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The Influence of Science Knowledge and Moral Sensitivity on Socioscientific Reasoning among form Four Students

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Abstract

Socioscientific reasoning is a process of making scientific judgments along with moral justification involving issues in science and society. This study aims to identify the level of Science Knowledge, Moral Sensitivity and Socioscientific Reasoning of secondary school students using Statistical Packages for Social Sciences 25.0 (SPSS) software. It also aims to identify the influence of Science Knowledge and Moral Sensitivity on Socioscientific Reasoning. Partial Least Squares Structural Equation Modeling (PLS SEM) technique is applied using SmartPLS 4.0 software. A total of 307 Form Four students from boarding school (Sekolah Berasrama Penuh, SBP) in Negeri Sembilan had been randomly selected to answer a survey consisting of four sections, namely demography section, a multiple-choice Science Knowledge test, a short structured Moral Sensitivity test and a multiple choice Socioscientific Reasoning test. The findings of the study show that students' Science Knowledge and Socioscientific Reasoning are at a moderate level while Moral Sensitivity level is high. PLS SEM structural equation model analysis shows that Science Knowledge influence Socioscientific Reasoning the most whereas Moral Sensitivity shows weak influence towards Socioscientific Reasoning. The findings of this study implies that teachers in schools should discuss socioscientific issues not only from scientific perspective but also in a more holistic way by including moral value aspect. This move is crucial in order to promote science literacy so that students will be able to apply their science knowledge to solve problems in daily lives.

Keywords: Science Literacy, Meaningful Learning, Cultural Responsive Pedagogy, Moral Value.

Introduction

Humanity of 21st century is facing crucial challenges in creating a sustainable future. Inevitably these challenges are value-laden and require science literacy to entail the ability of evaluating, negotiating, reasoning and making decisions regarding complex social issues with theoretical and conceptual links to science (Westbrook, 2019). These social issues such as global climate change, genetic engineering and many modern health care issues with scientific links are termed socioscientific issues.

In the recent decades many researchers suggest the use of socioscientific issues as an effective way for promoting learning aligned with science literacy goals, especially engaging in scientific practices for solving problems and negotiating complex societal issues (Li Ke et al., 2021; Zeidler, 2014). A construct named socioscientific reasoning (SSR) has been developed as an educational tool for teachers and researchers to evaluate student thinking practices as they work to resolve complex socioscientific issues. Many researchers claimed that SSR promotes exploration of reasoning processes in socioscientific contexts and provides vast explanation of the scientific information already learned in science education (Kinslow et al. 2019; Karahan & Roehrig, 2017).

It has been argued that socioscientific issues engaged students with relevant context of societal issues influenced by scientific phenomena, in which the students apply evidence-based science content knowledge to resolve real world socioscientific dilemmas (Nguyen & Matamoros, 2020). Previous studies have primarily reported that the use of socioscientific issues in science teaching and the discussion of controversial issues posit positive effect on students' science learning and SSR (Al-Maskari et al., 2022; Nguyen & Matamoros, 2020; Li Ke et al., 2021). However, despite the vast number of empirical evidence collected around the globe, not many study found in Malaysia concerning the factors that influence socioscientific reasoning among students. This information is important because socioscientific reasoning skill helps students to use science knowledge in the larger social contexts or in other words, promotes science literacy. In addition, before our teachers can use socioscientific issues in science teaching in the classroom, we need to determine to what extent our students can reason the science related issues they experienced in daily life. Since socioscientific issues are value-laden, we also need to determine whether students' moral value influence their socioscientific reasoning.

Therefore this study aims to identify the level of science knowledge, moral sensitivity and socioscientific reasoning among Form Four boarding school students (SBP). Moreover we tend to identify is there a direct relationship between scientific knowledge and socioscientific reasoning and we need to determine the strength of the relationship. This study also attempts to explore the direct relationship between moral sensitivity and students' socioscientific reasoning as well as the strength of the relationship. The contribution of this study is obvious as the resulting outcomes can be capitalized as guidelines to school teachers to teach efficiently using socioscientific issues in science classrooms. The long term implications of this study will impact the stakeholders to design science curriculum holistically so that science literacy among school children can be promoted.

