Skills to argue: using argument-based learning (AbL) and socio-scientific issues to promote university students’ argumentation skills in chemistry

MH Effendi-Hasibuan\textsuperscript{1}, A Bakar\textsuperscript{1}, Harizon\textsuperscript{1}

\textsuperscript{1}Chemistry Education Department, Faculty of Education and Teacher Training, Universitas Jambi, Indonesia

\textsuperscript{*}Corresponding author: hariseffendi@unja.ac.id

Abstract. Skills in making scientific argumentations are crucial for students to understand science concepts. This study had used an argument-based learning (AbL) adopting Toulmin’s Argumentation Pattern (TAP) and socio-scientific issues about heavy metals to promote the argumentation skills of the Indonesian university chemistry students. The effect of AbL in promoting the skills had been compared to Jigsaw and two-stay-two-stray (TSTS) learning that had been used in an earlier study. Data were collected using open-ended tests and observations. Quantitative and qualitative methods were employed to analyze the data. The results showed that the argumentation scale of the AbL-students was better than and significantly different from the argumentation scale of those in the other classes (Tukey-test; \(p < .05\)). Distinct opportunities the students had in each class to use the TAP was the factor that produced the scale differences. The results recommend the importance of involving students in a learning that mostly promotes argumentation activities -like the AbL- to develop the students’ argumentation skills in science.

1. Introduction

Widely known, skills in making argumentation involve the ability to make justifications, to find data, to pose warrant, to post theories, and to assume qualifiers [1-3]. This is called Toulmin’s Argumentation Pattern (TAP) and earlier authors have described how to use these [4]. These abilities sometimes are called casual/daily reasonings that encourage students to apply the inductive [5] rather than the deductive thinking process.

Skills to make arguments is highly important for students to improve their science conceptual understanding [4, 5]. These skills allow students to evaluate a scientific condition, to seek evidence to support the claim or result of the evaluation, and to think about logical reasons that link the data to the condition. In that way, students would reach a developed science understanding. Therefore, efforts to nurture science concepts in a science classroom are better conducted via a deep-thinking process than a routine traditional learning-approach.

Taken the benefits of using argumentation skills into account, these skills should be adopted by science teachers in classroom activities. Unluckily, rare implementations of these skills are observed in many schools [6-8]. Rather, activities that facilitate students with little opportunities to rehearse their ability to make arguments mostly dictate the learning process [9]. These involve the use of convergent questions that need answers which are short, simple, and routine [10,11]. Unquestionably, this brings some students to have low ability to make arguments that include the low ability to find
evidence to support their claims. Such argument-less teaching practices have been linked by previous authors [12,13] to the low competence of students’ conceptual understanding in science. Given this condition, scholars emphasized the importance of providing opportunities to the students to develop their ability to make scientific argumentation [14-16].

Cooperative learning strategies are beneficial in enhancing many aspects of students’ achievements [17,18] and these include the ability to make arguments [19]. Two of these strategies are jigsaw and two-stay-two-stray (TSTS) and the details can be found in the earlier authors’ works [20, 21]. Jigsaw strategy has been beneficial in improving many aspects of students’ learning outcomes [22, 23] while TSTS has also been successful in developing diverse aspects of students’ achievements [24-26]. In our earlier study, we had found that both strategies were also helpful in developing the argumentation skills of students. These strategies had helped students to gain better ability in making a claim, posing evidence, and constructing a warrant in the subject of chemistry [27].

Even though both jigsaw and TSTS -in our earlier study- had been proven effective in promoting the students’ skills to make arguments, some weaknesses were observed [27]. For instance, some lessons ended incompletely and those were because the jigsaw and the TSTS each contains complicated steps that needed a long time to complete. Consequently, a reasonable number of students produced incomplete arguments. Aiming to help students to develop their argumentation skills, thus, an argument-based learning (AbL) had been purposefully designed by the researchers and used in this study. The AbL encourages students to use TAP-integrated steps at a reasonable time. This is followed by an opportunity to conduct debates to seek confirmed answers.

