Teachings Based on Socioscientific Issues in Science Classrooms: A Review Study

Sasithep Pitpiorntapin [1]
Mustafa Sami Topcu [2]

Abstract

In recent years, teaching based on socioscientific issues (SSIs) is being adopted to promote scientific literacy. In this review study, we discuss the importance of SSI-based teaching and controversial issues surrounding it. Next, we present an instructional framework and discuss strategies and models for SSI-based teaching. We conclude with our observations for two types of SSI-based teaching adopted for tenth-grade students. Importantly, this study covers the keystones of SSI-based teaching, such as how SSIs can be explained and taught in classrooms from the perspective of science. Thus, our study has key implications for science teachers and related practitioners.

Keywords: Socioscientific issues, Teaching approach, Scientific literacy

1. Introduction

The rapid development of science and technology worldwide has given rise to various socioscientific issues (SSIs) in which social dilemmas are closely related to science (Kolstø, 2001). In this study, we use Thailand as a case study given its rapid scientific and technological change over the past 20 years and resultant social dilemmas. For example, in 2012, Thailand's government proposed the construction of a dam in Mae Wong National Park to ensure adequate water supply to local communities. However, it was estimated that the dam would

[1] *Division of Science Education, Department of Education, Faculty of Education, Kasetsart University, Bangkok, Thailand. E-mail: fedustp@ku.ac.th.*
[2] *Department of Elementary Science Education, Faculty of Education, Yıldız Technical University, Istanbul, Turkey. E-mail: mstopcu@yildiz.edu.tr.*

eliminate approximately 17.6 square kilometers of low-lying forest land in the park, resulting in a loss of habitat for many animals including Thailand's tigers. Conservationists argue that without an appropriate study of the potential environmental impact of the dam, Thailand can lose one of its most abundant forest regions (Vipoosanapat, 2014). Another SSI is the conflict between wild elephants and farmers. As farmers clear forests to build homes and plant crops, wild elephants are often displaced and forage for food in the farmers' fields, especially during periods of drought or food shortages within the forested regions (Wipatayotin, 2015). With elephants leaving the forest in search for cultivated food sources, conflicts between the elephants and humans have become more prevalent, such as attacks on tourists in the nearby Khao Yai National Park. The common dilemma between both these issues is human need versus the conservation of Thai resources. To this effect, the lack of understanding about interactions between social and scientific needs can result in feelings of fear, anger, and distrust toward the scientific community (Hodson, 2008).

To cope with these problems, it is important establish and strengthen the relationship between SSI curricula and the learning of science content. Doing so can enable students to exercise their scientific literacy by applying their understanding of science to contribute to public debates and make informed and balanced decisions about SSIs and their impact on human life (Sadler, Barab, & Scott, 2007). In the following sections, we focus on the use of SSI-based teaching as a powerful teaching approach to develop scientific literacy.

2. What are socioscientific issues?

Social issues left unresolved (Oulton, Dillon, & Grace, 2004) and clearly dividing groups that advocate conflicting explanations or solutions on the basis of alternative values (Stradling, 1985, p.9) are generally termed controversial issues. Levinson (2006, p.248) claims that addressing such controversial issues in a classroom can help increase awareness about ethics, economics, company law, politics, scientific norms, and anthropology, notwithstanding emotions generated by the discussion. In general, society can be easily divided given the various factors influencing decision making regarding controversial issues. For example, religious beliefs can affect an individual's decision about abortion or gay marriages (Oulton, Dillon, & Grace, 2004).

While several controversial issues directly stem from social conflicts, many others are based in science, particularly given the rapid development in the field. For example, genetic engineering is a highly developing area that includes both scientific and social aspects. While some support genetic engineering studies, since it can resolve many genetic diseases, many others oppose the idea because it contradicts moral values and religious beliefs. This can be defined as an SSI (Sadler, 2004; Topcu, Muğaloğlu, & Güven, 2014). SSIs exhibit two key characteristics: a relationship with science and social importance (Eastwood *et al.*, 2012).

To identify whether issues can be categorized as SSIs, we use Ratcliffe and Grace's (2003, pp. 2–3) framework and consider that SSIs "have a basis in science, frequently that at the frontiers of scientific knowledge; involve forming opinions, making choices at personal or societal level; are frequently media-reported, with attendant issues of presentation based on the purposes of the communicator; deal with incomplete information because of conflicting/incomplete scientific evidence, and inevitably incomplete reporting; address local, national and global dimensions with attendant political and societal frameworks; involve some cost-benefit analysis in which risk interacts with values; may involve consideration of sustainable development; involve values and ethical reasoning; may require some understanding of probability and risk; and are frequently topical with a transient life."

3. Importance of SSI-based teaching

SSI-based teaching emerged in the field of education during the 1980s. Prior to that, science education emphasized the science, technology, and society (STS) approach, which links science to matters of social importance (Aikenhead, 1980) and is concerned with the impact of decisions made in science and technology on society and does not explicitly focus on ethical issues (Zeidler *et al*., 2005). In addition, it does not account for the emotional aspects of learning science that is socially relevant (Sadler & Zeidler, 2005). In contrast to STS, SSI-based teaching focuses on the moral aspects of science-based issues concerning personal life as well as the physical and social world (Zeidler *et al*., 2005). When compared with the science, technology, society, and environment (STSE) approach, we found characteristics similar to those of SSI-based teaching, particularly the moral dimensions of socioscientific problems (Pedretti, 2003). Figure 1 provides an overview of these paradigm shifts and historical and conceptual relationships among existing science-related social approaches.

