Identification of Informal Reasoning Patterns of Biology Prospective Teachers Based on Socio-scientific Issues

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Abstract

This research was conducted to overcome the lack of integration of socio-scientific issues (SSI) at the Mandalika University of Education, especially the biology education department, and at the same time as a springboard for developing teaching programs. This basic qualitative research aims to identify and explain informal reasoning patterns of biology prospective teachers. In this study, 14 biology prospective teachers as samples were selected purposively, namely students who had taken animal physiology, genetics, and evolution courses. Furthermore, semi-structured interviews using thematic techniques focused on issues of common descent, GMOs, and organ transplants. The findings and conclusions of this study indicate that intuitive and emotive reasoning is the reasoning patterns most used by our respondents in responding to SSI issues. Then, for further research, it is stated briefly in the recommendations section.

Keywords: Socio-scientific issues; Informal reasoning patterns; Biology prospective teachers

INTRODUCTION

Teachers as social architects on which the quality of human resources depends (Khan, 2017). Therefore, teachers must realise education's primary goal, namely to improving students' scientific literacy (SL) (Badeo & Duque, 2022; Beniermann et al., 2021; Cebesoy, 2021). As we know, SL is not as simple as writing and reading (Ogunkola, 2013), but more than that SL leads to the use of data to evaluate arguments and information (Dragoş & Viorel, 2015), involves conceptual understanding, requires an understanding of the value of inquiry scientific, and the nature of problem-solving as part of scientific enquiry, including an understanding of scientific processes, practices and basic principles about scientific contexts (Presley et al., 2013).

Human life cannot be separated from science and will always be faced with problems and decisions that must be taken from their understanding and scientific perspective (Topcu, 2010). Then in learning, the relationship between problems and social life is called socio-scientific issues (SSI) (Garrecht et al., 2020), and now SSI is one of the trends in learning approaches that can be used to help students understand life's problems scientifically (Chang Rundgren, 2011). As a learning approach, SSI

integrates problems in life, especially controversial issues related to environmental issues, use of technology and ethics (Badeo & Duque, 2022; Özden, 2015), such as the use of genetic engineering (Beniermann et al., 2021; Cebesoy, 2021; Foong & Daniel, 2013), nuclear energy, cloning, forest expansion (Özden, 2015), smoking bans, leukaemia problems, and smartphone usage effect on health (Topcu, 2010).

The use of SSI as a learning approach not only helps students to understand issues or problems in life but also helps students to build and debate their arguments (Badeo & Duque, 2022). Or in other words, using SSI as a learning approach means expecting students to build SSI reasoning or arguments (Grooms et al., 2014), where SSI reasoning is identical to informal reasoning (Kolarova et al., 2013; Ozturk & Yılmaz-Tüzün, 2017; Wu, 2013), namely reasoning involving causes and effects, pros and cons, or the disadvantages and advantages of a proposition or decision (Ozturk & Yılmaz-Tüzün, 2017). In addition, informal reasoning involves cognitive and affective in the process of solving ill-structured problems (Kolarova et al., 2013), or types of reasoning related to problems that do not have a definitive solution (Georgiou et al., 2020; Karpudewan & Roth, 2018; Yen & Wu, 2017).

SSI as a learning approach has been widely used at various levels of education (Morris, 2014), but it is used more in universities, especially to prospective teachers (Topcu et al., 2014). Unfortunately, SSI is rarely used in Indonesia, including at the Mandalika University of Education (Nida et al., 2021). Specifically, at the Mandalika University of Education, we have not found studies on SSI but studies that focus a lot on scientific processes and critical thinking. Atabey and Topcu (2017) explained that one of the factors that caused SSI not to be explored was the lack of adequate teaching materials and support. It seems that this factor is not a reason not to use SSI as a learning approach. We believe there is no study of SSI at the Mandalika University of Education because teachers feel reluctant to teach controversial topics or issues (Kara, 2012).

As we know that 21st-century education emphasizes integrating SSI into learning (Morris, 2014). The integration of SSI not only produces prospective teachers who can make good decisions but are also responsible for making decisions related to social issues, such as corruption, pandemics, the use of technology, and so on (Ha et al., 2022). Several expert opinions and research results show the primacy of integrating SSI into learning. SSI is very relevant for students because it plays a role as a bridge between science and students' life experiences, and SSI also provides a meaningful learning context for students (Wu, 2013), helps students to make decisions based on evidence, improves students' reasoning abilities (Karpudewan & Roth, 2018). (Ke et al., 2021) shows the relationship between SSI and informal reasoning that can help students apply their scientific knowledge in life. It can help students understand natural phenomena and build reasoning about the relationship between science and social life.

