Investigating Socio-scientific Reasoning of Biology Prospective Teacher: Focus on Genetic Modified Organism (GMO)

Laras Firdaus[1,3(✉)], Ibrohim[2], Sri Rahayu Lestari[2], Sri Nopita Primawari[1], and Masiah[1]

[1] Department of Biology Education, Mandalika University of Education, Mataram, Indonesia
larasfirdaus@undikma.ac.id
[2] Department Biology Education, State University of Malang, Malang, Indonesia
[3] Fakultas Sains, Teknologi, dan Terapan, Program Studi Pendidikan Biologi, Universitas Pendidikan Mandalika, Jalan Pemuda No. 59A, Dasan Agung Baru, Kec. Mataram, Mataram, Nusa Tenggara Barat, Indonesia

Abstract. Socio-scientific reasoning (SSR) is an integral part of scientific literacy, not only focusing on formal reasoning but also on informal reasoning. Therefore, SSR can help students improve their scientific reasoning abilities and moral reasoning abilities. For this reason, as a first step in developing a teaching curriculum, it is necessary to investigate SSR competence. A total of 62 prospective biology teachers were involved in this study, consisting of 29 4th semesters and 33 6th semesters students. The data were collected using the Quantitative Assessment of SSR (QuASSR) in the form of ordered multiple-choice, then analyzed descriptively and statistically. Based on the results of the subsequent analysis, it can be concluded that the semester has no significant effect on SSR competence. Both groups of students (4th and 6th semesters) were low on the competence of inquiry and skepticism.

Keywords: Scientific literacy · Socio-scientific reasoning · QuASSR · Biology prospective teacher

1 Introduction

The main objective of education is to improve and develop students' scientific literacy skills [1–7], empowering students to become critical citizens and actively participate in democratic life, have sensitivity to environmental issues, and have sustainable education [8]. To support this goal, the teaching curriculum should be reconstructed by connecting society's problems with scientific content or scientific concepts in learning [9]. The interaction between science and social issues became known as socio-scientific issues (SSI) [10–12].

As a learning approach, SSI contains real-life issues that are open-ended or ill-structured [13–15], usually controversial [1, 16–21], relating to environmental issues and technology utilization [22]. Examples of socio-scientific issues are the issue of

A. P. Wibawa et al. (Eds.): ICE 2022, ASSEHR 736, pp. 158–166, 2023.
https://doi.org/10.2991/978-2-38476-020-6_17

genetic engineering [4, 6, 10, 12, 23], climate changes, cases of illegal logging, and air pollution [12], or other debatable issues which requires various alternative solutions [10, 24]. As a learning approach, SSI focuses on controversial contemporary issues requiring various alternative solutions, helping students to provide reasoning and argumentation based on knowledge and ethics [25] or cognitive and emotion [4, 26], multi-perspective in solving a problem [26, 27] which is not only related to formal reasoning (data-based reasoning through the inquiry process) but also requires moral reasoning [4, 28]. Therefore, the reasoning and arguments prepared by students based on SSI are called informal reasoning [7, 12, 29–31], or socio-scientific reasoning (SSR) [6, 32, 33], and socio-scientific decision making [16, 20].

Reasoning based on cognition and morality is the core of SSR [25]. However, in providing reasoning on an issue, we still pay attention to the lowest to highest cognitive gradations, which represent the scientific way of thinking to solve SSI problems [32]. Therefore, as part of informal reasoning, SSR has several competencies, including analyzing issues from various perspectives, skepticism, identifying aspects of SSI issues followed up through inquiry activities, and considering the complexity of SSI issues [6, 15, 28, 32, 34, 35]. *Perspective competence* represents the ability to identify different opinions on an issue [15], the ability to distinguish the views of others from their own view, and systematically evaluate various information related to SSI issues [34], and the ability to explain issues, provide counter-claims or counter-arguments from multi-perspective [28]. *Skepticism competence* is used to analyze information that has the potential for bias [6, 15, 28, 32, 35]. *Inquiry competence* is closely related to scientific literacy, so this inquiry competence becomes an effort to solve problems through continuous inquiry [28, 32]. Meanwhile, *complexity competence* is the ability to identify the complexity of SSI issues from a scientific and social perspective [32]. In this competency, students show progress from simply considering causal relationships to reflecting, thinking, and evaluating complex and conflicting forms of information from SSI issues [15].