This study will begin by presenting a literature review on the relationship between scientific literacy and socioscientific reasoning, followed by the influence of science knowledge and moral sensitivity on socioscientific reasoning. After that, the research method is further explained. Thereafter, the empirical findings are presented and discussed. Finally, the conclusion of the research is presented.

Literature Review

A literature review had been conducted to explore the concept of socioscientific reasoning and its role in promoting science literacy among students. Furthermore, a general explanation will be presented to discuss the influence of science knowledge and moral sensitivity on socioscientific reasoning.

Science literacy and its association with socioscientific reasoning

For the purpose of this paper, science literacy can be defined as a functional understanding of science including, but not limited to, (1) content knowledge consistent with those of the scientific community, (2) understanding of how science works, (3) a sense of what counts as evidence and how to interpret it, and (4) recognition of how science connects to the social dimensions of the world. This conceptualization of scientific literacy aligns with what Roberts (2007) called as Vision II science literacy that highlights the use of science to inform decisions in daily lives. Therefore a scientifically literate society is a dynamic society where they can grow in line with the rapidly progressing changes in science. They are expected to at least have the skills to ask questions and find the latest information, instead of merely memorizing facts in a rigid and traditional way (Cummings, 2017).

Socioscientific reasoning on the other hand is the outcome of high order thinking processes shown by an individual when he involved in socioscientific issue discussions (Zeidler & Sadler, 2011). Socioscientific reasoning skills are a necessity in the 21st century because these skills help students make fair justification on issues related to science and society, enabling them to formulate solutions with the support of scientific evidence (Sadler & Zeidler, 2005; Zeidler et al., 2009). These skills can be taught in schools through the practice of socioscientific issues discussions in the classroom. Many researchers have found that learning activities involving socioscientific issues would generate science literacy and sharpen students' reasoning skills (Cummings, 2017; Gutierez, 2015; Li Ke et al., 2021; Valladares, 2021)

The development of socioscientific reasoning in science education began when the Science, Technology and Society (STS) movement in the 1970s and 1980s failed to achieve its goals (Karahan, 2015; Rundgren & Rundgren, 2016). The problem with STS curriculum is that many of the issues (e.g., cloning, global warming) are not exciting or relevant to students because they are not related to their everyday personal experiences (Zeidler & Sadler, 2005). It fails to take into account the emotional, moral and sociocultural factors that play an important role in influencing the way students understand science (Zeidler & Sadler, 2005).

The failure of STS can be understood more clearly when Roberts (2007) presents the results of his five-decade literature review on the concept of science literacy. He categorized science literacy as Vision I and Vision II based on the their difference in perspective. Vision I science literacy refers to the early definition of the 1970s era where science literacy is defined merely as the application of science principle. On the other hand, Vision II of science literacy is also known as functional science literacy in which society and culture are found to be co-constructed by science (Valladares 2021). With Vision II science literacy, STS movement had gradually replaced by socioscientific reasoning movement in which science and technology diffused into the world, society and culture.

The influence of science knowledge and moral sensitivity on socioscientific reasoning

In the relevant science education literature review, it is concluded that socioscientific reasoning is influenced by science knowledge and moral values (Cian, 2019; Herman et al., 2020; Van der Leij et al., 2023). Therefore in the rest of this paper, relevant literature is discussed in terms of the influence of science knowledge and moral sensitivity to socioscientific reasoning. Information about these relationship is important to inform stakeholders whether the content of the our science curriculum is adequate to prepare our students in making fair justification and able to solve socioscientific problems that occur in the real world.

Literature review shows that students need science knowledge to assist them doing socioscientific reasoning. However recent studies by Davisson (2019); Herman et al (2020); Klaver et al (2023) reveal that this process did not occur so easily. The difficulty is due to the fact that although scientific knowledge able to explain natural phenomena based on facts and evidence but it is not easy to explain socioscientific issues, due to the complexity of socioscientific issue which is value laden, open and complicated. Thus we need other social skills to understand, justify and solve the issues.