Considering the conditions of integrating SSI at the Mandalika University of Education above, we see the need to see and apply a global view, especially regarding SSI and informal reasoning, to improve the quality of learning at the Mandalika University of Education. Therefore, our research can be understood as a steppingstone to developing a learning curriculum that should have gotten attention at the Mandalika University of Education, especially in biology prospective teachers. If the teacher is a social architect who has a role in improving scientific literacy, biology prospective teachers will have the same role. If the prospective teachers aim to

improve students' scientific literacy, the prospective teachers must also have the knowledge and understand how to improve scientific literacy.

Then, about using SSI as a learning approach, the topics or issues, researchers often use to look at students' informal reasoning and informal decisions are issues regarding gene cloning and the use of technology, both in agriculture and health, including genetic engineering (genetically modified organisms/GMOs), nuclear energy, environmental damage, and so on because these issues are related to social and ethical issues (Cebesoy, 2021). For example, Susilawati et al. (2021) uses SSI to increase environmental awareness in student-teacher candidates. Cebesoy (2021) and Kolarova et al. (2013) uses issues of gene therapy, COVID-19 (Ha et al., 2022), issues related to biotechnology (cloning) (Berne, 2014), climate change (Gul & Akcay, 2020), nuclear energy (Sağlam & Eroglu, 2022), GMOs (Chang Rundgren, 2011; Wu, 2013), organ tranpalantation (Ozden, 2020).

In this study, we used several issues that were not much different from the issues or topics used by previous researchers, namely GMOs and organ transplantation, and we used theoretical issues, namely regarding the concept of common ancestry. Considering the experts' opinions above regarding the main characteristics of SSI, the issues are controversial or the ill-structured problems. We view the controversial issue referred to by these experts as naturally controversial, not an issue to be controversial. Therefore, in this study, apart from using the issue of GMOs and organ transplantation, we also used a controversial theoretical issue, namely the concept of common ancestry. Another reason that supports us using this issue is that evolution is a compulsory subject in the biology education curriculum at the Mandalika University of Education, so we also need to know how the informal reasoning of prospective biology teachers relates to this concept of common ancestry. Based on this, this research was conducted to investigate and explaining the informal reasoning patterns of prospective biology teachers based on SSI issues. The research question that should be answered is what prospective biology teachers widely use informal reasoning patterns at the Mandalika University of Education based on SSI.

METHOD

This study is categorized as a basic qualitative study (Merriam & Tisdell, 2015), which was conducted at the Mandalika University of Education, Jalan Pemuda No. 59A Mataram. As a tertiary institution, the students of the Mandalika University of Education come from various statuses, whether religious, cultural, and economic. This study focuses on prospective biology teachers. The courses of expertise (related to biology) they take to get graduation are ecology, animal physiology, genetics, evolution, microbiology, and plant and animal taxonomy. Based on this, prospective biology teachers are certainly no strangers to controversial issues, such as cloning, GMOs, and organ transplants, including the controversy over the theory of evolution. Then, the purpose of this study was to investigate and explain the informal reasoning patterns of prospective biology teachers regarding the SSI context, namely GMOs, organ transplantation, and the concept of common ancestry. Furthermore, the research question to be answered in this study is whether the pattern of informal reasoning that prospective teacher students widely use at the Mandalika University of Education.

In this study, the pattern of informal reasoning refers to the classification given by Sadler, namely emotive, intuitive, integrative, and rationalistic reasoning (Cebesoy, 2021; Dawson & Carson, 2017; Georgiou et al., 2020; Kahn & Zeidler, 2016, 2019; Ozden, 2020; Rundgren et al., 2016; Topçu et al., 2011). Intuitive reasoning patterns are characterized by quick responses based on beliefs and are usually negative (Georgiou et al., 2020; Ozden, 2020; Topçu et al., 2011). Emotive reasoning patterns are based on emotion (Ozden, 2020), using feelings of sympathy or empathy in responding or making decisions (Georgiou et al., 2020; Topçu et al., 2011). The pattern of rationalistic reasoning is also called logical reasoning (Georgiou et al., 2020; Ozden, 2020), namely, reasoning based on reason (Topçu et al., 2011), based on logical reasoning, or based on pragmatic principles, based on an understanding of strengths and lack of an issue (Georgiou et al., 2020; Ozden, 2020), or patterns of reasoning that refer to cognitive reasoning characterized by the use of logic to defend opinions (Rundgren et al., 2016). On occasion, a person may use more than one pattern of reasoning. It may be a combination of emotional and rationalistic reasoning or intuitive and emotional. Reasoning like this is called integrative reasoning (Georgiou et al., 2020).