Research related to SSI focuses on various issues that enable students to form reasoning or arguments [36]. Several previous studies on SSI have shown that SSI can help students develop scientific literacy (SL) [15, 28] and improve students' argumentation skills [8, 13, 37–39]. SSI also aids students in understanding a concept and the nature of science [6], analyzing and synthesizing problems, evaluating various pieces of evidence to support an argument (reasoning), making moral decisions as the inseparable process of ethical issues, as well as helping students to make SSR [34, 40]. SSI and SSR function as a means of developing conceptual knowledge about science by considering non-scientific aspects of socio-scientific problems [41], but the integration of SSI in learning seems to be difficult [29]. Thus, SSI is rarely used as a learning approach (including in Indonesia) [42]. Meanwhile, in 21st-century education, learning should not only focus on formal reasoning but also involve informal reasoning (moral reasoning), as practiced in character education [21]. The initial step to achieve 21st-century and character education is to investigate student SSR competencies. Later, the results of this investigation process contribute to the preparation and development of teaching curricula (including the development of SSI-based teaching materials), especially in the department of biology education, Mandalika University of Education. For this reason,

this study was conducted to identify and describe the SSR competencies of prospective biology teachers. In this study, we investigate the prospective biology teachers' SSR competencies and their correlation with the prospective teachers' college semesters.

2 Method

This quantitative survey research was conducted at the Mandalika University of Education. Survey research can be done quantitatively and qualitatively [43]. As the name implies (quantitative survey), one of its characteristics is the quantitative data collection and analysis [44]. A total of 62 prospective biology teachers were involved in this study, consisting of 29 4th-semester students and 33 6th-semester students. In this study, we did not involve 2nd-semester students because we perceived that 2nd-semester students were still in a transitional period from high school. We also assumed that the 2nd-semester students did not have sufficient knowledge about genetics (especially about genetic engineering). Therefore, in this study, we only involved 4th and 6th-semester students because these two groups of students had already received the genetics course.

In this study, we used the Quantitative Assessment of SSR (QuASSR) as the research instrument, which focused on the GMO issue in the form of ordered multiple-choice (OMC) adapted from [6, 32]. Each two questionnaire items represented the perspective competency, complexity, inquiry, and skepticism. In solving the questions contained in the QuASSR, our respondents were asked to respond to the questionnaire items while also describing the reasons. The respondent then gave their responses along with their reasons. Each of the respondents' reasons was scored from the lowest (1) to the highest (3). In investigating the prospective biology teachers' SSR competencies, the obtained data were analyzed descriptively. Meanwhile, in discovering the correlation between the participants' college semesters to their SSR competence, the data were analyzed statistically (*t-test*) using SPSS 22 for windows at a significance level of 5%.

3 Results and Discussion

The SSI approach can possibly be adopted in teaching genetic engineering (including GMO and cloning) to biology students because GMOs are the content in the genetics course [3]. Issues related to bioethics, such as GMOs, involve both conceptual understanding and moral reasoning as the basis for preparing scientific reasoning [21]. Therefore, the SSI teaching approach is constructive for prospective biology teacher to develop their conceptual understanding and SSR competence. As stated above, the investigation of the SSR competency of prospective biology teachers is a crucial stepping stone to developing a teaching curriculum (including the development of teaching material based on SSI). The results of this study are expected to contribute to the development of the teaching curriculum. The results of our studies are summarized in Tables 1 and 2.

Table 1 shows the results of the SSR competence analysis of the prospective biology teachers (including the average value, standard deviation, and effect size), while Table 2 shows the result of statistical *t-test* analysis showing no significant effects of participants' college semesters on their SSR competence. This result is relatively similar to the findings reported by [14], that the average SSR of dental students is not significantly different from

Table 1. The results of descriptive analysis of SSR competencies

	Semester	N	Mean	Std. Deviation	Effect size (*g*)
Perspective	Semester 4th	29	4.07	1.223	0.47
	Semester 6th	33	4.61	1.088	
Complexity	Semester 4th	29	4.00	1.134	0.28
	Semester 6th	33	4.30	1.015	
Inquiry	Semester 4th	29	3.83	1.338	0.09
	Semester 6th	33	3.94	1.171	
Skepticism	Semester 4th	29	4.21	1.048	0.06
	Semester 6th	33	4.15	.939	

