Argumentation real-world inquiry to improve students' argumentation skill

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ABSTRACT

Student teachers' poor argumentation skill is one of the problems that should be solved. This research aims to develop an Argumentation Real-World Inquiry learning model that incorporates argumentation session on environmental, socio-scientific issues at each stage. The research subjects were the biology student teachers taking the Environmental Knowledge course. The research method used was Research and Development (R&D) which comprised 3 stages: Phase 1 (Development), Phase II (Pre-Experiment), and Phase III (Implementation and Evaluation). The data on argumentation skill were obtained from an essay that addressed the environmental, sociocultural issue about environmental pollution. The pre-experiment phase was conducted using weak experiment method and one group pretest-posttest design, while in the implementation phase, quasi experiment method and pretest-posttest control group design were used. The results of the pre-experiment stage showed that the learning model was able to increase the student teachers' argumentation skill, indicated by an increase in level 3 argumentation from 16% (pretest) to 68% (posttest) and a decrease in level 2 argumentation from 74% (pretest) to 21% (posttest). The results of the implementation phase showed that the student teachers' argumentation skill improved, with N-Gain score of 0.307 (medium category). The results of this research indicate that the Argumentation Real-World Inquiry learning model is able to train student teachers to develop their argumentation skill on environmental, socio-scientific issues.

Introduction

Argumentation is one form of conversation that involves a process of reasoning and triggers critical thinking (Bekiroglu & Eskin, 2012). Arguments in science education consist of 2 types, namely arguments about 1) scientific issues that do not have direct social implications, such as interpretation of experimental results, and 2) science issues involved in social conditions and include

personal decision making, political debate, and all something that has an impact on individuals and society (Christenson, Gericke, & Rundgren, 2017). The arguments that need to be familiarized in science education are not only those related to the results of experiments but also about issues involving social conditions that occur in the community.

The habit of arguing is important in everyday life because these arguments play a role in making correct and logical decisions on issues that are controversial (Yang & Tsai, 2010). Therefore, increasing human resources to become individuals who are skilled in argumentation is important so that these individuals are able to apply scientific concepts, principles, and practices to issues that are also influenced by social, political, ethical, and/or economic considerations.

Research Herawati, Widodo, Riandi, and Rochintaniawati (2015) shows that in general students in secondary schools are able to express claims that are accompanied by data and/or warrant in arguing, but scientific concepts/facts used as data, and student arguments for connecting data with claims are still invalid, rational, and relevant so that the arguments produced by students are weak arguments. Ardianto and Herawati (2016) also revealed that the quality of student argumentation was still at level 2, meaning that students were only able to express claims and reasons in arguing but were less skilled in providing empirical evidence. The study indicated the low quality of student argumentation, as expressed by Amin, Corebima, Zubaidah, and Mahanal (2017).

The low quality of student argumentation is caused by the lecture process, which is not in accordance with the nature of science. Based on data from the results field study of prospective biology teacher candidates in 2016, it shows that the learning that has been conducted by students places more emphasis on minds on. Students' skills in the inquiry process towards authentic phenomena related to concepts occur still rarely practiced in lectures. This fact is suspected to be the reason for the lack of students' skills in identifying scientific issues and causes students to be less skilled in asking questions that need to be investigated. This finding was reinforced by the students' response (52%), which

states that they rarely find facts and empirical evidence of problems/issues raised through observational/experimental activities (Ardianto & Herawati, 2016). The lecture process which rarely triggers students to submit problems, involve themselves with socioscientific issues, search for data and scientific concepts, as well as argumentation activities causes students to be less skilled in submitting logical decisions and propose strong arguments when dealing with sociocultural issues (Ardianto & Herawati, 2016).

Socioscientific issues are different from other issues in the field of science. Socioscientific issues do not only involve the scientific aspects, but also involve social, economic, political aspects, so that the socioscientific issues are open-ended, ill-structured, and debatable from various perspectives (Sadler & Zeidler, 2005). One issue that is currently being debated in Indonesia is that one of them is related to the environment. Environmental issues are debatable because they involve various aspects of the study so that solutions to environmental problems can differ depending on each individual's perspective. Ardianto and Herawati (2016) research results showed that most students have not been able to study environmental issues properly, analyze these issues from various perspectives so that decisions and arguments produced are still weak and illogical. However, argumentation skills are very important in everyday life, especially when an individual must make decisions on controversial issues faced, including environmental issues. Research by Istiana, Awaludin, Harisusanto, and Indriyani (2017) also showed that the ability of students to study and solve environmental problems requires stimulation through the lecture process that familiarizes students with environmental problems.