Data Collection

Respondents in this study were prospective biology teachers at the Mandalika University of Education who were selected purposively, namely students who had taken evolution, genetics, and animal physiology courses. These three courses have a strong relationship with the SSI topics used, namely GMOs, organ transplantation, and the concept of common descent. Thus, researchers can accurately identify and explain the prospective biology teacher students' reasoning patterns. Fourteen prospective biology teachers were involved in this study as research samples of five males and nine females. All prospective biology teachers involved in this study have the same conditions during the learning process. The groups are not given special treatment, either as an experimental group or as a comparison groups.

The data of informal reasoning patterns are gained using semi-structured interviews with three scenarios. All interview processes referred to SSI issues. Researchers listened and recorded the responses given by respondents regarding SSI issues. In the first scenario, the interview topic is the theory of evolution, especially the concept of common descent. As we know that the theory of evolution is a valid and scientific theory. However, this does not mean that the theory of evolution is free from controversy, especially regarding the concept of common descent. Therefore, in this study, we used the concept of common descent as one of the SSI topics. This is supported by the opinion of Beniermann et al. (2021) that SSI is related to controversial issues, including the theory of evolution, that can be used as an SSI topic.

Furthermore, in the second scenario, we use the topic of GMOs, specifically transgenic plants. Science and technology continue to develop. On the other hand, applying technology to human life is inseparable from ethics or social values, such as genetic engineering (including cloning and transgenic plants). This is what makes the application of modern technology controversial. The question now is whether the development of science and technology must follow the existing order of norms or must the current norms develop with the development of science and technology. For us, between norms, science and technological progress must go hand in hand. If science and norms do not go hand in hand, we will continue to be stuck in delays.

The selection of GMOs (i.e., transgenic plants) as an SSI topic is relevant to genetics courses. Then, we put it into the third scenario, related to health problems both as a result of the use of technology, lifestyle, and naturally, explicitly about organ transplantation as a method of healing. This third scenario is very relevant to the animal physiology course, which discusses not only scientific concepts but also the role of technology as a method of healing disease. Finally, selecting these three SSI topics is very relevant to prospective biology teachers at the Mandalika University of Education, not only related to cognitive aspects but also emotional and moral aspects.

Data Analysis

At this stage of the interview process, researchers heard and recorded the responses and coded each response. The coding is based on informal reasoning patterns (emotive, integrative, intuitive, and rationalistic). This process is referred to as the thematic analysis technique (Clarke & Braun, 2018). The coding is done on the pattern of informal reasoning and provides a code for each respondent. This aims to maintain the confidentiality of the respondent's identity. The respondents are coded in the forms of BPTs-1 to BPTs-14, while the code for the informal reasoning pattern was coded with Int (intuitive reasoning pattern), Emo (emotive reasoning pattern), Rat (rationalistic reasoning pattern), and Inte (integrative reasoning pattern). After the transcription of the interview results was analyzed, the next step was to report the results of the interview transcription. Thus, researchers arrange the reporting process in tabular form according to the compiled code. Researchers choose which ones include intuitive, emotive, rationalistic, and integrative reasoning patterns.

RESULTS AND DISCUSSION

This qualitative study aims to identify and explain prospective biology teachers' informal reasoning patterns based on the SSI. To achieve this goal, several scenarios are designed and implemented. Table 1 shows the informal reasoning patterns of prospective biology teachers on all SSI topics.

Intuitive Reasoning Patterns

Referring to the opinion of Ozden (2020) and Georgiou et al. (2020) above, intuitive reasoning is given spontaneously, usually negatively. Below are some examples of intuitive reasoning provided by our respondents.