Table 2. The results of the t-test analysis on each SSR competency based on college semester

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	*t*	df	Sig.
Perspective	.423	.518	−1.830	60	.072
Complexity	.022	.882	−1.110	60	.271
Inquiry	2.633	.110	−.351	60	.727
Skepticism	.859	.358	.219	60	.827

science and engineering students. Although the information in Table 2 could show SSR competence between the prospective biology teachers in a different semester. However, we can enhance the significance of this conclusion by utilizing the data in Table 1.

From the information shown in Table 1, we can see that the mean score on perspective, complexity, and inquiry competencies of 6th-semester students is higher than 4th-semester students. Meanwhile, for skeptical competence, 4th-semester students attained higher scores than students in the 6th semester. As described by [15] that, perspective competence represents students' ability to use multi-perspectives in observing or explaining SSI issues. Therefore, from the average and effect size value of perspective competence shown in Table 1, the 6th-semester students have slightly better perspective competence than the 4th-semester students. In other words, the college semester presents a 47% effect (has a high effect) [45] on perspective competence, indicating that 6th-semester students can view GMO issues from multi-perspectives. To be able to view an issue from multi-perspectives, students must separate their personal views or ego from the problem they are assessing [34]. If students still hold on to their egos in assessing an issue, they will face problems in observing an issue from multi-perspectives, preventing them from having various alternative solutions. This individual perspective in reasoning

is called egocentric (pre-conventional) reasoning, or the lowest level of reasoning in the gradation of moral judgments [46].

Perspective and complexity competencies support other SSR competencies (inquiry and skepticism competencies) [6]. According to [32] and [15], complexity competence refers to the ability to identify the complexity of SSI issues, both from a scientific and social perspective. As presented in Table 2, we do not find a significant difference in SSR competencies (including complexity competence), but basically, the two groups of students have a minimum difference. Table 1 showed a 28% of college semester effect on complexity competence. Meanwhile, in inquiry and skepticism competencies, the data presented in Table 1 suggested that these two groups have difficulty in these two competencies, with minimum effects of college semesters on these two competencies [45]. These results are in accordance with the findings of [32] that inquiry and skepticism are considered difficult by students. Likewise, [41] described that most students fail in skeptical competence. [47] also reported that skeptical competence is mainly avoided by students and should be forced to use emotion-based reasoning.

Genetics is the most advanced science and has provided many benefits in life. In its development and use, it is inseparable from controversy (such as GMOs). Besides, to understand genetics, scientific and ethical understanding are required [48]. Thus, it is not sufficient to merely employ genetic understanding to comprehend issues related to genetics (such as GMOs) [49]. Therefore, this result implies that these two groups of students should require further guidance to improve their SSR competence. Consequently, educators must be prepared to engage in SSR if we expect students to improve and develop their scientific literacy and SSR competencies [50]. So, in the end, they can view an issue from multiple perspectives (related to not only lecture material but also their authentic life issues), are able to analyze and evaluate the complexity of an issue, and provide various alternative solutions through inquiry activities. In the end, the prospective biology teachers are expected to apply inquiry activities to understand an issue while also analyzing and evaluating biased information.

4 Conclusion

Our analysis results showed that the inquiry and skepticism competencies are the most difficult competencies for prospective biology teachers. Therefore, the provision of facilitation should focus more on these two SSR competencies. Accordingly, we also suggest the genetics lectures use SSI as a teaching approach to improve students' SSR competencies (especially inquiry and skepticism). The use of SSI as a teaching approach can be combined with an inquiry learning model. Through the inquiry learning model, students understand the causality of phenomena by formulating hypotheses and testing them, both through observation and experimentation. In addition, because the inquiry learning model is combined with SSI, it is not only related to scientific reasoning but also moral reasoning. This research was only carried out on prospective biology teacher students at the Mandalika University of Education, so it might have different results if it was carried out on another campus. In addition, this research only investigated SSR competencies as a stepping stone for developing teaching curricula. Further research is suggested to examine the relationship between content knowledge and SSR competencies or develop an instrument to measure SSR competencies.