Based on these facts, the development of learning models that emphasize students to be able to argue about sociocultural issues, especially environmental issues, needs to be done. This is because the argumentation skills that develop systematically and continuously are a provision for students to be able to deal with and solve the problems they face in the present and the future. Several previous studies have shown that argumentation skills can be improved through explicit teaching of

argumentation on sociocultural issues (Belland, Gu, Armbrust, & Cook, 2015; Cetin, 2014; Chung, Yoo, Kim, Lee, & Zeidler, 2016; Cinici, 2016; Khishfe, 2014; Venville & Dawson, 2013). Ardianto research (2014) revealed that learning with the inquiry spectrum increased student activity in argumentation. Research Choi, Klein, and Hershberger (2015) and Grooms, Sampson, and Golden (2014) also states that students' inquiry and argumentation skills can be trained through argumentation-based inquiry learning. In addition, inquiry learning can also improve student skills in problem-solving (Istiana et al., 2017).

Based on this explanation, efforts can be made to improve the quality of learning and the lack of students' argumentation skills, namely by developing learning models for Argumentation Real-World Inquiry. This model was developed from one level of incurring teaching taught by Wenning (2005), named Real-world inquiry. The real-world inquiry is a level of inquiry teaching that requires students to apply the knowledge they have learned in new situations by seeking answers to authentic problems. The Argumentation Real-World Inquiry Model developed in this study was the learning model by inserting an argumentation session when conducting the inquiry stage. In practice, this model raises real-world problems and involves students to identify, investigate, and propose solutions to these problems in accordance with the stages of the learning model they are implementing (Figure 1). Thus, the existence of this model is expected to be able to train and develop students' argumentation skills in responding to social-scientific issues that occur in the environment around their homes.

Method

This research was conducted in January - November 2018 by involving research subject's prospective semester biology teacher candidates who took Environmental Studies courses in 3 classes. This research uses the Research and Development (R&D) research method from Gall, Gall, and Borg (2003). Gall, Gall, and Borg (2003) revealed ten stages in R&D research, but in this study, the stages of the study were grouped into three stages, namely: Phase I (Development), which

included (1) research and information collecting activities, (2) planning, (3) develop preliminary forms of the product; Phase II (Pre-experimental), which includes activities (4) preliminary field testing, (5) main product revision; and Phase III (Implementation and Evaluation) which includes activities (6) main field testing, (7) operational product revision, (8) operational field testing, (9) final product revision, (10) dissemination and implementation. This research was conducted in about one year so that product trials are still on a limited scale. Therefore, in this study, the eighth to tenth stages of Gall, Gall, and Borg have not been implemented.

In Phase I (Development), there was curriculum analysis, drafting the Argumentation Real-World Inquiry Model, and validation of the learning model by the expert. The validator analyzes the suitability of the characteristics with the stages of the model and the objectives of each stage developed in the learning model. The results of expert validation show that the model Argumentation Real-World Inquiry is feasible to be applied in research trials with revisions to the implementation process.

In Phase II (Pre-experiment), a limited learning model trial was carried out with a pre-experimental study (one group pretest-posttest design), analyzing and evaluating the results of the model prototype. In Phase III (Implementation and Evaluation), a revised implementation of the learning model was implemented using the pretest-posttest control group design, testing the effectiveness of the learning model, and evaluating the results of the implementation.

