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Fostering Moral Sensitivity through Socioscientific Issues: A Sustainable Approach to 21st Century Science Education

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Abstract

This article sought to give an overview on the use of socio-scientific issues (SSI) to promote moral sensitivity among secondary school students. Through literature review, this article examined the role of SSI in promoting moral sensitivity in order to support the development of holistic citizenry. Given that Malaysian science curriculum has explicitly incorporated socioscientific issues (SSI) into the secondary school syllabus, it is worthwhile to investigate the extent to which students demonstrate moral sensitivity toward SSI. Thus a total of 307 Form Four students from six secondary schools in Negeri Sembilan, Malaysia, were randomly selected to participate in the study. An instrument adapted from Test for Ethical Sensitivity, TESS (Clarkeburn 2002) and TESSplus (Fowler, Zeidler & Sadler 2009) had been used to measure the level of moral sensitivity among students. The findings revealed that the respondents demonstrated a high level of scores in Moral Sensitivity Test across all three SSI presented, namely Genetically Modified Crop Dilemma, Human Cloning Issue and Pharmaceutical Milk and Genetically Modified Cow issue. These results imply that the incorporation of relevant SSI into science education is capable of nurturing students' moral sensitivity.

Keywords: Holistic Education, Values-Based Science Teaching, Holistic Citizenship, Socioscientific Reasoning

Introduction

In the contemporary world of science and technology, societies are confronted with a multitude of complex issues and conflicts that permeate various aspects of human life. To effectively navigate these challenges, individuals must be equipped with adequate levels of scientific literacy to guide their decision-making. However, numerous reports and empirical studies have shown that students' levels of scientific literacy remain below expectations. For instance, Malaysia's performance in the Programme for International Student Assessment (PISA) from 2009 to 2015 revealed students' limited ability to apply scientific concepts to real-life contexts (Mohamad Hisyam & Muhamad Furkan, 2017). Similarly, the 2018 PISA assessment conducted by the Organisation for Economic Co-operation and Development (OECD) reported that Malaysian students achieved an average score of only 438 points in scientific literacy, significantly lower than the OECD average of 489. A review of the literature indicates that one of the key indicators of achieving scientific literacy is the ability to construct sound and reasoned justifications concerning socioscientific issues (Bosser, 2017; Cebesoy, 2021; Nguyen & Catalan-Matamoros, 2020). Consequently, a growing body of research has highlighted the importance of integrating socioscientific issues (SSI) into science education as a pedagogical approach to enhance students' scientific literacy and foster their critical reasoning skills (Cummings, 2017; Davisson, 2019; Suwono et al., 2017; Zangouri et al., 2018).

In general, socioscientific issues can be defined as issues that encompass both scientific, technology and social dimensions as inseparable aspects of an issue. Such issues are open-ended, lack of straightforward solutions and are often controversial from political, economic, ethical, cultural, and religious perspectives (Ali & Abdullah Aydin, 2018; Nguyen & Catalan -Matamaros, 2020; Steward, McConnell, & Dickerson, 2017). The use of socioscientific issues as teaching and learning tool not only able to enriches students' knowledge across various disciplines but also could foster critical thinking, problem-solving skills, and communication abilities (Geopany, Hernawati, & Meylani, 2021; Herman et al., 2019). Therefore, as a country with an aspiration to advance not only in science and technology but also to nurture citizens with well-rounded competencies, the use of socioscientific issues in classroom activities is the right choice (S. Alcaraz-Dominguez, M. Barajas 2021; Jackson et al. 2023)

A review of literature suggest the use of moral values as a scaffold to strengthen students' socioscientific reasoning, and subsequently to enhance scientific literacy (Chang Rundgren, Eriksson & Rundgren, 2016; Klaver et al., 2022). Thus insights into this relationship are essential to guide our stakeholders in cultivating both scientific understanding and moral awareness among school children. Several theoretical models have been proposed to guide the integration of SSIs and moral values into teaching and learning practices. These include the *Pedagogical Model for Ethical Inquiry in Socioscientific Issues* (Saunders & Rennie, 2013), the *Model of Moral Appreciation in the Context of Socioscientific Issues* (Fowler, Zeidler & Sadler, 2009), the *Four-Component Model of Morality* (Narvaez & Rest, 1995), and the *Theory of Moral Perception* (Blum, 1994).