Many studies showed that students tend to make socioscientific reasoning based on the values they believe in especially when they do not have enough scientific evidence to assist them in making decision (Chang & Chiu, 2008; Davisson 2019; Van der Leij et al., 2023). Many studies also discovered that when a comparison is made between students with more moral value and students with less moral value in socioscientific issues, students with less moral value were facing more problems in making socioscientific reasoning (Cian, 2019; Christenson et al., 2012; Lee et al., 2012; Rundgren et al., 2016; Altan et al., 2018). When compared with other constructs such as science knowledge and personal experience, some studies revealed that moral value was the most important contributor to students' socioscientific reasoning (Cian, 2009; Fowler et al., 2009; Lee et al., 2013; Rundgren & Rundgren, 2010; Westbrook, 2019). However some other studies unravel that science knowledge are more important (Nguyen & Matamoros, 2020; Levine & Barton, 2012).

Therefore, this study attempts to evaluate the level of science knowledge and moral sensitivity among Malaysia SBP elit schools in the state of Negeri Sembilan. Furthermore, the research also delves into comprehending the dynamics of the relationship between science knowledge and socioscientific reasoning as well as seeking to unravel the influence of moral sensitivity on socioscientific reasoning. The anticipation is that the research finding will present a nuanced perspective on how the integration of moral values with science curriculum can positively contribute to the empowerment of students' socioscientific reasoning.

Methodology

Sample and Sampling

This study's approach utilising a deductive method as it provides a useful, systematic approach for generating knowledge to solve basic and managerial problems. The use of a cross-sectional research design in this study enables the integrating of a literature review and a real data survey, as well as the use of both subjective and objective measurement as the primary data collection procedure, preventing and reducing the possibility of research bias and ensuring the highest possible accuracy of collected data (Fariz, 2018).

A total of 307 Form Four students (66.1% male and 33.9% female) participated in the survey. They are from science stream which registered for at least two elective subjects of Chemistry, Physics and Biology. The cluster random sampling method had been used for this study due to its suitability. By following this method, four out of eight SBPs in Negeri Sembilan had been selected randomly. The researcher would then collected data from the subset of the four choosen schools. This way, a random representative sample from a population provides the ability to generalize to a population (Creswell, 2014).

The sample size of this study is considered acceptable, according to Krejcie and Morgan (1970) who noted that as the population increases, the portion of the population required in the sample size is reduced or even becomes static after reaching a specific unit. They suggested that 278-285 participants are sufficient if the total population is 1000-1100.

However in this study 307 participants had been selected out of the total of 1021 Form Four students in Negeri Sembilan SBPs , slightly more than the amount suggested by Krejcie and Morgan (1970), merely as precaution if any participant decide to withdraw from the study at any point.

Participants were never required to give their names or reveal their identity in order to protect their privacy and confidentiality. All participants as well as the school involved were protected physically, psychologically and legally throughout the duration of the research.

Measures development, validity and reliability

The researchers adopted the measurement items for this research from previous studies as detailed in Table 1. Questionnaire was divided into five sections; the first section describes the purpose and introduction of the research with the surety to keep the data confidential while the second part consists of demographical information like gender and the reason why they choose to study in science stream. The third part comprises of Science Content Knowledge test, followed by the fourth part of Moral Sensitivity test and the fifth part, Socioscientific Reasoning test as shown in Table 1.

In this study, five experts were consulted to validate the items and the questionnaire was modified based on their suggestions. We also used SPSS version 25 to measure the constructs' validity and reliability (refer Table 1). In addition, this study used partial least square structural equation modelling (PLS SEM) analysis in order to gain information regarding relationships between constructs. PLS SEM analysis is chosen due to the fact that theories used in this research is less developed, and the primary objective of this research is to predict and explain the targeted construct Rigdon (2012), not to confirm a theory. In doing so, few PLS SEM prerequisite need to be met. Table 2 demonstrates all requirements that successfully achieved.

Table 1
Measurement items, validation procedure and reliability result

Instrument used	**Science Content Knowledge test**	**Moral Sensitivity test**	**Socioscientific Reasoning test**
Source	Developed by researcher based on *Bloom Taxanomy*	*Test for Ethical Sensitivity, TESS* (Clarkeburn 2002) and TESSplus (Fowler et al. 2009)	*Assessment of Contextual Socioscientific Reasoning* (ACSSR) (Cian 2019)
Type of question	20 multiple choice questions	3 open ended questions based on 3 socioscientific issues	10 multiple choice questions based on 1 socioscientific issue
Validation procedure	5 Expert (Supported)	5 expert (Supported)	5 expert (Supported)
Reliability	Kuder Richardson-20 = 0.77 Good	SPSS version 25. Spearman Rho = 0.993 Very good	Test and retest Spearman Rho correlation