Acknowledgements. We addressed our gratitude to the Ministry of Education and Culture, Research and Technology for financial support in completing this research through Decree No. 0969/LL8/AK.04/2022.

References

1. N. Atabey and M. S. Topcu, "The Development of a socio-scientific issues-based curriculum unit for middle school students: global warming issue," *Int. J. Educ. Math. Sci. Technol.*, vol. 5, no. 3, pp. 153–153, Jul. 2017, doi: https://doi.org/10.18404/ijemst.296027.
2. V. Dragoş and V. Mih, "Scientific literacy in school," *Procedia - Soc. Behav. Sci.*, vol. 209, pp. 167–172, Dec. 2015, doi: https://doi.org/10.1016/j.sbspro.2015.11.273.
3. C. Han-Tosunoglu and F. Ozer, "Exploring pre-service biology teachers' informal reasoning and decision-making about COVID-19," *Sci. Educ.*, vol. 31, no. 2, pp. 325–355, Apr. 2022, doi: https://doi.org/10.1007/s11191-021-00272-5.
4. T. Kolarova, I. Hadjiali, and I. Denev, "High school students' reasoning in making decisions about socio-ethical issues of genetic engineering: Case of gene therapy," *Biotechnol. Biotechnol. Equip.*, vol. 27, no. 2, pp. 3737–3747, Jan. 2013, doi: https://doi.org/10.5504/BBEQ.2012.0133.
5. M. Ozden, "Elementary school students' informal reasoning and its' quality regarding socio-scientific issues," *Eurasian J. Educ. Res.*, vol. 20, no. 86, pp. 1–24, Apr. 2020, doi: https://doi.org/10.14689/ejer.2020.86.4.
6. W. L. Romine, T. D. Sadler, J. M. Dauer, and A. Kinslow, "Measurement of socio-scientific reasoning (SSR) and exploration of SSR as a progression of competencies," *Int. J. Sci. Educ.*, vol. 42, no. 18, pp. 2981–3002, Dec. 2020, doi: https://doi.org/10.1080/09500693.2020.1849853.
7. Y. T. Wu, "University Students' Knowledge structures and informal reasoning on the use of genetically modified foods: Multidimensional analyses," *Res. Sci. Educ.*, vol. 43, no. 5, pp. 1873–1890, Oct. 2013, doi: https://doi.org/10.1007/s11165-012-9343-9.
8. H.-H. Wang, Z.-R. Hong, S.-C. Liu, and H.-S. Lin, "The impact of socio-scientific issue discussions on student environmentalism," *EURASIA J. Math. Sci. Technol. Educ.*, vol. 14, no. 12, Sep. 2018, doi: https://doi.org/10.29333/ejmste/95134.
9. J. Grooms, V. Sampson, and B. Golden, "Comparing the effectiveness of verification and inquiry laboratories in supporting undergraduate science students in constructing arguments around socio-scientific issues," *Int. J. Sci. Educ.*, vol. 36, no. 9, Art. no. 9, Jun. 2014, doi: https://doi.org/10.1080/09500693.2014.891160.
10. U. B. Cebesoy and S.-N. C. Rundgren, "Embracing socio-scientific issues-based teaching and decision-making in teacher professional development," *Educ. Rev.*, pp. 1–28, Jun. 2021, doi: https://doi.org/10.1080/00131911.2021.1931037.
11. C. Garrecht, M. Eckhardt, T. N. Höffler, and U. Harms, "Fostering students' socio-scientific decision-making: exploring the effectiveness of an environmental science competition," *Discip. Interdiscip. Sci. Educ. Res.*, vol. 2, no. 1, p. 5, Dec. 2020, doi: https://doi.org/10.1186/s43031-020-00022-7.
12. M. Karpudewan and W.-M. Roth, "Changes in primary students' informal reasoning during an environment-related curriculum on socio-scientific issues," *Int. J. Sci. Math. Educ.*, vol. 16, no. 3, pp. 401–419, Feb. 2018, doi: https://doi.org/10.1007/s10763-016-9787-x.
13. J. L. Eastwood, T. D. Sadler, D. L. Zeidler, A. Lewis, L. Amiri, and S. Applebaum, "Contextualizing nature of science instruction in socio-scientific issues," *Int. J. Sci. Educ.*, vol. 34, no. 15, pp. 2289–2315, Oct. 2012, doi: https://doi.org/10.1080/09500693.2012.667582.