In Malaysia, the Ministry of Education has made concerted efforts to promote scientific literacy through the integration of socioscientific issues (SSI) into the *Kurikulum Standard Sekolah Menengah* (KSSM). This initiative reflects an educational shift towards developing students who are not only scientifically knowledgeable but also capable of

applying their understanding to real-world problems that encompass ethical and social considerations. SSI-based instruction is intended to help students connect scientific knowledge with contemporary societal issues such as environmental degradation, biotechnology, and sustainable development, thereby nurturing informed and responsible decision-making.

However, the effectiveness of this curricular approach remains inconclusive. Empirical research examining how SSI integration influences students' scientific literacy in the Malaysian context is still scarce. While the curriculum explicitly promotes inquiry and argumentation through SSI, there is limited evidence demonstrating measurable improvements in students' ability to reason scientifically, justify claims, or apply moral considerations when addressing complex issues. Moral values such as justice, empathy, and social responsibility are regarded as a critical indicator of authentic scientific literacy. Students may possess conceptual knowledge of science yet struggle to apply it ethically or to recognise the broader implications of their choices for society and the environment. This disconnect suggests that scientific literacy cannot be deemed fully achieved without the integration of moral sensitivity and ethical reasoning.

Addressing these gaps requires systematic empirical investigation into how SSI-based pedagogies shape students' cognitive and moral engagement with science. Such research would clarify the relationship between SSI instruction, scientific literacy, and moral development, particularly within Malaysia's sociocultural and educational context. Insights from these studies could inform the refinement of curriculum design, teacher professional development, and classroom practices, ultimately contributing to the formation of scientifically literate citizens who are ethically conscious and capable of responding to the multifaceted socioscientific challenges of the twenty-first century.

The Four Component Model of Morality

The Four Component Model of Morality is a theoretical framework developed by Rest (1986) and later refined by Narvaez and Rest (1995) to guide scholars with their research regarding moral issues. This model proposes four psychological components that contribute to moral behavior, that are; moral sensitivity, moral reasoning, moral commitment, and moral perseverance. According to this model, cognitive and affective (emotional) processes are indicated to be distinct yet interrelated. Narvaez and Rest (1995) argued that affective processes play an important role as a bridge in the transmission of information across components. Therefore, affective processes exert a direct influence in determining which component is the most strongly shape moral reasoning. These findings are consistent with those stated in literature, such as by Jamaluddin, Azizan and Wan Zailan (2017), Westbrook and Breiner (2019), Airen Suraya et al. (2021) and Cian (2019).

Moral sensitivity constitutes the first component of the Four Component Model. It refers to an individual's ability to interpret others' reactions and emotions. This includes the capacity to recognize the presence of few alternatives when choosing an action, driven by an awareness of the potential consequences that may arise from each choice. Individuals with moral sensitivity understand that any decision made can result in a chain of cause and effect, impacting not only the decision-maker but also others. Moral sensitivity requires moral imagination, enabling individuals to construct possible scenarios and develop action plans

after taking into account both the positive and negative consequences these actions may have on the decision-maker and others (Saunders and Rennie, 2013).

Moral sensitivity is also a blend of cognitive information processing and emotion, involving aspects such as moral perception, moral imagination, and empathy (Narvaez & Vaydich, 2008). This process includes understanding who is involved and affected, recognizing who cares about the situation, empathizing with those impacted, and feeling responsible for resolving the issue. Furthermore, moral sensitivity encompasses awareness of how potential courses of action could affect others. A morally sensitive person is capable of envisioning various potential risks resulting from their actions. This ability stems from a capacity to think through cause-and-effect relationships when any desicion is made (Narvaez, 1996).

Moral sensitivity is deeply embedded in the human brain and develops naturally alongside emotions, memory, and behavior. It is highly responsive to feedback from others (Narvaez & Vaydich, 2008). This sometimes results in individuals overreacting to others' responses, which can lead to adverse outcomes. In this regard in certain situations, moral ambiguity may arise where there are no clear lines demarcating right from wrong. Nevertheless, individuals with high moral sensitivity would not only capable of making accurate moral judgments but also able to possess social intelligence about what is happening, and able to anticipate how others may be affected, thus know how to respond appropriately (Curzer, 2014).