Learning with Argumentation Real World Inquiry consists of 3 main components, namely: 1) investigation, 2) evaluation, 3) exploration and solutions, and involves five stages of activities, namely Orientation, Manipulation, Generalization, Verification, and Application, where at each stage they are inserted argumentation session (Figure 1). The learning process in the Argumentation Real-World Inquiry begins by displaying socioscientific issues or issues that relate to environmental concepts (such as the issue of damage to natural resources in Bogor, especially at Puncak and Bogor Districts due to land function change, and the issue of air pollution in Bogor due to an

increase in the number of vehicles). Prospective teacher students are asked to identify problems (Orientation Phase), plan and carry out investigations to the location of observation and seek information from various sources (Manipulation Phase), present data on the results of the investigation (Generalization Phase), analyze and evaluate findings (Verification Phase), and submit solutions and conclusions for the issues they are investigating (Application Stage).
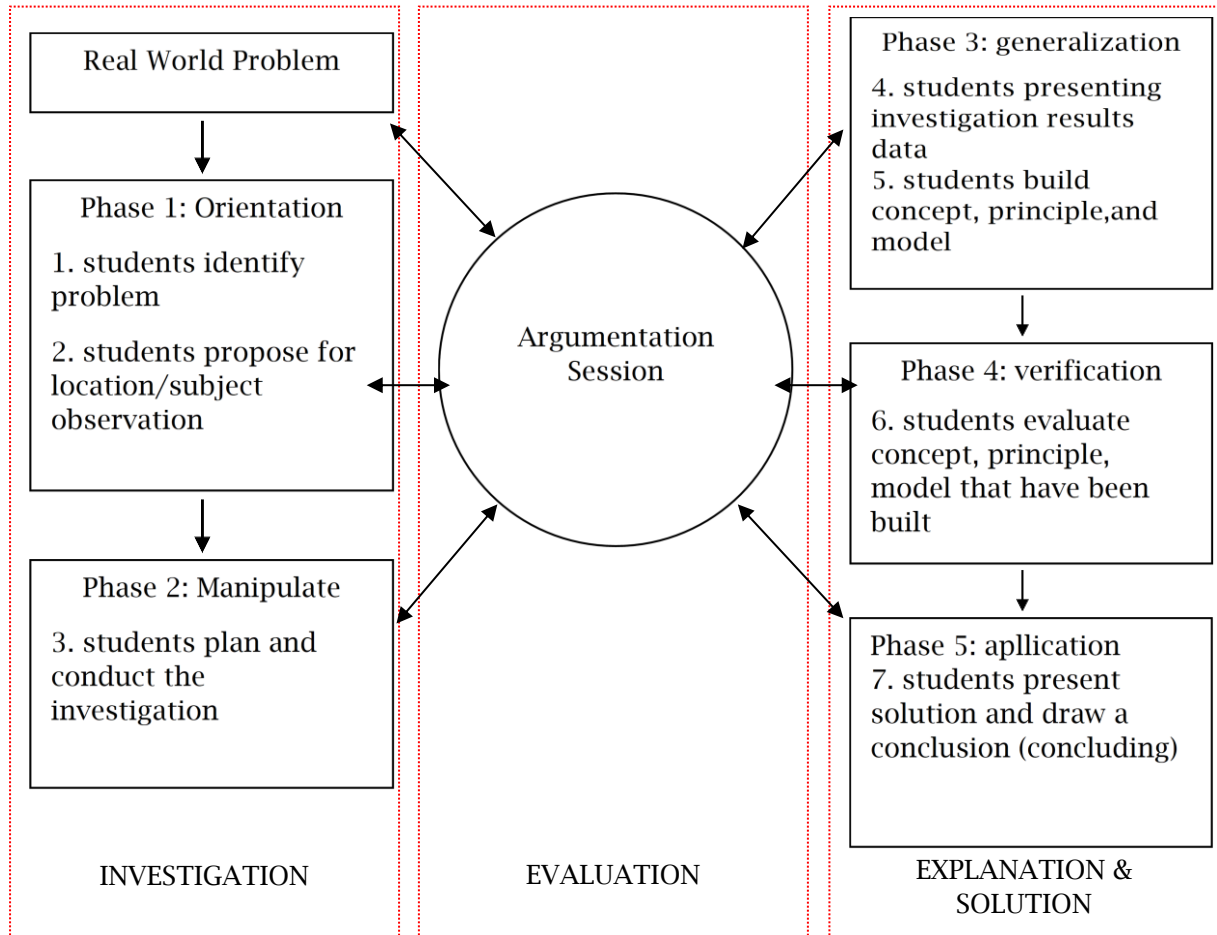

Figure 1.Stages of the learning model Real-World Inquiry Argumentation

Students are given an argumentation skills test on environmental sociocultural issues in the Bogor area before and after the learning process with the model Argumentation Real World Inquiry. Argumentation skills data were captured through essay instruments composed of the context of environmental sociocultural issues. The arguments of prospective teacher students in this study were analyzed using the Toulmin argumentation framework (Toulmin Argumentation Pattern, TAP). Based on this framework, the argument is composed of six components, namely claims, data, warranties, backing, and rebuttal (Inch, Warnick, & Endres, 2006).