BPTs-3: *The theory of common descent shared by all organisms is one of the principles of evolution. According to the theory of evolution, every living species descended from a common ancestor (common descent concept).*

BPTs-5: *Among humankind, some sacrifice themselves to seek the pleasure of Allah, and Allah is forbearing to His servants (organ transplantation).*

BPTs-6: *I have no idea. I don't understand the GMOs, so sorry (GMOs).*

BPTs-8: *Organ transplantation is an excellent treatment technique (organ transplantation).*

BPTs-10: *Transplanting organs without Syar'I or Islamic law justified reason is haram (organ transplantation).*

Table 1. The informal reasoning patterns of prospective biology teachers based on SSI

BPTs	Theory of evolution				Genetic technology (GMO)				Organ transpalantation			
	Intu	Emo	Rat	Inte	Intu	Emo	Rat	Inte	Intu	Emo	Rat	Inte
BPTs-1			X			X				X		
BPTs -2	X				X				X			
BPTs -3	X					X			X			
BPTs -4	X				X					X		
BPTs -5	X				X					X		
BPTs -6	X					X			X			
BPTs -7			X				X				X	
BPTs -8	X				X					X		
BPTs -9	X					X				X		
BPTs -10	X					X			X			
BPTs -11			X				X			X		
BPTs -12	X				X				X			
BPTs -13	X					X				X		
BPTs -14	X					X				X		
Total	11		3		5	7	2		5	8	1	
%	78.57	00.00	21.43	00.00	35.71	50.00	14.29	00.00	35.71	57.14	7.14	

Note: Intu = Intuitive; Emo = Emotive; Rat= Rationalistic; Inte= Integrative

Emotive Reasoning Patterns

Based on the definitions or criteria for each pattern of informal reasoning as given by the experts above, we can distinguish them clearly. Examples of our participants' emotional reasoning pattern responses to the SSI topic follow.

BPTs-1: *I disagree because organ transplantation can endanger a person's life (organ transplantation).*

BPTs-6: *My reaction to GMOs is that natural plants. It should not be changed because it can affect health (GMO).*

BPTs-13: *I disagree because GMOs are also dangerous (GMOs).*

Rationalistic Reasoning Patterns

Following are some examples of rationalistic reasoning patterns our respondents gave regarding SSI issues.

BPTs-1: *The common descent is not the same as the ancestors of other organisms, such as we and our brothers and sisters have the same ancestor, namely our father and mother, but are not the same as the ancestors of other organisms or species (the concept of a common descent).*

BPTs-7: *Organ transplantation can save lives. It is often the only option after all attempts at some treatments for organ failure have failed. WHO states in the case of the end-level kidney disease, although it can be treated through certain therapies, but in general kidney transplantation is accepted as the best treatment in terms of quality of life, but what needs to be considered is the issue of the cost of treatment (organ transplantation).*

BPTs-11: *Various efforts have been made to address the challenges of food shortages, including by applying biotechnology through genetic engineering. Genetic engineering is a*

human effort to get superior seeds by changing and modifying an organism. One example of genetically modified plants is transgenic plants, which have superior characteristics, such as higher productivity, resistance to pests, and better nutritional quality. The results of this genetic engineering are expected to overcome food shortages (GMOs).

As explained by the experts above regarding SSI, it relates to informal reasoning. In responding or making decisions based on SSI, students can use various types or patterns of reasoning, namely intuitive, rationalistic, emotive, and integrative. Then, paying attention to the results shown in Table 1, most of our respondents used intuitive reasoning patterns (78.57%) for the issue of the concept of common descent, followed by emotive reasoning patterns (50.00% and 57.14%) for the issue of GMOs and organ transplantation. This result is relatively the same as Ozden finding (2020) that most respondents used intuitive and emotive reasoning patterns on all SSI issues. However, it is very different from the findings of Kolarova et al. (2013) that the majority (around 57.6%) of respondents used rationalistic reasoning on the issue of gene therapy, followed by emotive reasoning patterns (24.2%) and intuitive reasoning patterns (18.2%). Likewise, the findings of Ozturk and Yılmaz-Tüzün (2017) showed that 91% of the respondents used rationalistic reasoning, and the remaining 7% used intuitive reasoning on the issue of nuclear energy. Furthermore, Han-Tosunoglu and Ozer (2022) used the COVID-19 pandemic as an SSI issue, showing that most respondents made decisions based on rationalistic reasoning, followed by emotive reasoning and intuitive reasoning patterns.