Among the four components of morality, moral sensitivity is considered the most fundamental prerequisite for engaging in moral reasoning (Clarkeburn, 2002; Fowler, Zeidler & Sadler, 2009). According to Fowler, Zeidler, and Sadler (2009), this is due to the ability of an individual to recognize that a particular socioscientific issue requires moral discernment rather than merely a scientific or technical solution. Possessing moral sensitivity enables individuals to consider the potential risks or harm that others may face as a result of a given action, thereby allowing them to explore alternative solutions that minimize or avoid such harm. While it is widely acknowledged that formal moral education does not always influence moral sensitivity, studies have shown that certain instructional approaches using socioscientific issues as teaching and learning tool able to cultivate moral sensitivity effectively (Bebeau, 2002; Fowler, Zeidler & Sadler, 2009).

Socioscientific Issues as a Tool to Promote Moral Sensitivity

The 21st century is marked by rapid advancements in science and technology, presenting complex challenges that impact life and the environment in multifaceted ways. These developments necessitate a shift in science education, from viewing science as an isolated discipline to integrating it within broader societal contexts. Therefore students must be equipped to solve real-world problems so that they will be able to function as scientifically literate and responsible citizens (Roberts & Bybee, 2014).

The use of socioscientific issues (SSIs) as a pedagogical strategy for fostering scientific literacy has gained significant traction (Cian, 2019; Cummings, 2017; Roberts & Bybee, 2014). A distinguishing feature of SSIs is their requirement for moral consideration during the reasoning process (Van der Leij et al., 2022; Westbrook & Breiner, 2019). SSI-based learning encourages both individual and collaborative engagement, enabling students to meet

curricular objectives. For instance, classroom discussions on the causes of global warming may not yield definitive solutions, but they raise students' awareness of environmental responsibility by connecting scientific knowledge to societal concerns (Klosterman, Sadler & Brown, 2011).

Moral considerations involve affective domains and attitudes, which are influenced by socio-cultural backgrounds, including religious beliefs, cultural norms and institutional contexts (Cian, 2019; Airen, Piang & Noor Banu, 2021; Westbrook & Breiner, 2019). The more controversial a SSI is, the greater the need for moral reasoning. Without moral reasoning, scientific literacy loses its holistic dimension. Numerous studies show that moral factors are integral to achieving genuine scientific literacy (Cian 2019; Ozturk & Yilmaz-Tuzun 2017). Researchers indicate that students often reason through SSIs based on their values, especially when lacking clear scientific evidence (Christenson, Rundgren & Zeidler, 2014). It is also found that students with lower levels of moral sensitivity tend to face greater challenges in socioscientific reasoning (Chang Rundgren et al., 2016; Ozturk & Yilmaz-Tüzün, 2017). Compared to other constructs, moral sensitivity emerges as a significant predictor of SSI reasoning (Cian, 2019; Hyunju Lee et al., 2013; Powell, 2014).

Research Objective

This study focuses on one of nine objectives outlined in a more comprehensive and in-depth research regarding the development of socioscientific reasoning among Malaysian students. In this paper, the researchers aimed to determine the level of moral sensitivity of Form Four students concerning three socioscientific issues adapted from TESS (Clarkburn 2002) and TESSplus (Fowler, Zeidler & Sadler 2009*)* instruments.

Sample and Sampling Procedure

This study employed a deductive research approach, which offers a systematic and structured method for generating knowledge aimed at addressing both theoretical and practical problems. A cross-sectional research design was adopted, enabling the integration of literature review with real-world data collection. A total of 307 Form Four students (66.1% male, 33.9% female) participated in the study. A cluster random sampling method was employed due to its appropriateness for the population studied. Using this method, six out of eight boarding schools (SBP) in the state of Negeri Sembilan were randomly selected. The researchers then collected data from the subsets of these selected schools, thus ensuring that the sample was randomly drawn and representative of the broader population. This sampling strategy enhances the generalizability of the findings (Creswell, 2014).

The sample size was deemed adequate based on the guidelines proposed by Krejcie and Morgan (1970), who suggested that for a population size ranging between 1,000 to 1,100 individuals, a sample of approximately 278–285 participants is sufficient. In this study, 307 participants were selected from a population of 1,021 Form Four students across the selected SBPs in Negeri Sembilan, which slightly exceed the recommended sample size. This surplus was intentional, serving as a precautionary measure to account for potential participant attrition or withdrawal during the study.

To ensure ethical integrity, participants were not required to disclose their names or any personally identifiable information. Confidentiality and anonymity were strictly

maintained throughout the research process. Moreover, all participants and the institutions involved were safeguarded from any physical, psychological, or legal harm in accordance with established ethical research standards.