Therefore, this article is talking about the effect of AbL in developing the skills of Indonesian university students in making arguments in the issue about the effect of heavy metals on humans’ health. Such an issue - categorized as the socio-scientific issue- has been used in some studies that aim to provide large challenges for students to make arguments and debates. The effectiveness of AbL was learned by making comparisons to the jigsaw and the TSTS learning. Two questions are used to guide the discussions as follow: “(1) How effective are the AbL, jigsaw, and TSTS in promoting the university students’ argumentation skills in the issue about the effect of heavy metals on humans’ health? and (2) What factors that bring the differences in the students’ argumentation-skills?”.

2. Method

This study was conducted in 2019 in the chemistry education department of the University of Jambi (UNJA) Indonesia. Some 90 first-year students (mix gender, 18-19 years of age) had participated in this study. They were recruited using the convenient sampling technic [28] and the process complied with the ethical clearance protocol applied in the UNJA. They -based on the anecdotal evidence- had the minimal ability to make chemistry argumentations.

This study was begun by allocating the 90 students into the AbL, the Jigsaw, and the TSTS classes. The AbL and the TSTS class each consisted of 6 groups (5 students) and the jigsaw class consisted of 5 home-groups (6 students) and of 6 expert-groups (5 students). The details of the classroom activities/phases can be seen in Table 4. The lessons were conducted by the researchers three times each 100 minutes and the data were collected using video-assisted observations. Students handed individual reports at the end of the study responding to the tasks/questions. In this study, however, the students were only asked to state a claim/answer, provide data/evidence, and compose reasons (CER). The question/task for each meeting is as follow:

Meeting 1:  Is this correct that the presence of Plumbum (Pb) in blood cells can cause anemia on humans? Make your claim and support it with evidence and reasons!

Meeting 2:  Is this correct that the presence of Iron (Fe) in blood cells can avoid anemia on humans? Make your claim and support it with evidence and reasons!

Meeting 3:  Is this correct that the presence of mercury (Hg) in blood cells can be harmful to humans? Make your claim and support it with evidence and reasons!

A researcher-developed rubric (Table 1) was used to assess the students’ argumentations. Six scale (0-5) categories were utilized to capture the wide variety of the students’ argumentations. The
trustworthiness of the rubric was achieved by using a content-validity process which was started by making the conceptual constructs and drafts, performing continuous discussions between the researchers, and ending it up when the researchers agreed with the final rubric.

In the end, the data were analyzed using different ways. A statistical method that includes the categorization of the students’ answers into scales (Table 2) were performed on the students’ reports. This was followed by the use of one-way ANOVA test (SPSS-23) to see the effect of the three strategies on the argumentation skills of students. In addition, observational data were analyzed using interpretive-focused method. This focused on the difference in the way the students make the claim, the evidence, and the warrants; in the use of time; and in conducting the classroom debates.

Table 1. The rubric and the scores to assess argumentation skills

| Scales | Scores | Descriptions                                                                 |
|--------|--------|-----------------------------------------------------------------------------|
| 5      | 10     | The claim is correct and complete (1), the data are correct and relevant (2), the reasons are correct and link the data to the claim (2) |
| 4      | 8      | The claim is correct and complete (1), the data are correct and relevant (2), the reasons are correct but limitedly link the data to the claim (1) |
| 3      | 6      | The claim is correct and complete (1), the data are correct and relevant (2), the reasons are incorrect and unlink the data to the claim (0) |
| 2      | 4      | The claim is correct and complete (1), the data are correct but irrelevant (1), no reasons (0) |
| 1      | 2      | The claim is correct and complete (1), the data are incorrect and irrelevant (0), no reasons (0) |
| 0      | 0      | The claim is incorrect and incomplete (0), the data are incorrect and irrelevant (0), no reasons (0) |

3. Results and Discussion

This study had invited 90 first-year chemistry-education students of the University of Jambi (UNJA) Indonesia in the AbL, Jigsaw, and TSTS classes to learn the issue about the effect of heavy metals on human’s health for three meetings each 100 minute. These students were encouraged to make a claim, evidence and reasons related to the issues. Two pre-mentioned questions will be discussed below.