Furthermore, the argumentation skills of prospective teacher students are identified through the Dawson and Venville rubric (2009) which has been developed by researchers so that the argumentation abilities of prospective teacher students are grouped into level 1, level 2, level 3, level 4, and level 5 (Table 1) based on completeness component of the argument.

Table 1. Argument skills rubric

Level	Description
1	Contains only *claims.*
2	Contains *claims* and *data,* and/or *warrant.*
3	Contains *claims, data, warranties,* and *backing/qualifier/rebuttal.*
4	Contains *claims, data, warranties, backing,* and *qualifier/rebuttal.*
5	Contains all components of the argumentation: *claim, data, warrant, backing, qualifier,* and *rebuttal.*

Results and Discussion

The ability to formulate and evaluate arguments has been widely recognized as the basis of good thinking skills and is one of the goals of science education. Macagno and Konstantinidou (2012) revealed that students who learn science must be able to present accurate statements, communicate them to others convincingly, respond to other people's arguments, and compare various arguments logically. Scientific arguments have a role to present and overcome the gap between ideas and evidence through valid statements. When student teacher candidates make a decision and then submit an argument on sociocultural issues, the student-teacher learns to reason so that he can express reasons (warrant) based on facts, evidence, and concepts understood (data), supported by basic assumptions (backing), and also the rebuttal claim (rebuttal). The results of the research stage on the prospective teacher students' argumentation skills on environmental sociocultural issues before and after lecturing with the Real-World Inquiry Argumentation are presented in Figure 2.
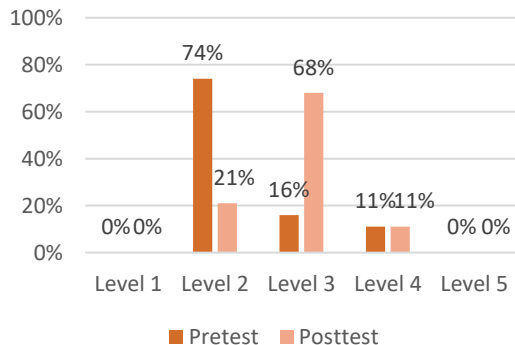

Figure 2. Argumentation skills for prospective teacher students in pre-experimental phase

Based on the data presented in Figure 2, there are no arguments for prospective teacher students who are at level 1, both before and after lectures with the learning model *Argumentation Real–World Inquiry*.

Level 1 argument

I agree that environmental damage in Puncak was due to land-use change (*claim*).

The absence of level 1 in student arguments is a good thing because it means students are able to submit views accompanied by data or reasons (level 2), not only their views (level 1).

Changes in the argumentation skills of prospective teacher students' occurred at level 2 and level 3. Before lecturing with the Argumentation Real-World Inquiry learning model, the arguments of prospective teachers students related to air pollution were at most level 2 (74%) compared to the arguments at level 3 (16%). This shows that prior to the implementation of the model, students were able to submit arguments with their reasons, but only a few students equipped their arguments with data and valid assumptions to strengthen the arguments presented.

Level 2 argument

I disagree with the damage to the environment at Puncak due to land-use change (*claim*). This is because the Puncak area has the potential for medium to high ground movement if rainfall is above normal (*data*) so that the Puncak is prone to landslides (*warrant*).

Level 3 argument

I disagree with the damage to the environment at Puncak due to land-use change (*claim*). This is because the Puncak area has the potential for medium to high ground movement if rainfall is above normal (*data*) so that the Puncak is prone to landslides (*warrant*). Soil movement can occur due to rock types or unstable soil (*backing*).