Instrument Development, Validity, and Reliability

The measurement instrument used in this study were adapted from established sources, as detailed in Table 1. The questionnaire was structured into three sections. The first section introduced the purpose of the study and provided an assurance of confidentiality. The second section collected demographic information. The third section consisted of Moral Sensitivity Test as shown in Table 1. To ensure content validity, five subject matter experts were consulted to review and evaluate the questionnaire items. Revisions were made in accordance with their feedback. Subsequently, SPSS version 25 was used to assess the construct reliability of the instruments (see Table 1).

Table 1
Measurement Instrument, Validation Procedures, and Reliability Results

Instrument Used	Moral Sensitivity Test
Source	Test for Ethical Sensitivity in Science (TESS) (Clarkeburn, 2002) and TESSplus (Fowler et al., 2009)
Question Type	3 open-ended questions based on 3 socioscientific issues
Validation Procedure	Reviewed and supported by 5 experts
Reliability	Spearman's Rho = 0.993 (Very Good) (Cohen, 2000)

The three socioscientific issues as suggested by Clarkburn (2002) and Fowler et al. (2009) are as follows:

Issue 1: **Genetically Modified Crop Dilemma**
(*Adapted from Clarkeburn, 2002*)
A group of researchers is currently considering the development of a novel genetically engineered plant through the use of plant viruses. These viruses would undergo genetic modification using advanced biotechnological techniques. The aim is to ensure that, upon infecting the host plant, the virus would trigger the plant tissues to produce a specific protective protein. The researchers anticipate that the resulting protein could serve as a vital supplementary nutrient for humans, potentially enhancing immune system function.
To this end, the research team has conducted extensive studies on more than 900 plant viruses. All of the viruses selected for study are known to be plant pathogens, with no documented adverse effects on the human digestive system, nor have they been shown to pose any risks to individuals handling them. The ultimate goal of the project is to make this genetically modified plant available to developing countries as a potential solution to nutritional deficiencies and related health challenges.

Question
In your opinion, should this research be continued? Provide at least three justifications to support your stance.

Issue 2
Human Cloning
(*Adapted from Fowler et al. 2009*)
In today's world, many couples face infertility and are unable to conceive children. While advancements in reproductive technologies (such as fertility drugs and in-vitro fertilization, IVF) have enabled some couples to have biological offspring, others remain unsuccessful despite these interventions. For such couples, cloning procedures may be considered as an alternative path to parenthood.
Through cloning, the genetic material from one of the parents (either the mother or the father) is extracted and inserted into an egg cell. This egg cell, now containing the genetic material from only one parent, develops into an embryo. The embryo is then implanted into the mother's womb, where it can grow into a fetus and eventually be delivered as a baby. (Note: Cloning is fundamentally different from in-vitro fertilization (IVF). In cloning, the resulting child does not inherit genetic material from both parents; instead, the child carries the genetic information of only one biological parent.)
Question:
In your opinion, should this line of research be continued? Provide at least three justifications to support your answer.

Issue 3: Pharmaceutical Milk and Genetically Modified Cows
(*Adapted from Clarkeburn, 2002*)
Cystic fibrosis is a hereditary genetic disorder that severely impairs the respiratory and digestive systems. A group of researchers is developing a genetically modified breed of cows capable of producing a special milk protein intended to treat this condition. To achieve this, genetic material (DNA) from another non-bovine species will be inserted into bovine DNA through nuclear transfer techniques. The resulting genetically modified cells will then be used in a cloning process to produce a new breed of cows that secrete pharmaceutical-grade milk containing the therapeutic protein.
Despite numerous previous attempts, scientists have not yet discovered a fully effective or affordable treatment for cystic fibrosis. Current treatments are either inadequate or extremely costly. Should this project succeed, the research team stands to gain both significant recognition and substantial financial rewards from commercializing such a breakthrough product.
Question:
In your opinion, should this research be pursued? Provide at least three considerations to justify your response.

Result and Discussion
A total of 307 students responded to the Moral Sensitivity Test instrument. Students' responses were evaluated using the scoring rubric developed by the original creator of the instrument, Clarkeburn (2002), which had undergone expert validation procedures. Students were required to articulate the considerations they employed in resolving the issues presented. Those who successfully articulated both well-reasoned and comprehensive moral

and scientific considerations were awarded higher scores compared to students whose reasoning was grounded solely in scientific rationales.

In summary, the scoring guidelines adapted from Clarkeburn (2002) are as follows:

1. For each student's response, a score ranging from 0 to 3 points is assigned in accordance with Clarkeburn's (2002) protocol, as illustrated in Table 2.
2. If more than one response conveyed the same consideration but is phrased differently, only the more complete statement will be evaluated.
3. If the researcher is uncertain about assigning a response to a particular category, it will be placed at the lower level.