Taking into account the results shown in Table 1 above, we try to explain why our respondents use more intuitive and emotive reasoning patterns than rationalistic reasoning, even though at the university level, rationalistic reasoning is reasoning that is expected to be used in responding or making decisions related to SSI issues (Han-Tosunoglu & Ozer, 2022). Regarding this, several factors influence the reasoning of our responses, including religious beliefs, risk considerations, attitudes and views of respondents regarding global issues (such as GMOs and organ transplants), content knowledge, and political identity (Beniermann et al., 2021). It is undeniable that both students and college students providing responses or decisions regarding SSI are sometimes based on ethics or social norms and religious beliefs (Wu, 2013) because these factors (such as religious beliefs) are often factors that influence informal reasoning and even respondents whom those with strong religious beliefs tend to use intuitive reasoning (Cebesoy, 2021). Likewise, previous experience, culture, and religious beliefs often influence respondents' reasoning patterns and decisions (Buzdar et al., 2015). We can see this from the reactions given by our respondents (BPTs-5) regarding the issue of organ transplantation (*Among humankind, some sacrifice themselves to seek the pleasure of Allah, and Allah is forbearing to His servants*). BPTs-10 (*Transplanting organs without Syar'I or Islamic law justified reason is haram*).

In addition, the respondent's reasoning is also influenced by feelings of sympathy or empathy. Reasoning like this is natural reasoning that considers aspects of risk or safety (Beniermann et al., 2021) or reasoning that prioritizes socio-ethical aspects so that they tend to show more sympathy when it comes to one's life (Pope et al., 2017). We can see this from the reactions of our respondents to the issue of GMOs and organ transplantation, namely BPTs-1 (*I disagree because organ transplantation can endanger a person's life*). BTS-6 (*My reaction to GMOs is that natural plants should not be*

changed because they can affect health), and BPTs-10 (*I disagree because GMOs are also dangerous*). Previous research conducted by Dawson and Carson (2017) in the case of climate change showed that some respondents gave responses based on risk considerations. Topçu et al. (2011) showed that some respondents reacted based on the safety or risk related to cloning issues, that cloning is a dangerous technology. Gardner et al. (2010) added that students' perceptions of the use of nanotechnology are influenced by the effects of nanotechnology products that can interfere with the health and welfare of society. This is in accordance with Kolarova et al. (2013) that some students strongly oppose gene therapy, express their feelings of empathy, such as sadness and anxiety, and offer other options to solve the problem.

Furthermore, the main concern is that our respondents are more dominant in using intuitive and emotions reasoning patterns. Referring to the statement of Han-Tosunoglu and Ozer above regarding rationalistic reasoning, it should be used more dominantly at the university level than other reasoning (intuitive and emotive). In everyday life, we are undoubtedly inseparable from making decisions, and sometimes we make decisions based on intuition, norms or ethics, and even religious beliefs. The decisions we make have to do with rejection and acceptance. Alternatively, in our decisions, whether to reject or accept SSI issues, we sometimes use intuitive reasoning and emotive reasoning patterns. Likewise, with rationalistic reasoning related to acceptance and rejection, only acceptance and rejection from the perspective of rationalistic reasoning are based on evidence (Kolarova et al., 2013).

To make rationalistic reasoning, either rejecting or accepting, the respondent must have good knowledge (Milbourne & Wiebe, 2018; Puig et al., 2020; Wu, 2013). In making decisions or preparing arguments, good knowledge has a vital role. It is also the same as content knowledge, and conceptual understanding deeply affects argument preparation (Puig et al., 2020). It can be understood that knowledge of an issue or problem is needed in making decisions or solving iil-structured and structured problems (Milbourne & Wiebe, 2018). Respondents cannot make good arguments because they do not have good content knowledge. A good understanding of content knowledge influences informal reasoning in the SSI context. Alternatively, respondents who do not have knowledge or understanding of an issue usually tend to base their decisions intuitively or emotionally (Georgiou et al., 2020). NGSS added that science education is an important part of all citizens, so content knowledge is fundamental to understanding aspects of science, including understanding phenomena, and current issues, choosing and using technology, or making decisions (Kahn & Zeidler, 2019).

We know that knowledge plays a very important role in decision making. But on the other hand, it is undeniable that students feel uneasy in solving problems and decision-making processes relating to SSI and real-life contexts. In this case, moral considerations are also very much needed. When facing this condition, it may be more difficult to discuss emotionally charged issues related to rationalistic reasoning. Clore (2011) states that rational thinking is a very important in solving problems or decision-making, but it must also consider ethical and moral aspects.

Furthermore, Grooms et al. (2014) explain that in the context of SSI, students are required to provide sound arguments based on scientific evidence and make decisions. They must also consider non-scientific evidence, such as moral considerations. One of the important aspects of integrating SSI into the learning process is that students are not forced to use their beliefs to assess problems. Still, it

helps them develop open-mindedness and flexibility and integrate rationalistic reasoning with emotive reasoning (Kahn & Zeidler, 2019). Because of this, the emotional or moral aspect is not an obstacle for students to provide rationalistic reasoning regarding the SSI issue. The integration of SSI into the learning process facilitates students to analyze and evaluate various issues or problems rationally using scientific principles. It helps students use moral reasoning by carefully paying attention to ethical issues (Zeidler et al., 2019).