The first question of this article is “How effective are the AbL, jigsaw, and TSTS in promoting the students’ argumentation skills in the issue about the effect of heavy metals on humans’ health?”. A one-way ANOVA test had been used to answer this question and the fitness of this test had been granted by the normality of each data which was higher than $\alpha = .05$ (AbL $p$-value = .2, jigsaw $p$-value = .2, and TSTS $p$-value = .152). This is followed by the homogeneity of the data which was also higher than $\alpha = .05$ ($p$-value = .358).

Based on the results of the test (Table 2), it is seen that there was significant difference in the effects of the strategies on the argumentation skills of the students (F= 29.83, p-value< .05). The AbL students had the highest score and scale (mean = 78.67 and 3.93), followed by the jigsaw students (mean= 69.11 and 3.45), and the TSTS students (mean= 67.56 and 3.37). Also, these findings are supported by the number of students who produced the scale 4 and 5 of argumentation skills (Figure 1). Figure 1 reveals that the scale 4 and 5 were produced mostly by the AbL class (8.9% and 75.55%), followed by the Jigsaw class (1.11% and 44.44%), and the TSTS class (1.11% and 35.56%). Therefore, it can be said that there was different effectiveness amongst the strategies in increasing the skills of making arguments of the students in the issue about the effect of heavy metals on humans’ health.

Table 2. The University of Jambi students’ argumentation skills in the related issue

| Learning strategies (n=30) | ANOVA Score (Mean) | Score Standard Deviation (SD) | Scale (Mean) |
|--------------------------|-------------------|-------------------------------|--------------|
| AbL                      | F=29.83           | 78.67                         | 5.07         | 3.93         |
Furthermore, to justify the different effects amongst the strategies, a post-hoc Tukey HSD test was applied. The results of this test show that significant difference existed between AbL and both Jigsaw and TSTS (p-value < .05). However, significant difference did not exist between Jigsaw and TSTS (p-value (.528) > .05) in influencing the development of argument making ability of the students (Table 3). This infers that the Abl, jigsaw, and TSTS had assisted the students in diverse ways developing their argumentation skills. The AbL was the most effective learning strategy amongst the Jigsaw and the TSTS in improving such ability.

The second question of this article is “What factors that bring the differences in the students’ argumentation-skills?” Data from observations were used to address this question. Data from observations (Table 4) reveal the facts that the AbL had given the students with larger opportunities to rehearse their ability to make arguments than the other strategies had. The AbL had involved the students in intense argumentative-discussions with clear steps, instructions, and timeframe for making a claim, evidence, and reasons (CER). These included the discussions in an individual way, in groups, and debate activities. This way, the AbL-students had clearer sessions and guidance to make the CER. Meanwhile, the other strategies had not specifically involved the students in doing so. The students did not have clear instructions when to make the CER as they were simply given freedom to do so in the group discussions. This certainly produced the students’ confusion that in turn influenced them not to use the time concisely.

In addition, the AbL contained fewer steps than the other strategies had. This way, the AbL-students had more time to compose the CER including more time for conducting the debates (90 minutes). Meanwhile, the other strategies had more steps that caused the students to have less time to make the CER particularly to do the classroom discussions (45 and 30 minutes each). Consequently, a reasonable number of the latter students produced low-level arguments due to the time limitation.