Table 2
Example of scoring rubric for the Moral Sensitivity Test

Response score	**Guidelines**	**Example of student response**
0	The response considered only scientific or other non-moral aspects, without addressing moral considerations at all.	"How does genetic modification affect the cow's original genetics?" "What is the genetic origin?"
1	States a low-level moral consideration that has the potential to lead to higher-level reasoning, but the latter is not clearly articulated.	"What are the side effects of genetic modification on cows?" "Is the nuclear transfer technique safe?"
2	Demonstrates a clearer understanding of the risks involved, with moral elements explicitly stated.	"Wouldn't the cow suffer in producing genetically modified milk?" "Animals should not be subjected to suffering or stress in the process of producing genetically modified milk."
3	Reflects maturity and confidence in recognising the presence of a moral issue in the scenario, with moral considerations clearly articulated.	"For how much longer must animals continue to suffer so that humans can enjoy the profit?"

(Source: Adapted from Clarkeburn, 2002)

The analysis of mean scores across the three issues, as presented in Table 3, indicates that the participants demonstrated a high level of moral sensitivity.

Table 3
Mean scores for students' moral sensitivity across tested issues

No.	**Issue**	**Mean (%)**	**Standard Deviation**	**Level**
1	Genetically Modified Crops	84.60	10.00	High
2	Human Cloning	83.06	10.04	High
3	Pharmaceutical Milk and Genetically Modified Cow	82.85	12.34	High
	Overall Mean	**83.50**	**10.17**	High

As shown in Table 3, the highest mean score for moral sensitivity was recorded in the issue concerning *Genetically Modified Crops*, with a score of 84.60% (SD = 10.00), which is interpreted as high level. This was followed by the *Human Cloning* issue, with a mean score of 83.06% (SD = 10.04), classified also at high level. The lowest mean score was observed in

the issue of *Pharmaceutical Milk and Genetically Modified Cow*, with 82.85% (SD = 12.34), also interpreted as high level. Overall, the average moral sensitivity score across all three issues was 83.50% (SD = 10.17), which reflects a high level of moral sensitivity among the participants.

From Table 3 it can be concluded that students demonstrated the highest mean level of moral sensitivity toward the issue of *Genetically Modified Crops*, whereas the issue of *Pharmaceutical Milk and Genetically Modified Cow* yielded the lowest mean score but still at high level category. These results are in line with the body of literature that highlights the critical role of emotions and moral values in shaping students' socioscientific reasoning processes (Cian, 2019; Fowler et al., 2009; Lee et al., 2013; Rundgren & Rundgren, 2010; Van der Veij et al., 2023; Westbrook, 2019).

In explaining the differences in mean values of Moral Sensitivity among individuals, Chang Rundgren and Rundgren (2010) and Nielson (2012) argue that factors such as culture, values, and emotions play a crucial role in shaping how individuals respond to particular issues. According to Villarin and Fowler (2019) and Van der Leij et al. (2023), students tend to demonstrate higher moral sensitivity when the issue presented feels closely related to their daily lives. This perspective may explain why the issue of Genetically Modified Crops received the highest mean value in moral sensitivity. In this scenario, a group of scientists was portrayed as planning to genetically engineer plants by introducing a virus to alter their genetic structure. This approach aimed to produce a type of protein that could serve as a protective agent for humans against diseases.

The students' elevated moral sensitivity towards this issue may be attributed to its perceived proximity to their lived experience. The Genetically Modified Crops issue revolves around the use of genetically modified viruses injected into plants to produce protective proteins. This issue bears a resemblance to the processes widely discussed during the development of vaccines amidst the COVID-19 pandemic, which was ongoing at the time this data were collected in 2020. During that period, public discourse was heavily influenced by controversy surrounding vaccine safety, accompanied by speculations involving pharmaceutical hidden agendas and biological warfare. Consequently, this issue likely felt more relevant and comprehensible to students, thus eliciting a higher level of moral sensitivity.

