there is no other data, you cannot calculate the ΔH (rebuttal).*

4. CONCLUSION

Scientific argumentation is an important component in science literacy, which needs to be mastered by students who are prospective chemistry teachers. ICLS gives the experience of scientific argumentation explicit in its learning stages. The results showed that ICLS improves student's scientific argumentation skills. The improvement of students' scientific argumentation skills in ICLS class is higher than that of the conventional class. Significantly ICLS learning has a higher influence in enhancing scientific argumentation skills than conventional strategies. The results of this study can contribute to efforts to improve 21st century skills, especially chemical literacy skills as part of science literacy. ICLS can be applied or modified by teachers, practitioners and researchers in learning who specifically want to develop students' scientific argumentation skills by presenting context which varies both related to SSI and related to content. In this study, it was found that students' argumentation skills related to content still need to be guided by guiding questions to be able to provide the correct claim, data, warrant, backing, and rebuttal. A student's scientific argumentation skill level related to SSI is not consistently related to their argumentation skills related to content. Based on these findings, it is necessary to carry out further research to explore the causal factors and explore the ICLS teaching stages that need to be perfected to develop students' scientific argumentation abilities even better.

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