After student teacher candidates conduct lectures with the Argumentation Real-World Inquiry, the argumentation of student-teacher candidates increases with a higher percentage of level 3 argument appearances (68%) compared to level 2 arguments (21%). This change shows that the learning model *Argumentation Real–World Inquiry* able to train prospective teacher students to deal with social-scientific issues related to the environment, as well as train prospective teacher students to be able to submit arguments related to these issues, especially in the submission of claims, data, warrant, and backing, although there is no increase for student arguments at level 4 and level 5.

Argument level 4

I agree (*claim*). At the Puncak, there are more than 300 buildings that do not have a building permit (*data*). The change of land usage causes the water catchment area to decrease so that it is prone to flooding and landslides in the downstream area (*warrant*) if there is heavy rain

(*qualifier*). Increasingly reduced trees on the Puncak, high-intensity rainwater cannot be absorbed and directly flows downstream (*backing*).

Argument level 5

I agree (*claim*). At the Puncak, there are more than 300 buildings that do not have a building permit (*data*). The conversion of this land decreases the water catchment area so that it is prone to flooding and landslides in the downstream area (*warrant*) if there is heavy rain (*qualifier*). The more trees decrease on the Puncak, made high-intensity rainwater cannot be absorbed and directly flows downstream (*backing*). Although it is not only caused by land-use change but also the behavior of people throwing away trash can be the cause (*rebuttal*).

The absence of changes in the emergence of student arguments at level 4 and level 5 after the implementation of the model shows that students have not been able to complete their arguments in responding to the sociocultural issues with supporting data (*backing*) and rebuttal. This indicates that the application of the Argumentation Real-World Inquiry learning model still needs to continue to be applied in order to train and familiarize prospective teacher students in arguing.

After evaluating and refining the Argumentation *Real–World Inquiry* model, the model implementation phase is carried out by involving the experimental class and the control class. The achievement of

students' argumentation skills before and after the learning process in both classes was measured by N-Gain scores (Figure 3) and N-Gain scores per Biology prospective teacher students (Figure 4).
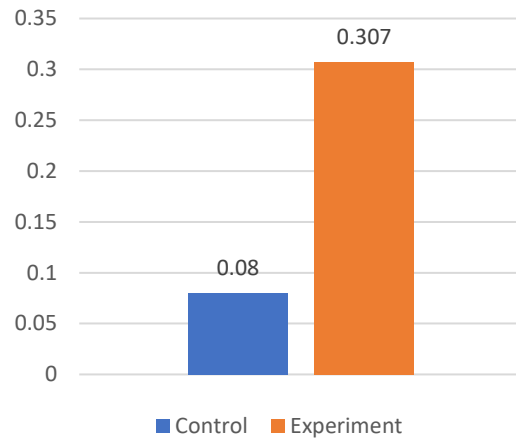

Figure 3. N-Gain value of the control and experiment class

Based on the data presented in Figure 3, the experimental class has higher argumentation skills (0.307) than the control class (0.08). It was caused by the Argumentation Real-World Inquiry learning model at each stage made students faced with an argumentation session to study environmental sociocultural issues. Because of that, argumentation skills in the experimental class were better trained than students in the control class.
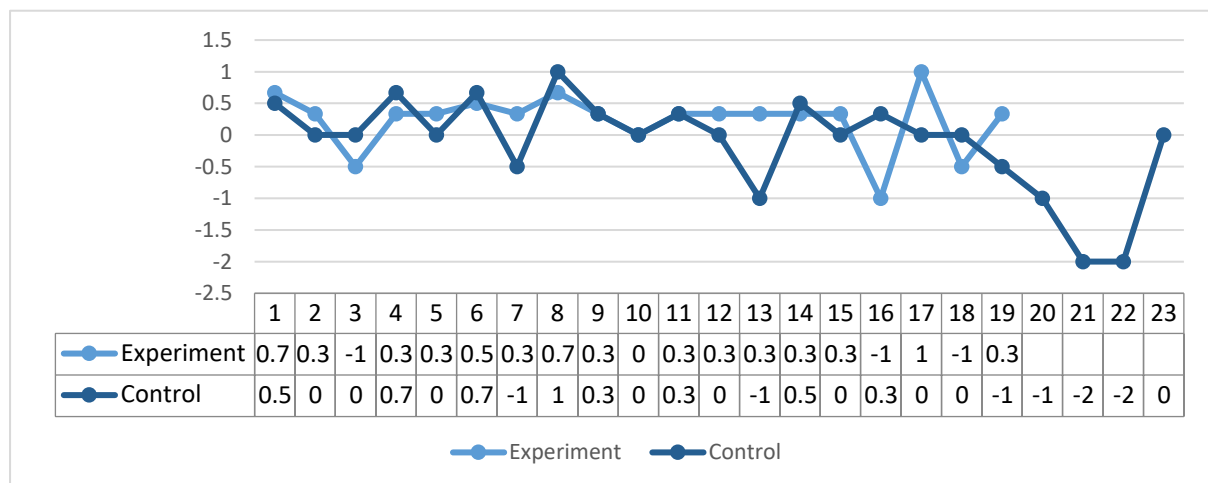