The issue of Human Cloning recorded the second-highest mean value of moral sensitivity, surpassing that of the Pharmaceutical Milk and Genetically Modified Cow issues. According to Sadler (2004), individuals are generally more inclined to engage with issues concerning human welfare than those involving the welfare of animals or plants. In the Pharmaceutical Milk and Genetically Modified Cow scenario, the moral question posed was whether it is ethically justifiable to use cows as experimental subjects in order to produce genetically modified milk for treating human diseases. Students may not have perceived this as a significant moral issue, possibly due to the commonly held view that the use of animals for human benefit is acceptable. In contrast, human cloning is seen as more controversial, complex, and fraught with moral conflict, particularly because it involves the creation of a child using only the genetic material of one parent. Such practices may be perceived as

unnatural and in conflict with traditional norms, especially within Eastern societies that adhere closely to Islamic teachings concerning lineage and moral boundaries.

Conclusion

This study addresses the urgent need to strengthen students' scientific literacy in Malaysia, particularly their ability to reason through complex socioscientific issues (SSIs) with both scientific and moral considerations. Despite curricular reforms embedding SSIs within the Malaysian science syllabus, national and international assessments such as PISA consistently reveal students' limited capacity to apply scientific knowledge to real-world contexts. The integration of SSIs into teaching is widely recognised for enhancing critical thinking, problem-solving, and communication skills, but its potential to cultivate moral sensitivity are still not explored widely in Malaysian context.

Moral sensitivity, as conceptualised in the Four Component Model of Morality, involves recognising the moral dimensions of a situation, anticipating the consequences of one's actions on others, and empathising with those affected. Previous research highlights moral sensitivity as a key predictor of students' ability to navigate SSIs effectively, especially when issues lack definitive scientific solutions and require value-based judgment. In this light, evaluating students' moral sensitivity offers a more holistic measure of scientific literacy than conventional examinations, which typically overlook affective and ethical dimensions.

This research is significant for several reasons. First, it empirically investigates moral sensitivity among Malaysian secondary students using validated instruments (TESS and TESSplus), thus filling a notable gap in the literature. The findings reveal a generally high level of moral sensitivity, with variations across different SSIs, suggesting that the nature and perceived relevance of an issue influence students' moral engagement. For example, Genetically Modified Crops Issue elicited the highest sensitivity, possibly due to parallels with vaccine-related public debates during the COVID-19 pandemic, whereas animal-related issues were met with comparatively lower moral concern. This reinforces the idea that cultural context, lived experience, and socio-emotional factors significantly shape students' moral reasoning.

Second, the study provides evidence-based insights for educators and policymakers on the importance of explicitly integrating moral dimensions into SSI-based instruction. Given that moral sensitivity underpins ethical reasoning and informed decision-making, strengthening this capacity in students contributes to the formation of scientifically literate citizens who are not only knowledgeable but also socially responsible. The research underscores that fostering moral awareness is not an optional supplement to science education but an integral component for preparing learners to address controversial, multidimensional challenges in an increasingly interconnected world.

Finally, the study's methodological contribution lies in demonstrating the feasibility of assessing moral sensitivity in school settings using open-ended, context-specific SSI scenarios. This approach moves beyond traditional assessment models, offering a more nuanced understanding of students' reasoning processes. By linking moral sensitivity to socioscientific reasoning, this work lays the groundwork for further research and pedagogical innovation

aimed at developing ethically conscious, critically engaged, and scientifically competent future citizens.

References

Airen Surayya Khairu Anuar, Tan, B. P., & Noor Banu Mahadir Naidu. (2021). Sensitiviti moral melalui interaksi pelajar pelbagai budaya. *Muallim Journal of Social Sciences and Humanities, 5*(2), 41–56. https://doi.org/10.33306/mjssh/125

Albe, V. (2008). Students' positions and considerations of scientific evidence about a controversial socioscientific issue. *Science & Education, 17*(8–9), 805–827. https://doi.org/10.1007/s11191-007-9086-6

Alcaraz-Dominguez, S., & Barajas, M. (2021). Conceptualization of socioscientific issues in educational practice from a review of research in science education. *International Journal of Information and Education Technology, 11*(6), 280–286. https://doi.org/10.18178/ijiet.2021.11.6.1521

Bebeau, M. J., Rest, J. R., & Yamoor, C. M. (1985). Measuring dental students' ethical sensitivity. *Journal of Dental Education, 49*(4), 225–235. https://doi.org/10.1002/j.0022-0337.1985.49.4.tb01804.

Bell, R. L., & Lederman, N. G. (2003). Understandings of the nature of science and decision making on science and technology based issues. *Science Education, 87*(3), 352–377. https://doi.org/10.1002/sce.10063

Blum, L. A. (1994). *Moral perception and particularity*. Cambridge University Press. https://doi.org/10.1017/CBO9780511624994

Bosser, U. (2018). *Exploring the complexities of integrating socioscientific issues in science teaching* (Doctoral dissertation, Linnaeus University). Linnaeus University Press.