14. M. Irmak, "Socio-scientific reasoning competencies and nature of science conceptions of undergraduate students from different faculties," *Sci. Educ. Int.*, vol. 31, no. 1, pp. 65–73, Mar. 2020, doi: https://doi.org/10.33828/sei.v31.i1.7.
15. A. T. Kinslow, T. D. Sadler, and H. T. Nguyen, "Socio-scientific reasoning and environmental literacy in a field-based ecology class," *Environ. Educ. Res.*, vol. 25, no. 3, pp. 388–410, Mar. 2019, doi: https://doi.org/10.1080/13504622.2018.1442418.
16. S. Eggert, F. Ostermeyer, M. Hasselhorn, and S. Bögeholz, "Socio-scientific decision making in the science classroom: The effect of embedded metacognitive instructions on students' learning outcomes," *Educ. Res. Int.*, vol. 2013, pp. 1–12, 2013, doi: https://doi.org/10.1155/2013/309894.
17. C. Jansong, S. Pitiporntapin, P. Chumnanpuen, L. M. Hines, and S. Yokyong, "Using socio-scientific issues-based teaching to develop grade 10 students' informal reasoning skills," *Kasetsart J. Soc. Sci.*, vol. 43, no. 1, 2022, doi: https://doi.org/10.34044/j.kjss.2022.43.1.29.
18. D. Karisan and D. L. Zeidler, "Contextualization of nature of science within the socio-scientific issues framework: A review of research," *Int. J. Educ. Math. Sci. Technol.*, pp. 139–152, Nov. 2016, doi: https://doi.org/10.18404/ijemst.270186.
19. M. S. Topcu, E. Z. Mugaloglu, and D. Guven, "Socio-scientific issues in science education: The case of Turkey," *Educ. Sci. Theory Pract.*, 2014, doi: https://doi.org/10.12738/estp.2014.6.2226.
20. B. Tuncay, Ö. Yılmaz-Tüzün, and G. T. Teksoz, "Moral reasoning patterns and influential factors in the context of environmental problems," *Environ. Educ. Res.*, vol. 18, no. 4, pp. 485–505, Aug. 2012, doi: https://doi.org/10.1080/13504622.2011.630576.
21. S. F. Yap, "Beliefs, values, ethics and moral reasoning in socio-scientific education," *Issues Educ. Res.*, vol. 24, no. 3, 2014.
22. M. Özden, "Prospective elementary school teachers' views about socio-scientific issues: A concurrent parallel design study," no. 3, p. 22, 2015.
23. A. Beniermann, L. Mecklenburg, and A. Upmeier zu Belzen, "Reasoning on controversial science issues in science education and science communication," *Educ. Sci.*, vol. 11, no. 9, p. 522, Sep. 2021, doi: https://doi.org/10.3390/educsci11090522.
24. M. D. Gul and H. Akcay, "Structuring a new socio-scientific issues (SSI) based instruction model: Impacts on pre-service science teachers' (PSTs) critical thinking skills and dispositions," *Int. J. Res. Educ. Sci.*, vol. 6, no. 1, p. 141, Nov. 2019, doi: https://doi.org/10.46328/ijres.v6i1.785.
25. N. Christenson, S.-N. Chang Rundgren, and H.-O. Höglund, "Using the SEE-SEP model to analyze upper secondary students' use of supporting reasons in arguing socio-scientific issues," *J. Sci. Educ. Technol. - J SCI EDUC TECHNOL*, vol. 21, pp. 1–11, 2012, doi: https://doi.org/10.1007/s10956-011-9328-x.
26. J. Grooms, V. Sampson, and B. Golden, "Comparing the effectiveness of verification and inquiry laboratories in supporting undergraduate science students in constructing arguments around socio-scientific issues," *Int. J. Sci. Educ.*, vol. 36, no. 9, pp. 1412–1433, Jun. 2014, doi: https://doi.org/10.1080/09500693.2014.891160.
27. C.-J. Rundgren, M. Eriksson, and S.-N. C. Rundgren, "Investigating the intertwinement of knowledge, value, and experience of upper secondary students' argumentation concerning socio-scientific issues," *Sci. Educ.*, vol. 25, no. 9–10, pp. 1049–1071, Dec. 2016, doi: https://doi.org/10.1007/s11191-016-9859-x.
28. D. Zeidler, *Socio-scientific issues as a curriculum emphasis: Theory, research, and practice.* Routledge, 2014, pp. 711–740. doi: https://doi.org/10.4324/9780203097267-45.
29. S. S. El Arbid and H. H. Tairab, "Science teachers' views about inclusion of socio-scientific issues in UAE science curriculum and teaching," *Int. J. Instr.*, vol. 13, no. 2, pp. 733–748, Apr. 2020, doi: https://doi.org/10.29333/iji.2020.13250a.