---

**Table 3.** The result of Tukey HSD test about the difference of effects amongst the strategies

| Test     | Cat (I) | Cat (J) | Diff of Mean of skill (I-J) | Std. Error | Sig.  |
|----------|---------|---------|----------------------------|------------|-------|
| Tukey    | AbL     | Jigsaw  | .4500'                     | .074       | .000  |
|          | TSTS    | Jigsaw  | .5300'                     | .074       | .000  |
|          | Jigsaw  | TSTS    | .0800'                     | .074       | .528  |

---

**Figure 1.** The University of Jambi students’ argumentations scale
Table 4. Students’ activities in the three argumentative lessons

|                     | AbL (300 mins) | Jigsaw (300 mins) | TSTS (300 mins) |
|---------------------|----------------|-------------------|-----------------|
| Content delivery    |                |                   |                 |
| - The students were given materials and phenomena about heavy metals (30 mins) | Content delivery | - The students were given materials and phenomena about heavy metals (30 mins) | Content delivery | - The students were given materials and phenomena about heavy metals (30 mins) |
| Problem or Task Delivery |                | Problem or Task Delivery |               |
| - The students were given questions/tasks (15 mins) | - The students were given questions/tasks (15 mins) | - The students were given questions/tasks (15 mins) |
| Individual argumentation |                | Home-group discussion |               |
| - The students were clearly asked to work on the task individually to: | - The students were asked to work individually. | - The students were asked to work individually. |
| - make claim (15 mins) |                | - The teachers provided freedom for the students to construct their claim, evidence, and explanation (30 mins). | - The teachers provided freedom for the students to construct their claim, evidence, and explanation (30 mins). |
| - find relevant data (45 mins) |                | Expert-group discussion |               |
| -make explanations (45 mins) |                | - The students were instructed to form a new group and manage a new discussion about the tasks with new peers (75 mins). | - The students were instructed to form a new group and manage a new discussion about the tasks with new peers (75 mins). |
| NA                  |                |                   |                 |
| Group argumentation |                | Home-group discussion | Regroup discussion |
| - The students were grouped and asked to verify their claim, evidence, and explanations (45) | - The students returned to the first group to share what they had learned from the expert-group discussions (90 mins) | - The students returned to the first group to share what they had learned from the expert-group discussions (90 mins) |
| Intra-group debates |                | Classroom discussion | Classroom discussion |
| - Students were encouraged to conduct debates between groups (90 Mins) | - Students were encouraged to conduct classroom discussion (45 mins) | - Students were encouraged to conduct classroom discussion (30 mins) |
| Review              |                | Review            | Review         |
| - Lecturers provided feedbacks and final answers (15 mins) | - Lecturers provided feedbacks and final answers (15 mins) | - Lecturers provided feedbacks and final answers (15 mins) |

The low effectiveness of jigsaw and TSTS compared to AbL in affecting the students’ argumentation skills were understandable. The structures of these strategies were not specifically designed for an argument-based lesson that contains argument-driven activities. Rather, these were designed to activate students to learn cooperatively to achieve a wider scope of learning outcomes [21, 22]. In contrast, the AbL was purposefully designed to help the students to nurture their ability in making arguments. The AbL encouraged the students to make the CER using a scaffolding approach encompassing the step of individual argumentation, the group argumentation, and the intra-group debate. As a result, the students had large multi-phased opportunities to compose and to verify their
argumentations with peers. Cho [29] reckoned that by using technic of scaffolding guidance in a cooperation-based learning situation the argument making ability of students in science could enhance effectively.

Therefore, it can be said that the dense and multi-staged opportunities the Abl-students had during the lesson were the key factor in helping the students to generate argument with a high quality. This is congruent with what Zohar et al [30] reckoned that the use of high-intense thinking learning activities would assist students in enhancing their learning advantages including ability to make arguments in science. Furthermore, Leonard [31] affirmed that the more intense the learning experiences given to students the more learning benefits the students will attain.

4. Conclusion and Future Research
This study has been successful in promoting the argument making skills of 90 first-year university students in Indonesia about the issue of the effect of heavy metals on humans' health. Argument-based learning (AbL) was the most effective amongst the jigsaw and TSTS in promoting the skills. Diverse opportunities the students had in each class to make a claim, evidence and reasons was the underpinning factor that produced the skill differences in making the arguments.