Carter, L. (2008). Sociocultural influences on science education: Innovation for contemporary times. *Science Education, 92*(1), 165–181. https://doi.org/10.1002/sce.20259

Chang, S. N., Chang, Y. Y., & Tseng, Y. C. (2010). Trends of science education research: An automatic content analysis. *Journal of Science Education and Technology, 19*(4), 315–331. https://doi.org/10.1007/s10956-009-9202-2

Choi, K., Lee, H., Shin, N., Kim, S. W., & Krajcik, J. (2011). Re-conceptualization of scientific literacy in South Korea for the 21st century. *Journal of Research in Science Teaching, 48*(6), 670–697. https://doi.org/10.1002/tea.20424

Christenson, N., Rundgren, S. N. C., & Höglund, H. O. (2012). Using the SEE-SEP model to analyze upper secondary students' use of supporting reasons in arguing socioscientific issues. *Journal of Science Education and Technology, 21*(3), 342–352. https://doi.org/10.1007/s10956-011-9328

Çimer, A., Uşak, M., & Yurdatapan, M. (2014). Students' conceptions of the nature of science: A study of educational reform in Turkey. *Research in Science & Technological Education, 32*(3), 300–323. https://doi.org/10.1080/02635143.2014.944493

Demiral, U., & Türkmen, L. (2008). The effect of constructivist science teaching on 4th grade primary school students' understanding of the nature of science. *Elementary Education Online, 7*(3), 716–733. http://ilkogretim-online.org.tr

Eastwood, J. L., Sadler, T. D., Zeidler, D. L., Lewis, A., Amiri, L., & Applebaum, S. (2012). Contextualizing nature of science instruction in socioscientific issues. *International Journal of Science Education, 34*(15), 2289–2315. https://doi.org/10.1080/09500693.2012.667582

Erduran, S., & Dagher, Z. R. (2014). *Reconceptualizing the nature of science for science education: Scientific knowledge, practices and other family categories*. Springer. https://doi.org/10.1007/978-94-017-9057-4

Fowler, S. R., & Zeidler, D. L. (2016). Lack of evolution acceptance inhibits students' negotiation of biology-based socioscientific issues. *Journal of Biological Education, 50*(4), 407–424. https://doi.org/10.1080/00219266.2015.1100648

Grace, M. M., & Ratcliffe, M. (2002). The science and values that young people draw upon to make decisions about biological conservation issues. *International Journal of Science Education, 24*(11), 1157–1169. https://doi.org/10.1080/09500690210134848

Herman, B. C., Zeidler, D. L., & Newton, M. (2019). Students' emotive reasoning through place-based environmental socioscientific issues. *Research in Science Education, 50*(6), 2401–2429. https://doi.org/10.1007/s11165-018-9774-5

Herman, B. C., Zeidler, D. L., & Newton, M. (2020). Students' emotions in socioscientific issues based environments. *Journal of Research in Science Teaching, 57*(9), 1271–1306. https://doi.org/10.1002/tea.21655

Khishfe, R. (2012). Nature of science and decision-making. *International Journal of Science Education, 34*(1), 67–100. https://doi.org/10.1080/09500693.2011.559490

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

Khishfe, R. (2015). A measure of the sophistication of high school students' nature of science conceptions. *International Journal of Science Education, 37*(2), 232–261. https://doi.org/10.1080/09500693.2014.976157

Khishfe, R., & Lederman, N. G. (2006). Teaching nature of science within a controversial topic: Integrated versus nonintegrated. *Journal of Research in Science Teaching, 43*(4), 395–418. https://doi.org/10.1002/tea.20137

Klaver, L. T., Walma van der Molen, J. H., Sins, P. H. M., & Guérin, L. J. F. (2023). Students' engagement with socioscientific issues: Use of sources of knowledge and attitudes. *Journal of Research in Science Teaching, 60*(5), 1125–1161. https://doi.org/10.1002/tea.21828

Klosterman, M. L., Sadler, T. D., & Brown, J. (2012). Science teachers' use of mass media to address socioscientific and sustainability issues. *Research in Science Education, 42*(1), 51–74. https://doi.org/10.1007/s11165-010-9196-8

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement, 30*(3), 607–610. https://doi.org/10.1177/001316447003000308