30. Y. C. Lee and M. Grace, "Students' reasoning and decision making about a socio-scientific issue: A cross-context comparison: students' reasoning and decision making about a SSI," *Sci. Educ.*, vol. 96, no. 5, pp. 787–807, Sep. 2012, doi: https://doi.org/10.1002/sce.21021.
31. M. I. M. Saad, S. Baharom, and S. E. Mokhsein, "Scientific reasoning skills based on socio-scientific issues in the biology subject," *Int. J. Adv. Appl. Sci.*, vol. 4, no. 3, pp. 13–18, Mar. 2017, doi: https://doi.org/10.21833/ijaas.2017.03.003.
32. W. L. Romine, T. D. Sadler, and A. T. Kinslow, "Assessment of scientific literacy: Development and validation of the quantitative assessment of socio-scientific reasoning (QuASSR)," *J. Res. Sci. Teach.*, vol. 54, no. 2, pp. 274–295, Feb. 2017, doi: https://doi.org/10.1002/tea.21368.
33. T. D. Sadler and V. Dawson, "Socio-scientific issues in science education: Contexts for the promotion of key learning outcomes," in *Second International Handbook of Science Education*, B. J. Fraser, K. Tobin, and C. J. McRobbie, Eds. Dordrecht: Springer Netherlands, 2012, pp. 799–809. doi: https://doi.org/10.1007/978-1-4020-9041-7_53.
34. S. Kahn and D. L. Zeidler, "Using our heads and HARTSS*: Developing perspective-taking skills for socio-scientific reasoning (*Humanities, ARTS, and Social Sciences)," *J. Sci. Teach. Educ.*, vol. 27, no. 3, pp. 261–281, Apr. 2016, doi: https://doi.org/10.1007/s10972-016-9458-3.
35. A. Peel, T. Sadler, P. Friedrichsen, A. Kinslow, and J. Foulk, "Rigorous investigations of relevant issues: A professional development program for supporting teacher design of socio-scientific issue units.," *Innov. Sci. Teach. Educ.*, vol. 3, Jul. 2018.
36. N. Christenson, S.-N. Chang Rundgren, and D. Zeidler, "The Relationship of discipline background to upper secondary students' argumentation on socio-scientific issues," *Res. Sci. Educ.*, vol. 44, Dec. 2013, doi: https://doi.org/10.1007/s11165-013-9394-6.
37. B. Berne, "Progression in ethical reasoning when addressing socio-scientific issues in biotechnology," *Int. J. Sci. Educ.*, vol. 36, no. 17, pp. 2958–2977, Nov. 2014, doi: https://doi.org/10.1080/09500693.2014.941957.
38. C.-C. Foong and E. G. S. Daniel, "Students' argumentation skills across two socio-scientific issues in a confucian classroom: Is transfer possible?," *Int. J. Sci. Educ.*, vol. 35, no. 14, pp. 2331–2355, Sep. 2013, doi: https://doi.org/10.1080/09500693.2012.697209.
39. J. A. Nielsen, "Science in discussions: An analysis of the use of science content in socio-scientific discussions," *Sci. Educ.*, vol. 96, no. 3, pp. 428–456, 2012, doi: https://doi.org/10.1002/sce.21001.
40. D. Zeidler, B. C. Herman, and T. D. Sadler, "New directions in socio-scientific issues research," *Discip. Interdiscip. Sci. Educ. Res.*, vol. 1, no. 1, p. 11, Dec. 2019, doi: https://doi.org/10.1186/s43031-019-0008-7.
41. D. C. Owens, D. N. Petitt, D. Lally, and C. T. Forbes, "Cultivating water literacy in STEM education: Undergraduates' socio-scientific reasoning about socio-hydrologic issues," *Water*, vol. 12, no. 10, p. 2857, Oct. 2020, doi: https://doi.org/10.3390/w12102857.
42. S. Nida, V. R. Mustikasari, and I. Eilks, "Indonesian pre-service science teachers' views on socio-scientific issues-based science learning," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 17, no. 1, p. em1932, Jan. 2021, doi: https://doi.org/10.29333/ejmste/9573.
43. J. Ponto, "Understanding and evaluating survey research," *J. Adv. Pract. Oncol.*, vol. 6, no. 2, pp. 168–171, 2015.
44. M. Odoh and I. Chinedum E, "Research designs, survey and case study," *IOSR J. VLSI Signal Process.*, vol. 4, no. 6, pp. 16–22, 2014.
45. J. M. Maher, J. C. Markey, and D. Ebert-May, "The other half of the story: Effect size analysis in quantitative research," *CBE Life Sci. Educ.*, vol. 12, no. 3, pp. 345–351, 2013, doi: https://doi.org/10.1187/cbe.13-04-0082.
46. Y.-J. Choi, H. Han, M. Bankhead, and S. J. Thoma, "Validity study using factor analyses on the defining issues test-2 in undergraduate populations," *PLOS ONE*, vol. 15, no. 8, p. e0238110, Aug. 2020, doi: https://doi.org/10.1371/journal.pone.0238110.