CONCLUSION

Based on the results of the analysis that has been done, the reasoning patterns most used by our respondents are intuitive and emotive reasoning patterns. In addition, in this study, no patterns of integrative reasoning were found. The dominant use of intuitive and emotive reasoning patterns is because our respondents need to learn more about the SSI issues used.

RECOMMENDATION

This research was only conducted on prospective biology teacher students at the Mandalika University of Education. Therefore, these results cannot be applied in general and may differ if carried out at other campuses. Even so, at least the research results emphasize us as lecturers in the biology education department to improve our respondents' rationalistic reasoning abilities. In addition, referring to (Clore, 2011), in giving arguments or making decisions, it is necessary to pay attention to non-rational aspects such as ethics or social norms. So, through integrating SSI into learning, it is hoped that the primary goal of education at the Mandalika University of Education can be realized, namely the formation of character in our respondents, especially in their reasoning patterns, not only focusing on aspects of rationality but also aspects of morality.

In integrating SSI into learning, first, identify issues related to SSI, both global and local. Furthermore, the selection of learning models can accommodate the integration of the SSI. The main characteristic of SSI is to help students understand social issues or problems scientifically. Therefore, the inquiry learning model is a learning model that can accommodate SSI integration. Through the issues related to SSI that have been identified, for further research, we would like to see the ability of our respondents to make decisions regarding SSI.

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Declaration of interests

The researchers declare no conflict of interests.

REFERENCES

Atabey, N., & Topcu, M. S. (2017). The Development of a Socioscientific Issues-Based Curriculum Unit for Middle School Students: Global Warming Issue. *International Journal of Education in Mathematics, Science and Technology*, *5*(3), Article 3. https://doi.org/10.18404/ijemst.296027

Badeo, J. M., & Duque, D. A. (2022). The effect of Socio-Scientific Issues (SSI) in teaching science: A meta-analysis study. *Journal of Technology and Science Education*, *12*(2), 291. https://doi.org/10.3926/jotse.1340

Beniermann, A., Mecklenburg, L., & Upmeier zu Belzen, A. (2021). Reasoning on Controversial Science Issues in Science Education and Science Communication. *Education Sciences*, *11*(9), 522. https://doi.org/10.3390/educsci11090522

Berne, B. (2014). Progression in Ethical Reasoning When Addressing Socio-scientific Issues in Biotechnology. *International Journal of Science Education*, *36*(17), Article 17. https://doi.org/10.1080/09500693.2014.941957

Buzdar, M. A., Ali, A., & Tariq, R. U. H. (2015). Religious orientations as a predictor of rational thinking among secondary school students. *Thinking Skills and Creativity*, *16*, 1–8. https://doi.org/10.1016/j.tsc.2014.11.005

Cebesoy, U. B. (2021). Pre-service Science Teachers' Informal Reasoning Patterns and Risk Perceptions in SSI: Case of Gene Therapy. *European Journal of Science and Mathematics Education*, *9*(4), 211–229. https://doi.org/10.30935/scimath/11237

Chang Rundgren, S.-N. (2011). How does background affect attitudes to socioscientific issues in Taiwan? *Public Understanding of Science (Bristol, England)*, *20*(6), 722–732. https://doi.org/10.1177/0963662509359998

Clarke, V., & Braun, V. (2018). Using thematic analysis in counselling and psychotherapy research: A critical reflection. *Counselling and Psychotherapy Research*, *18*. https://doi.org/10.1002/capr.12165

Clore, G. L. (2011). Psychology and the Rationality of Emotion. *Modern Theology*, *27*(2), 325. https://doi.org/10.1111/j.1468-0025.2010.01679.x

Dawson, V., & Carson, K. (2017). Using climate change scenarios to assess high school students' argumentation skills. *Research in Science & Technological Education*, *35*(1), Article 1. https://doi.org/10.1080/02635143.2016.1174932

Dragoş, V., & Viorel, M. (2015). Scientific Literacy in School. *Procedia - Social and Behavioral Sciences*, *209*, 167–172. https://doi.org/10.1016/j.sbspro.2015.11.273