However, some limitations were seen in this study. Future studies should cover the need of seeing the effectiveness of AbL in larger areas of socio-scientific issues that may relate to environment, foods, animals, energy, etc. Nevertheless, these findings may echo the importance of involving students in an argument-based learning to develop their argumentation skills in science.

Acknowledgment
Thanks to the Ministry of Research and Higher Education as well as the University of Jambi Indonesia for the funding so that this study could be performed as intended.

References
[1] Reznitskaya A and Gregory M 2013 Educ. Psychol. 48 114
[2] Styslinger ME and Overstreet JF 2014 Voices Middle 22 58
[3] Zhang Z and Lu J 2014 Int. Educ. Stud. 7120
[4] Dawson V and Carson K 2016 Res. Sci. Technol. Educ. 35 1
[5] Acar O and Bruce R P 2012 Procedia Soc. Behav. Sci. 46 4756
[6] Jonassen DH and Kim B 2010 Educ. Technol. Res. Dev. 58 439
[7] Osborne J 2010 Science. 328 463
[8] Viyanti 2015 Indones. J. Sci. Educ. 4 86
[9] Newton P, Driver R and Osborne J 1999 Int. J. Sci. Educ. 21 553
[10] Almeida 2010 Int. J. Learning and Change. 4 237
[11] Khan WB and Inamullah HM 2011 Asian Soc. Sci. 7 149
[12] Effendi-Hasibuan MH, Harizion, Ngatijo, and Mukminin A 2019 J. Turk. Sci. Educ. 16 18
[13] Effendi-Hasibuan MH, Ngatijo, and Sulistyo U 2019 J. Turk. Sci. Educ. 16 538
[14] Kuhn, D. 2005 Education for thinking. Cambridge, MA: Harvard University Press.
[15] Reznitskaya, A., Anderson, R.C., Dong, T., Li, Y., Kim, I., & Kim, S. 2008 Learning to think well: Application of argument schema theory. In C. C. Block & S. Parris (Eds.), Comprehension instruction: Research-based best practices (pp. 196 – 213). New York, NY: Guilford
[16] Sherry MB 2014 Res. Teach. Engl. 49 141
[17] Khise R and NG Lederman 2006 J. Res. Sci. Teach. 43 395
[18] Persky A M and Gary M Pollack 2009 Am. J. Pharm. Educ. 73 1
[19] Matuk C 2015 Argumentation Environments, In Encyclopedia of Science Education. ed Richard Gunstone 59-61
[20] Johnson DW, Johnson RT and Stane ME 2000 Cooperative learning methods: a meta-analysis. cooperative learning center. Website: http://www.pubmedcentral.org/direct3.egi.
[21] Joyce B and Weil M Calhoun E 2009 Models of teaching, 8th. Ed, (BostonUSA-Pearson)
[22] Mengduo Q and Jin Xiaoling 2010 Chin. J. Appl. Linguist. (Bimon.) 33 113
[23] Perkins D V and Renee N Saris 2001 Teach. Psychol., 28 111
[24] Harahap KA and Edy Surya 2017 Int. J. Sci.: Basic Appl. Res. (IJSBAR) 33 156
[25] Lusiana I A, Setyosari P and Soetjipto BE 2017 Int. J. Acad. Res. Progress. Educ. Dev. 6 97
[26] Tae L F 2017 Innovative Creative Education and Teaching International Conference (ICETIC), Badajoz Spainpp 204
[27] Effendi-Hsb MH et al 2019 J. Phys.: Conf. Ser. 1317 012143
[28] Creswell J W 2012 Educational research: planning, conducting, and evaluating quantitative and qualitative research 4th edition (USA-Pearson)
[29] Cho K and David H J 2002 ETR&D. 50 1042
[30] Zohar A and Flora Nemet 2002 J. Res. Sci. Teach. 39 35
[31] Leonard W H 1980 Am. Biol. Teach. 42 338