47. H. Ha, W. Park, and J. Song, "Preservice elementary teachers' socio-scientific reasoning during a decision-making activity in the context of COVID-19," *Sci. Educ.*, Jul. 2022, doi: https://doi.org/10.1007/s11191-022-00359-7.
48. J. Vlckova and M. Kubiatko, "Perception of genetics by using of semantic differential at high school students: Preliminary results," *EURASIA J. Math. Sci. Technol. Educ.*, vol. 14, no. 1, Nov. 2017, doi: https://doi.org/10.12973/ejmste/79803.
49. N. G. Lederman, A. Antink, and S. Bartos, "Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A pathway to developing a scientifically literate citizenry," 2014, doi: https://doi.org/10.1007/S11191-012-9503-3.
50. D. C. Owens, B. C. Herman, R. T. Oertli, A. A. Lannin, and T. D. Sadler, "Secondary science and mathematics teachers' environmental issues engagement through socio-scientific reasoning," *EURASIA J. Math. Sci. Technol. Educ.*, vol. 15, no. 6, Jan. 2019, doi: https://doi.org/10.29333/ejmste/103561.
51. D. L. Zeidler, B. C. Herman, M. Ruzek, A. Linder, and S.-S. Lin, "Cross-cultural epistemological orientations to socio-scientific issues," *J. Res. Sci. Teach.*, vol. 50, no. 3, pp. 251–283, 2013, doi: https://doi.org/10.1002/tea.21077.
52. M. G. Lindahl and M. Lundin, "How do 15–16 year old students use scientific knowledge to justify their reasoning about human sexuality and relationships?," *Teach. Teach. Educ.*, vol. 60, pp. 121–130, Nov. 2016, doi: https://doi.org/10.1016/j.tate.2016.08.009.
53. M. Pedaste *et al.*, "Phases of inquiry-based learning: Definitions and the inquiry cycle," *Educ. Res. Rev.*, vol. 14, pp. 47–61, Feb. 2015, doi: https://doi.org/10.1016/j.edurev.2015.02.003.
54. P. Bernard and K. Dudek-Różycki, "Influence of training in inquiry-based methods on in-service science teachers' reasoning skills," *Chem. Teach. Int.*, vol. 1, no. 2, Jul. 2019, doi: https://doi.org/10.1515/cti-2018-0023.
55. L. M. McCool and J. A. Bremser, "Individual Differences in Disgust Sensitivity Do Not Influence Moral Reasoning, but a Discipline-Specific Ethics Course Does," *SAGE Open*, vol. 4, no. 3, p. 2158244014541774, Jul. 2014, doi: https://doi.org/10.1177/2158244014541774.