Foong, C.-C., & Daniel, E. G. S. (2013). Students' Argumentation Skills across Two Socio-Scientific Issues in a Confucian Classroom: Is transfer possible? *International Journal of Science Education*, *35*(14), 2331–2355. https://doi.org/10.1080/09500693.2012.697209

Gardner, G., Jones, G., Taylor, A., Forrester, J., & Robertson, L. (2010). Students' Risk Perceptions of Nanotechnology Applications: Implications for science education. *International Journal of Science Education - INT J SCI EDUC*, *32*, 1951–1969. https://doi.org/10.1080/09500690903331035

Garrecht, C., Eckhardt, M., Höffler, T. N., & Harms, U. (2020). Fostering students' socioscientific decision-making: Exploring the effectiveness of an environmental science competition. *Disciplinary and Interdisciplinary Science Education Research*, *2*(1), 5. https://doi.org/10.1186/s43031-020-00022-7

Georgiou, M., Mavrikaki, E., Halkia, K., & Papassideri, I. (2020). Investigating the Impact of the Duration of Engagement in Socioscientific Issues in Developing Greek Students' Argumentation and Informal Reasoning Skills. *American Journal of Educational Research*, *8*(1), 16–23.

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

Gul, M. D., & Akcay, H. (2020). Structuring a New Socioscientific Issues (SSI) Based Instruction Model: Impacts on Pre-service Science Teachers' (PSTs) Critical Thinking Skills and Dispositions. *International Journal of Research in Education and Science*, *6*(1), Article 1. https://doi.org/10.46328/ijres.v6i1.785

Ha, H., Park, W., & Song, J. (2022). Preservice Elementary Teachers' Socioscientific Reasoning During a Decision-Making Activity in the Context of COVID-19. *Science & Education*. https://doi.org/10.1007/s11191-022-00359-7

Han-Tosunoglu, C., & Ozer, F. (2022). Exploring Pre-service Biology Teachers' Informal Reasoning and Decision-Making About COVID-19. *Science & Education*, *31*(2), Article 2. https://doi.org/10.1007/s11191-021-00272-5

Kahn, S., & Zeidler, D. L. (2016). Using Our Heads and HARTSS*: Developing Perspective-Taking Skills for Socioscientific Reasoning (*Humanities, ARTS, and Social Sciences). *Journal of Science Teacher Education*, *27*(3), Article 3. https://doi.org/10.1007/s10972-016-9458-3

Kahn, S., & Zeidler, D. L. (2019). A Conceptual Analysis of Perspective Taking in Support of Socioscientific Reasoning. *Science & Education*, *28*(6–7), Article 6–7. https://doi.org/10.1007/s11191-019-00044-2

Kara, Y. (2012). Pre-service biology teachers' perceptions on the instruction of socio-scientific issues in the curriculum. *European Journal of Teacher Education*, *35*(1), Article 1. https://doi.org/10.1080/02619768.2011.633999

Karpudewan, M., & Roth, W.-M. (2018). Changes in Primary Students' Informal Reasoning During an Environment-Related Curriculum on Socio-scientific Issues. *International Journal of Science and Mathematics Education*, *16*(3), 401–419. https://doi.org/10.1007/s10763-016-9787-x

Ke, L., Sadler, T. D., Zangori, L., & Friedrichsen, P. J. (2021). Developing and Using Multiple Models to Promote Scientific Literacy in the Context of Socio-Scientific Issues. *Science & Education*, *30*(3), Article 3. https://doi.org/10.1007/s11191-021-00206-1

Khan, Z. N. (2017). Reasoning pattern and personal qualities of successful mathematics teachers. *International Education and Research Journal (IERJ)*, *3*(6), Article 6. http://ierj.in/journal/index.php/ierj/article/view/1086

Kolarova, T., Hadjiali, I., & Denev, I. (2013). High School Students' Reasoning in Making Decisions about Socio-Ethical Issues of Genetic Engineering: Case of Gene Therapy. *Biotechnology & Biotechnological Equipment*, *27*(2), 3737–3747. https://doi.org/10.5504/BBEQ.2012.0133

Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative Research: A Guide to Design and Implementation* (4th edition). John Wiley & Sons.