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Experiment	0.7	0.3	-1	0.3	0.3	0.5	0.3	0.7	0.3	0	0.3	0.3	0.3	0.3	0.3	-1	1	-1	0.3				
Control	0.5	0	0	0.7	0	0.7	-1	1	0.3	0	0.3	0	-1	0.5	0	0.3	0	0	-1	-1	-2	-2	0

Figure 4.Gain N score per student in control and experimental class

The inquiry learning model shows good results in training prospective teacher students to argue both verbally and in writing (Farida Ch & Gusniarti, 2014). Nevertheless, argumentation skills at level

5 remain a challenge for students in both the control class and the experimental class, so that the appearance of argumentation at this level is still very low. In Figure 4, there is only one prospective

teacher-student who has been trained in arguing that can reach level 5.

The results of interviews with prospective teacher-students show that the difficulty in argumentation in writing was how to take key information in a source, then relate it to facts and data which was owned. There are also many sources of references that are referred to from non-scientific literature that is not trusted, such as blogs, not from research results. None of the prospective teacher students referred to international journals because of their lack of foreign language skills. To overcome this problem, lecturers try to motivate prospective teacher students by providing references to reputable national and international journals, both in Indonesian and foreign languages. Although the ability to study data sources still needs to be improved, students already have a sufficient foundation of environmental concept knowledge so that they can provide a strong reason/warrant. As stated by Acar, Patton, and White (2015) that the mastery of a person's concept greatly influences how to think scientifically.

In this study also seen the arguments of prospective biology teacher students when they argued verbally. The involvement of prospective teacher students in oral argumentation has shown good collaborative argumentation, because if in one group there are learning partners who are able to argue well then the other members will be motivated, so the learning environment must be designed in such a way to help students present their arguments well when discussing (Vogel et al., 2016). When discussions and debates take place, prospective teacher students must be able to express their opinions verbally by having a strong foundation of knowledge. In the debate process also seen how students build and share their knowledge (Deane & Song, 2015). The context of environmental issues also provides stimulus to prospective teacher students. Prospective teacher students who understand content in the context of sociocultural issues encountered tend to be able to submit arguments more strongly than prospective teacher students who do not understand the content in the context of the issue. This is supported by several research results (Dawson & Schibeci, 2003; Jönsson, 2016; Yang & Anderson, 2003) which show that the quality of students'

arguments has a positive and strong correlation with mastery of content.

In the implementation of the learning model *Argumentation Real–World Inquiry*, lecturers have a central role in directing the arguments of prospective teacher students, encouraging prospective teacher students to express their views, as well as providing direction on arguments related to environmental socioscientific issues. This is in accordance with research conducted by Litman and Greenleaf (2018) that the more lecturers who teach arguments to prospective teacher students, the more their skills will be trained in expressing scientific opinions correctly. The role of the teacher or lecturer is very important to apply the argumentation because their beliefs about the argumentation can have an impact on how science practices are integrated into their classrooms (McNeill, Singer, Howard, & Loper, 2016).

Argumentation skills need to be continuously trained in each learning process. Students are not yet accustomed to the argumentation activities and learning models that have just been applied, providing great challenges for students to be able to implement them. Therefore, the model *Real–World Inquiry Argumentation* needs to be implemented on a broad scale so that it can accustom students to argue and be independent in facing everyday issues or phenomena.