(Aron, Aron dan Coups 2006)	(Cohen 1988)	r= 0.91 Good

Table 2
Prerequisites for PLS SEM and their outcomes

Measurement Model	**Outer model test**	**Prepequisite**	**outcome**
Reflective model **1. Sc knowledge** **2. Moral sensitivity**	Covergent validity test	Outerloading > 0.7 AVE > 0.5 (Hair et al 2017; Henseler et al. 2017)	Science knowledge: AVE = 0.908 (supported) Moral sensitivity: AVE = 0.852 (supported)
	Discriminant validity test	HTMT < 0.85 (Kline 2015)	Supported
	Construct reliability test	< 0.6 : weak > 0.6 , < 0.8 : Good > 0.8 : Very good (Henseler et al. 2017; Sekaran & Bougie 2016)	Science knowledge : = 0.975 (supported) Moral sensitivity: = 0.945 (supported)
Formative model **1. Socioscientific reasoning**	Convergent validity test (redundancy analysis)	Path coefficient > 0.7 R square > 0.50 (Hair et al. 2017)	Path coefficient = 0.803 (supported) R square > 0.5 (supported)
	Collinearity issue	VIF < 5.0 (Hair et al. 2017)	Global item = 1 Subconstruct inquiry= 1.425 Subconstruct complexity= 2.592 Subconstruct perspective= 2.109 Subconstruct sceptical = 3.037 No collinearity issue (supported)

Result and Discussion

Level of Science Knowledge

Table 3 shows the mean, standard deviation and level of Science Knowledge among Form 4 students of SBP schools in Negeri Sembilan.

Table 3
Mean, standard deviation and level of science knowledge subconstruct

Science knowledge subconstruct	Mean	Standard deviation	Level
Genetically modified crops	66.70	18.29	Intermediate
Human cloning technology	64.75	16.96	Intermediate
Pharmaceutical milk and genetically modified cow	65.26	18.81	Intermediate
Genetic screening test	66.58	17.10	Intermediate
Mean average	**65.82**	**17.79**	**Intermediate**

The mean for each subconstruct shows that the level of science knowledge among the students are at intermediate level. The finding is similar with Malaysia's score in Programme International Students Assessment (PISA) 2018 which merely gain 438 point, much lower than PISA 2018 bench mark point of 489. Students' knowledge regarding Genetically Modified Crops topics shows the highest mean of 66.70% whereas students' knowledge in Human Cloning Technology shows the lowest mean of 64.75%. The finding is consistent with the study by Topcu et al (2011) which revealed that students were having problems in understanding cloning socioscientific issues. Jackson et al (2023) explains that students tend to understand science concepts easier when the content were closely related to their daily lives. It is obvious that Genetically Modified Crops issues are more familiar with students' daily lives compared to Human Cloning Technology issue. Therefore it explains why students able to answer questions regarding Genetically Modified Crops issue better.

Level of Moral Sensitivity

Table 4 shows the mean, standard deviation and level of Moral Sensitivity for Form 4 students of SBP schools in Negeri Sembilan.

Table 4
Mean, standard deviation and level of Moral Sensitivity among Form 4 students of SBP Negeri Sembilan

Moral Sensitivity subconstructs	Mean	Standard Deviation	Level
Genetically modified crops	84.60	10.00	High
Human cloning technology	83.06	10.04	High
Pharmaceutical milk and genetically modified cow	82.85	12.34	High
Average	**83.50**	**10.17**	**High**

From Table 4 it can be concluded that students' moral sensitivity mean value towards Genetically Modified Crops issue are the highest whereas Pharmaceutical Milk and Genetically Modified Cow issue acquired lowest mean value. As a large and growing body of

literature had suggested, emotion and moral value plays an important role in influencing students' socioscientific reasoning process (Cian, 2019; Fowler et al., 2009; Lee et al., 2013; Rundgren & Rundgren, 2010; Van der Veij et al., 2023; Westbrook, 2019). According to Fowler et al (2009); Van der Veij et al (2023) students will show more moral values when they are the stakeholders of the said issues. Genetically Modified Crops issue consists of a narrative of how scientists create new virus species. This virus is used to induce the formation of protein as an effort to protect the host plant. The way the virus act is similar to the way a vaccine is produced to fight Covid-19. Therefore plausibly this issue recorded the highest mean value because the issue is quite familiar with their lives, causing they to build strong emotion tied to the story-line.