Milbourne, J., & Wiebe, E. (2018). The Role of Content Knowledge in Ill-Structured Problem Solving for High School Physics Students. *Research in Science Education*, *48*(1), 165–179. https://doi.org/10.1007/s11165-016-9564-4

Morris, H. (2014). Socioscientific Issues and Multidisciplinarity in School Science Textbooks. *International Journal of Science Education*, *36*(7), 1137–1158. https://doi.org/10.1080/09500693.2013.848493

Nida, S., Mustikasari, V. R., & Eilks, I. (2021). Indonesian Pre-Service Science Teachers' Views on Socio-Scientific Issues-Based Science Learning. *Eurasia Journal of*

Mathematics, Science and Technology Education, *17*(1), Article 1. https://doi.org/10.29333/ejmste/9573

Ogunkola, B. J. (2013). Scientific Literacy: Conceptual Overview, Importance and Strategies for Improvement. *Journal of Educational and Social Research*, 3.

Özden, M. (2015). Prospective elementary school teachers' views about socioscientific issues: A concurrent parallel design study. *International Electronic Journal of Elementary Education*, *7*(3), 333–354.

Ozden, M. (2020). Elementary School Students' Informal Reasoning and Its' Quality Regarding Socio-Scientific Issues. *Eurasian Journal of Educational Research*, *20*(86), Article 86. https://doi.org/10.14689/ejer.2020.86.4

Ozturk, N., & Yılmaz-Tüzün, Ö. (2017). Preservice Science Teachers' Epistemological Beliefs and Informal Reasoning Regarding Socioscientific Issues. *Research in Science Education*, *47*(6). https://doi.org/10.1007/s11165-016-9548-4

Pope, T., Dawson, V., & Koul, R. (2017). Effect of Religious Belief on Informal Reasoning about Biotechnology Issues. *Teaching Science*, *63*(2), 27–34.

Presley, M., Sickel, A., Muslu, N., Merle-Johnson, D., Witzig, S., Izci, K., & Sadler, T. (2013). A framework for socio-scientific issues based education. *Science Educator*, *22*(1), 26–32.

Puig, B., Blanco Anaya, P., Gil Quílez, M. J., & Grace, M. (2020). *Biology Education Research. Contemporary topics and directions*. Servicio de Publicaciones Universidad de Zaragoza. https://doi.org/10.26754/uz.978-84-16723-97-3

Rundgren, C.-J., Eriksson, M., & Rundgren, S.-N. C. (2016). Investigating the Intertwinement of Knowledge, Value, and Experience of Upper Secondary Students' Argumentation Concerning Socioscientific Issues. *Science & Education*, *25*(9–10), Article 9–10. https://doi.org/10.1007/s11191-016-9859-x

Sağlam, H. İ., & Eroglu, B. (2022). A Mixed-Method Study on Pre-Service Teachers' Informal Reasoning Regarding Nuclear Energy Use: Research Article. *Journal of Turkish Science Education*, *19*(2), Article 2. https://www.tused.org/index.php/tused/article/view/1321

Susilawati, Aznam, N., Paidi, & Irwanto, I. (2021). Socio-Scientific Issues as a Vehicle to Promote Soft Skills and Environmental Awareness. *Socio-Scientific Issues as a Vehicle to Promote Soft Skills and Environmental Awareness*, *10*(1), 161–174.

Topcu, M. (2010). Development of Attitudes towards Socioscientific Issues Scale for undergraduate students. *Evaluation & Research in Education*, *23*(1), 51–67. https://doi.org/10.1080/09500791003628187

Topcu, M. S., Mugaloglu, E. Z., & Guven, D. (2014). Socioscientific Issues in Science Education: The Case of Turkey. *Educational Sciences: Theory & Practice*. https://doi.org/10.12738/estp.2014.6.2226

Topçu, M. S., Yılmaz-Tüzün, Ö., & Sadler, T. D. (2011). Turkish Preservice Science Teachers' Informal Reasoning Regarding Socioscientific Issues and the Factors Influencing Their Informal Reasoning. *Journal of Science Teacher Education*, *22*(4), Article 4. https://doi.org/10.1007/s10972-010-9221-0

Wu, Y.-T. (2013). University Students' Knowledge Structures and Informal Reasoning on the Use of Genetically Modified Foods: Multidimensional Analyses. *Research in Science Education*, *43*(5), 1873–1890. https://doi.org/10.1007/s11165-012-9343-9

Yen, M.-H., & Wu, Y.-T. (2017). The role of university students' informal reasoning ability and disposition in their engagement and outcomes of online reading

regarding a controversial issue: An eye tracking study. *Computers in Human Behavior*, *75*, 14–24. https://doi.org/10.1016/j.chb.2017.04.054

Zeidler, D., Herman, B. C., & Sadler, T. D. (2019). New directions in socioscientific issues research. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1), Article 1. https://doi.org/10.1186/s43031-019-0008-7