Kutluca, A. Y., & Aydin, A. (2018). Pre-service science teachers' nature of science understandings' influence on their socioscientific argumentation quality. *Elementary Education Online, 17*(2), 642–657. https://doi.org/10.17051/ilkonline.2018.419302

Leij, T. van der, Avraamidou, L., Wals, A., & Goedhart, M. (2022). Supporting secondary students' morality development in science education. *Studies in Science Education, 58*(2), 141–181. https://doi.org/10.1080/03057267.2021.1895906

Mohamad Hisyam Ismail, & Muhamad Furkan Mat Salleh. (2017). Malaysian education plan 2013–2025: Transformation on science classroom towards students' achievement in TIMSS and PISA. *The Social Sciences, 12*(1), 6–12.

Narvaez, D., & Rest, J. (1995). The four components of acting morally. In W. Kurtines & J. Gewirtz (Eds.), *Moral behavior and moral development: An introduction* (pp. 385–400). McGraw-Hill.

Narvaez, D., & Vaydich, J. L. (2008). Moral development and behavior under the spotlight of the neurobiological sciences. *Journal of Moral Education, 37*(3), 289–312. https://doi.org/10.1080/03057240802009578

Nguyen, A., & Catalan-Matamoros, D. (2020). Digital misinformation and public engagement with health and science controversies: Fresh perspectives from COVID-19. *Media and Communication, 8*(2), 323–328. https://doi.org/10.17645/mac.v8i2.3352

Nielsen, J. A. (2012). Science in discussions: An analysis of the use of science content in socioscientific discussions. *Science Education, 96*(3), 428–456. https://doi.org/10.1002/sce.21001

OECD. (2018). *PISA 2015 assessment and analytical framework: Science, reading, mathematic and financial literacy*. OECD Publishing. https://doi.org/10.1787/9789264281820

Ozturk, N., & Yilmaz-Tuzun, O. (2017). Preservice science teachers' epistemological beliefs and informal reasoning regarding socioscientific issues. *Research in Science Education, 47*(6), 1275–1304. https://doi.org/10.1007/s11165-016-9548-4

Powell, W. A. (2014). The effects of emotive reasoning on secondary school students' decision-making in the context of socioscientific issues (Doctoral dissertation, University of South Florida). *ProQuest Dissertations Publishing*.

Rest, J. R. (1986). *Moral development: Advances in research and theory*. Praeger.

Rest, J. R., Narvaez, D., Bebeau, M. J., & Thoma, S. J. (1999). A neo-Kohlbergian approach to morality research. *Journal of Moral Education, 29*(4), 381–395. https://doi.org/10.1080/03057240050293734

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. 2, pp. 545–558). Routledge.

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), 1049–1071. https://doi.org/10.1007/s11191-016-9859

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching, 41*(5), 513–536. https://doi.org/10.1002/tea.20009

Stewart, C. O., John, R. O., McConnell, & Dickerson, D. L. (2017). Socioscientific and epistemic dimensions of support for science: Associations with science education and religiosity. *International Journal of Science Education, 39*(11), 1421–1443. https://doi.org/10.1080/09500693.2017.1330577

Suwono, H., Rizkita, L., & Susilo, H. (2017). Peningkatan literasi saintifik siswa SMA melalui pembelajaran biologi berbasis masalah sosiosains. *Jurnal Ilmu Pendidikan, 21*(2), 136–144. https://doi.org/10.17977/jip.v21i2.8332

Van der Leij, T., Goedhart, M., Avraamidou, L., & Wals, A. (2023). Designing a module for supporting secondary biology students' morality through socioscientific issues in the human–nature context. *Journal of Biological Education*. Advance online publication. https://doi.org/10.1080/00219266.2023.2174160

Villarín, L. J., & Fowler, S. (2019). Socioscientific issues to promote content knowledge and socioscientific reasoning in Puerto Rican high school students. *The American Biology Teacher, 81*(5), 328–332. https://doi.org/10.1525/abt.2019.81.5.328

Westbrook, E. G., & Breiner, J. M. (2019). A case study of the development of moral sensitivity in preservice science teachers as the result of exposure to unintegrated and integrated socioscientific issues. *Journal for Research and Practice in College Teaching, 4*(1), 67–83.

Zangori, L., Foulk, J., Sadler, T. D., & Peel, A. (2018). Exploring elementary teachers' perceptions and characterizations of model-oriented issue-based teaching. *Journal of Science Teacher Education, 29*(7), 555–577. https://doi.org/10.1080/1046560X.2018.1469181