Level of Socioscientific Reasoning

Table 5 shows the mean, standard deviation and level of Socioscientific Reasoning of Form 4 students of SBP schools in Negeri Sembilan.

Table 5

Mean, standard deviation and level of Socioscientific Reasoning among students of SBP schools in Negeri Sembilan

	Mean	**Standard deviation**	**Level**
Complexity	55.71	24.35	Intermediate
Perspective	47.60	27.59	Low
Inquiry	70.02	25.30	High
Sceptical	51.74	23.63	Intermediate
Average	**56.26**	**25.22**	**Intermediate**

According to Sadler et al (2007), socioscientific reasoning involves the process of making decisions in the context of recognizing the complexity of the situation, examining multiple perspectives, appreciating the need for ongoing inquiry, and exhibiting skepticism over possibly biased information. All these skills are closely related to citizenship goals and may help foster skill for dealing with scientific issues as members of society.

The finding of this study revealed that the highest mean value is shown by Inquiry subconstruct whereas the lowest mean value is Perspective subconstruct. From these data we can conclude that the Malaysia Ministry of Education had succeeded in nurturing inquiry skill among students. The effort could clearly be seen in Inquiry Based Science Education (IBSE) Programme and in the implementation of Malaysia Education Blueprint 2013-2025. However students are still lacking in perspective-taking skill. Irmak (2020) defined perspective-taking as the ability of a person to recognise a problem not only from his own perspective but also from other person's standpoint and able to evaluate arguments from each perspective. This skill does not seem to be taught thoroughly in our curriculum.

Relationship between Science Knowledge, Moral Sensitivity and Socioscientific Reasoning

Table 6 demonstrates the degree of path coefficient and significant test for the influence of Science Knowledge on Socioscientific Reasoning as well as Moral Sensitivity on Socioscientific Reasoning. The table indicates that both hipotheses H1 and H2 are statistically significant. However Science Knowledge tend to show more powerful influence on Socioscientific Reasoning compared to Moral Sensitivity.

Table 6
Result of path coefficient and significant test

Hipothesis	Path	Original sample (OS)	Sample mean	SDev	T	Sig.	Decision
H1	Science Knowledge → Socioscientific Reasoning	0.496	0.502	0.044	11.155	0.0000	H1 supported, strong influence
H2	Moral Sensitivity → Socioscientific Reasoning	0.155	0.157	0.051	3.060	0.0020	H2 supported, weaker influence

Table 7 indicates the coefficient of determination, R^2 value which represent the model fit. This coefficient is a measure of the model's predictive power. The coefficient represents the combination effects of Science Knowledge and Moral Sensitivity on Socioscientific Reasoning. That is, the coefficient shows the amount of variance in Socioscientific Reasoning explained by all exogenous constructs linked to it. In other words, it represents a measure of in-sample predictive power (Henseler et al. 2017).

Table 7
The coefficient of determination, R^2 value (model fit)

Endogenous variable	R Square	Decision
Socioscientific reasoning	0.402	Moderate

According to Hair et al (2017), it is difficult to provide the rules of thumb for acceptable R^2 value as it depends on the model complexity and the research discipline. R^2 values of 0.2 are considered high in disiplines such as consumer behaviour. However in success driver study, researchers expectation are higher, such as 0.75 and above. Therefore for this study, R^2 value of 0.402 can be considered moderate.

Conclusion

This paper presented results of the influence of science knowledge and moral sensitivity on socioscientific reasoning among Form Four students of SBP boarding schools in Negeri Sembilan, Malaysia. It is observed that the level of science knowledge among students is intermediate whereas moral sensitivity level is high. The socioscientific reasoning level is found to be intermediate in which Inquiry subconstruct showed the highest level achievement meanwhile Perspective subconstruct presented lowest level. Surprisingly the study also revealed that the impact of science knowledge is higher than moral sensitivity in influencing students reasoning towards socioscientific issues.