Conclusion

The learning model Real-World Inquiry Argumentation consists of 5 stages, namely the Orientation, Manipulation, Generalization, Verification, and Application stages. The results of the research at the pre-experimental and implementation stages show that the Argumentation Real-World Inquiry learning model able to train prospective Biology teachers to develop their argumentative skills on environmental sociocultural issues. It was shown by the quality of their arguments increases after conducting lectures with Argumentation Real-World Inquiry. Students' argumentation skills were also influenced by knowledge of student content on the context of the issue and the role of the lecturer in stimulating students to be able to argue about environmental socioscientific issues.

Acknowledgment

References

Acar, Ö., Patton, B. R., & White, A. L. (2015). Prospective secondary science teachers' argumentation skills and the interaction of these skills with their conceptual knowledge. *Australian Journal of Teacher Education*, *40*(9), 132–156. https://doi.org/10.14221/ajte.2015v40n9.8

Amin, A. M., Corebima, A. D., Zubaidah, S., & Mahanal, S. (2017). Identifikasi kemampuan bertanya dan berpendapat calon guru biologi pada mata kuliah fisiologi hewan. *Bioedukasi: Jurnal Biologi Dan Pembelajarannya*, *15*(1), 24–31. Retrieved from https://jurnal.unej.ac.id/index.php/BIOED/article/view/4704/3462

Ardianto, D. (2014). *Implementasi pembelajaran IPA Terpadu tema fluida dengan model guided discovery dan problem based learning untuk meningkatkan literasi sains siswa SMP.* (Universitas Pendidikan Indonesia). Retrieved from http://repository.upi.edu/id/eprint/11956

Ardianto, D., & Herawati, D. (2016). *Argumentation skills of prospective biology teachers students on sociocultural issues.* Bogor.

Bekiroglu, F. O., & Eskin, H. (2012). Examination of the relationship between engagement in scientific argumentation and conceptual knowledge. *International Journal of Science and Mathematics Education*, *10*(6), 1415–1443. https://doi.org/10.1007/s10763-012-9346-z

Belland, B. R., Gu, J., Armbrust, S., & Cook, B. (2015). Scaffolding argumentation about water quality: a mixed-method study in a rural middle school. *Educational Technology Research and Development*, *63*(3), 325–353. https://doi.org/10.1007/s11423-015-9373-x

Cetin, P. S. (2014). Explicit argumentation instruction to facilitate conceptual understanding and argumentation skills. *Research in Science & Technological Education*, *32*(1), 1–20. https://doi.org/10.1080/02635143.2013.850071

Choi, A., Klein, V., & Hershberger, S. (2015). Success, difficulty, and instructional strategy to enact an argument-based inquiry approach: Experiences of elementary teachers. *International Journal of Science and Mathematics Education*, *13*(5), 991–1011. https://doi.org/10.1007/s10763-014-9525-1

Christenson, N., Gericke, N., & Rundgren, S.-N. C. (2017). Science and language teachers' assessment of upper secondary students' socioscientific argumentation. *International Journal of Science and Mathematics Education*, *15*(8), 1403–1422. https://doi.org/10.1007/s10763-016-9746-6

Chung, Y., Yoo, J., Kim, S.-W., Lee, H., & Zeidler, D. L. (2016). Enhancing students' communication skills in the science classroom through socioscientific issues. *International Journal of Science and Mathematics Education*, *14*(1), 1–27. https://doi.org/10.1007/s10763-014-9557-6

Cinici, A. (2016). Balancing the pros and cons of GMOs: socio-scientific argumentation in pre-service teacher education. *International Journal of Science Education*, *38*(11), 1841–1866. https://doi.org/10.1080/09500693.2016.1220033

Dawson, V., & Schibeci, R. (2003). Western Australian high school students' attitudes towards biotechnology processes. *Journal of Biological Education*, *38*(1), 7–12. https://doi.org/10.1080/00219266.2003.9655889

Dawson, V., & Venville, G. J. (2009). High-school students' informal reasoning and argumentation about Biotechnology: An indicator of scientific literacy? *International Journal of Science Education*, *31*(11), 1421–1445. https://doi.org/10.1080/09500690801992870

Deane, P., & Song, Y. (2015). The key practice, discuss and debate ideas: Conceptual framework, literature review, and provisional learning progressions for argumentation. *ETS Research Report Series*, *2015*(2), 1-21. https://doi.org/10.1002/ets2.12079

Farida Ch, I., & Gusniarti, W. F. (2014). *Profil keterampilan argumentasi siswa pada konsep koloid yang dikembangkan melalui pembelajaran inkuiri argumentatif.* *6*(1), 32-40. Retrieved from http://journal.uinjkt.ac.id/index.php/edusains/article/view/1098

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). *Educational research: An introduction* (7th ed.). United States of America: Allyn and Bacon.