One of the most important findings that emerged from this study is that it revealed that although students' science knowledge is merely at intermediate level but the students used it as their prime tool (49.6%) in the process of making socioscientific reasoning. The study also unveiled that students' moral sensitivity contributed very small effect to socioscientific reasoning despite they showed high level moral sensitivity. These findings portrayed that the students do not have enough courage and confidence to use their own

moral sensitivity to justify a socioscientific issue. It also reflected that Vision II science literacy is yet to be achieved.

Science literacy is the ultimate goal in science education, and socioscientific issue have been indicated as a suitable context to promote science literacy in the globalized world of today. Through socioscientific issues discussions in classrooms, students were taught not only to memorise content knowledge of science, but also to develop critical thinking and decision making. However in this challenging 21st century education, critical thinking and decision making skills are simply insufficient. Students must be equipped with citizenship education which emphasizes the importance of moral values in producing holistic and fair justification. Therefore it is hoped that moral value and ethics receive special attention within socioscientific science education, taught either by science teachers or socioscientific issues being integrated into other subjects in schools such as Islamic Studies and Moral Education.

This research contributes to the need to undertake more systematic analysis of an educational model that can be defined as socioscientific reasoning in formal education. More specifically, the research concerns to built a model that represents factors that contributes to socioscientific reasoning skills in formal secondary education.

Therefore this study elicit the associations between socioscientific reasoning and two different ways to express the purpose of formal education; scientific literacy and citizenship education. Considering the contribution of science knowledge and moral sensitivity to socioscientific reasoning, the following views have emerged: a) socioscientific reasoning is linked to the development of four skills that are important for science literacy development, that are complexity, perspective, inquiry and sceptical, b) socioscientific reasoning are related to moral sensitivity which promotes a student to grow as a better citizen.

References

Altan, B. E., Ozturk, N., & Turkoglu, Y. A. (2018). Socio-scientific issues as a context for STEM education: A case study research with pre-service science teachers. *European Journal of Educational Research*, 7(4), 805-812. doi: 10.12973/eu-jer.7.4.805

Chang, S. N., Chiu, M. H. (2008). Lakatos' scientific research programmes as a framework for analysing informal argumentation about socio-scientific issues. *Int J Sci Educ* 30:1753–1773

Christenson, N., Rundgren, C. S. N., & 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.* Vol. 21(3): 342–352. doi:10.1007/s10956-011-9328-x

Cian, H. (2019). Influence of student values, knowledge and experience and socioscientific topic on measures of high-school student socioscientific. PhD thesis. Graduate School of Clemson University.

Clarkeburn, H. (2002). A test for ethical sensitivity in science. *Journal of Moral Education*. Vol. 31. 439–453.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). New Jersey: Lawrence Erlbaum Associates, Publishers.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative and mixed methods approaches (4th ed.)*. Los Angeles: Sage

Cummings, K. M. (2017). Searching for scientific literacy and critical pedagogy in socioscientific curricula: a critical discource analysis. PhD Thesis. Tift College of Education. Mercer University.

Davisson, S. (2019). Curriculum based on socioscientific issues: Bringing the controversy into science class. Master Degree of Science thesis. Carlifornia State University. Proquest LLC. Parkway.

Fowler, S. R., Zeidler, D. L., & Sadler, T. D. (2009). Moral sensitivity in the context of socioscientific issues in high school science students. *International Journal of Science Education* 31(2): 279–296. doi:10.1080/09500690701787909

Gutierez, S. (2015). Integrating socio-scientific issues to enhance the bioethical decision-making skills of high school students. *International Education Studies; Vol. 8, No. 1; 2015* ISSN 1913-9020 E-ISSN 1913-9039

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). A premier on partial least squares structural equation modelling (PLS-SEM) (2nd ed.). Thousand Oaks: Sage Publications.

Henseler, J., Hubona, G. S., & Ray, P.A. (2017). Partial Least Square path modelling: Updated guidelines. In H. Latan, & R. Noonan (Eds). Partial Least Square Structural Equation Modeling: Basic Concepts, Methodological Issues and Applications (pp. 19-39). Heidelberg: Springer.

Herman, B. C., Zeidler, D. L., & Newton, M. (2020). Students' Emotive Reasoning through Place-Based Environmental Socioscientific Issues. *Research in Science Education*, 50(5), 2081–2109. https://doi. org/10.1007/s11165-018-9764-1

Holbrook, J., & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Science Education.* Vol. 4(3). 275−288.