Grooms, J., Sampson, V., & Golden, B. (2014). Comparing the effectiveness of verification and inquiry laboratories in supporting undergraduate science students in constructing arguments around socioscientific issues. *International Journal of Science Education, 36*(9), 1412-1433. https://doi.org/10.1080/09500693.2014.891160

Herawati, D., Widodo, A., Riandi, R., & Rochintaniawati, D. (2015). Students' scientific reasoning about global warming. *Proceedings of 2nd International Seminar on Mathematics, Science, and Computer Science Education (MSCEIS).* Bandung: Universitas Pendidikan Indonesia.

Inch, E. S., Warnick, B. H., & Endres, D. (2006). *Critical thinking and communication: The use of reason in argument* (5th ed.). London: Pearson Publisher.

Istiana, R., Awaludin, T., Harisusanto, L., & Indriyani, I. (2017). *Penerapan model pembelajaran inkuiri untuk meningkatkan kemampuan memecahkan permasalahan kependudukan berbasis lesson study.* Bogor.

Jönsson, A. (2016). Student performance on argumentation task in the Swedish National Assessment in science. *International Journal of Science Education, 38*(11), 1825-1840.

https://doi.org/10.1080/09500693.2016.1218567

Khishfe, R. (2014). Explicit nature of science and argumentation instruction in the context of socioscientific issues: an effect on student learning and transfer. *International Journal of Science Education, 36*(6), 974-1016. https://doi.org/10.1080/09500693.2013.832004

Litman, C., & Greenleaf, C. (2018). Argumentation tasks in secondary english language arts, history, and science: Variations in instructional focus and inquiry space. *Reading Research Quarterly, 53*(1), 107-126. https://doi.org/10.1002/rrq.187

Macagno, F., & Konstantinidou, A. (2012). What students' arguments can tell us: Using argumentation schemes in science education. *SSRN Electronic Journal, 27*(3), 225-243. https://doi.org/10.2139/ssrn.2185945

McNeill, K. L., Singer, R. K., Howard, M. G., & Loper, S. (2016). Factors impacting teachers' argumentation instruction in their science classrooms. *International Journal of Science Education, 38*(12), 2026-2046. https://doi.org/10.1080/09500693.2016.1221547

Sadler, T. D., & Zeidler, D. L. (2005). The significance of content knowledge for informal reasoning regarding socioscientific issues: Applying genetics knowledge to genetic engineering issues. *Science Education, 89*(1), 71-93. https://doi.org/10.1002/sce.20023

Venville, G., & Dawson, V. (2013). Introducing high school biology students to argumentation about socioscientific issues. *Canadian Journal of Science, Mathematics and Technology Education, 13*(4), 356-372. https://doi.org/10.1080/14926156.2013.845322

Vogel, F., Kollar, I., Ufer, S., Reichersdorfer, E., Reiss, K., & Fischer, F. (2016). Developing argumentation skills in mathematics through computer-supported collaborative learning: the role of transactivity. *Instructional Science, 44*(5), 477-

500. https://doi.org/10.1007/s112 51-016-9380-2

Wenning, C. J. (2005). Levels of inquiry: Hierarchies of pedagogical practices and inquiry processes. *J. Phys. Teach. Educ.Online, 2*(3), 3-- 12. Retrieved from http://www.phy.ilstu.edu/pte/publ ications/levels_of_inquiry.pdf

Yang, F.-Y., & Anderson, O. R. (2003). Senior high school students' preference and reasoning modes about nuclear energy use. *International Journal of Science Education, 25*(2), 221–244. https://doi.org/10.1080/09500690 210126739

Yang, F.-Y., & Tsai, C.-C. (2010). Reasoning about science-related uncertain issues and epistemological perspectives among children. *Instructional Science, 38*(4), 325– 354. https://doi.org/10.1007/ s11251-008-9084-3