Jackson, W. M., Binding, M. K., Grindstaff, K., Hariani, M., Koo, B. W. (2023). Addressing Sustainability in the High School Biology Classroom through Socioscientific Issues. *Sustainability.* 15, 5766. https://doi.org/10.3390/ su15075766

Karahan, E., & Roehrig, G. (2017). Secondary school students' understanding of science and their socioscientific reasoning. *Research in Science Education*, 47(4), 755- 782. doi:10.1007/s11165-016-9527-9

Kinslow, A. T., Sadler, T. D., & Nguyen, H. T. (2019). Socio-scientific reasoning and environmental literacy in a field-based ecology class. *Environmental Education Research*, 25(3), 388-410.

Kline, R. B. (2015). *Principles and Practice of Structural Equation Modeling*. 4th Edition. New York: The Guilford Press.

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement.* Vol. 30: 607-610.

Lee, H., Yoo, J., Choi, K., Kim, S. W., Krajcik, J., Herman, B. C., & Zeidler, D. L. (2013). Socioscientific Issues as a Vehicle for Promoting Character and Values for Global Citizens. *International Journal of Science Education.* Vol. 35(12): 2079–2113. doi:10.1080/09500693.2012.749546

Lee, T. Y., & Lok, D. P. (2012). Bonding as a positive youth development construct: A conceptual review. *The Scientific World Journal.* Article ID 481471. Doi: 10.1100/2012/481471.

Rose, L. S., & Barton, C. A. (2012). Should great lakes city build a new power plant? How youth navigate socioscientific issues. *Journal of Research in Science Teaching*. Vol. 49(5). 541-567. 10.1002/tea.21017

Irmak, M. (2020). Socioscientific Reasoning Competencies and Nature of Science Conceptions of Undergraduate Students from Different Faculties. *Science Education International.* 31(1), 65-73 https://doi.org/10.33828/sei.v31.i1.7

Nguyen, A., & Catalan-Matamoros, D. (2020). Digital mis/disinformation and public engagement with health and science controversies: fresh perspectives from Covid-19. *Media and Communication*, 8(2), 323–328

Rigdon, E. E. (2012). Rethinking partial least squares path modelling: In praise of simple methods. *Long Range Planning, 45,* 341-358.

Roberts, D. A. (2007). *Scientific literacy/science literacy*. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research in science education (pp. 729-780). Mahwa, New Jersey: Lawrence Erlbaum Associates.

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 and Education*. Vol. 25(9–10): 1049–1071. doi:10.1007/s11191-016-9859-x

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

Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? *Research in Science Education*. Vol. 37, 371-391

Sekaran, U., & Bougie, R. (2016). *Research Methods for Business: A Skill Building Approach*. 7th Edition. United Kingdom: John Wiley & Sons, Inc.

Topçu, M. S., Yilmaz-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), 313-332. doi:10.1007/s10972-010-9221-0

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 Socio-scientific Issues. *Journal for Research and Practice in College Teaching*. Vol. 4(1): 67–83

Valladares, L. (2021). Scientific Literacy and Social Transformation: Critical Perspectives About Science Participation and Emancipation. *Science & Education*. Vol. 30:557–587 https://doi.org/10.1007/s11191-021-00205-2. 557-587.

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education*. Vol. 89(3): 357–377. doi:10.1002/sce.20048

Zeidler, D. L., Sadler, T. D., Applebaum, S., & Callahan, B. E. (2009). Advancing reflective judgment through socioscientific issues. *Journal of Research in Science Teaching*. Vol. 46(1). 74-101.

Zeidler, D., & Sadler, D. (2011). An inclusive view of scientific literacy: Core issues and future directions of socioscientific reasoning in Linder, C. Ostman, L, Roberts, D.A., Wickman, P., Erickson, G. & MacKinnon, A. (Eds.), *Promoting scientific literacy: Science education research in transaction.* New York: Routledge / Taylor & Francis Group. (pp. 176- 192).

Zeidler, D. L. (2014). *Socioscientific issues as a curriculum emphasis: Theory, research, and practice*. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research in Science Education*. Vol. 2, pp. 697-726. New York, NY: Routledge.