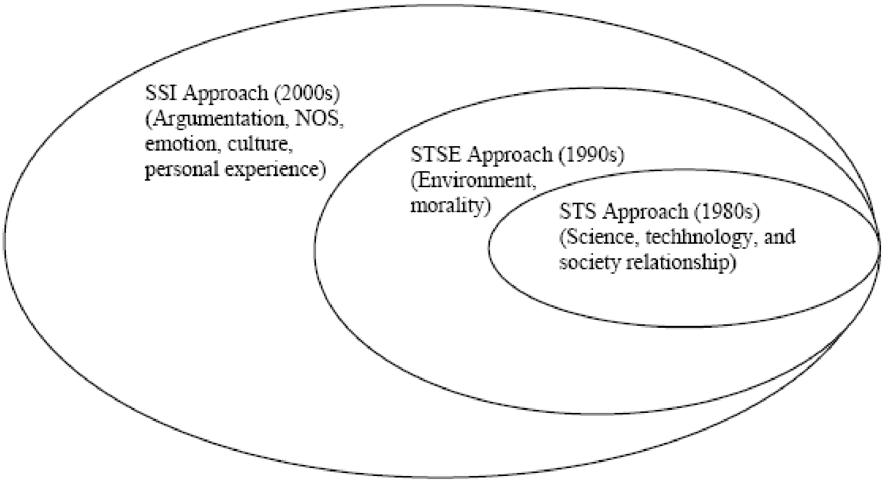

Figure 1. Historical and conceptual relationships among science-related social approaches
Source: Topcu (2008)

Today, many countries, such as England, have accepted and adapted SSI-based teaching for their elementary to secondary levels to promote scientific literacy (21st Century Science Project Team, 2003). SSI curricula and SSI-based teaching differ from traditional approaches. In traditional approaches, students are taught as passive learners who receive knowledge from the teacher. By contrast, SSI-based teaching is concerned with frontier science, an SSI characteristic which people often consider ill-structured; has no consensus within the science community (Aikenhead, 2006); and is influenced by social, political, and ethical factors (Roberts, 2007).

Given these characteristics, students are challenged to exercise their scientific literacy (Presley *et al*., 2013) in the context of real-life situations, which promotes higher-order thinking, problem solving, awareness of the personal and social impacts of science; the application of scientific knowledge for the benefit of society; and moral decision-making skills regarding science, technology, society, and environmental issues that impact daily lives (The Institute for Promotion of Teaching Science and Technology (IPST), 2002).

4. Instructional framework for SSI-based teaching

To describe and understand science teachers' SSI-based teaching practices in the classroom, we draw on Presley *et al*. (2013) and Zeidler *et al.*'s (2005) SSI-based teaching frameworks. Their frameworks highlight the focus of instruction, characteristics of instruction (pedagogical choices), roles of teachers and students, and classroom environment.

4.1. Focus of teaching

SSI incorporates both scientific and social knowledge and issues (Ratcliffe & Grace, 2003). Successful teaching methods tend to focus on the use of SSIs to learn specific scientific content (Sadler, Barab, & Scott, 2007) and explore relationships with other areas of science and disciplines. In addition, they focus on providing students with opportunities to learn the themes based on the nature of science in the classroom and engage in higher-order practices (Presley *et al.*, 2013) e.g., analyzing and interpreting data, using evidence to participate in argumentation and collection, and evaluating and communicating information on the basis of the Next Generation Science Standards (NRC, 2012).

4.2. Characteristics of instruction

To successfully implement SSI-based teaching in the classroom, teachers should provide students with scaffolding to engage in practices, such as argumentation, reasoning, and decision making (Presley *et al.*, 2013). As for teaching aids and materials for SSI-based teaching, teachers can use media such as articles from newspapers, magazines, reports, or interviews from the television to establish a connection between what students learn in the classroom and current world events (Klosterman, Sadler, & Brown, 2012). In addition, technology can be used in various ways to enhance SSI-based teaching and has the potential to serve as a powerful tool that provides access to relevant social issues (Evagorou, 2011). Students can access SSI media resources with technology (Presley *et al.*, 2013).

Learning assessments should include students' higher-order practices such as scientific claims and arguments (Kolstø *et al*., 2006). To measure students' engagements in SSI learning experiences, teachers should conduct formative assessments in the form of constant feedback to promote such learnings (Tal & Kedmi, 2006) and provide opportunities for students to reflect upon and refine their ideas (Sadler, 2011). In addition, teachers can use summative assessments at the end of a unit or topic coverage to capture what a student has learned and the quality of learning and judge the performance against certain standards (NRC, 2001).

4.3. Roles of teachers and students

In SSI-based teaching, teachers avoid playing authoritarian roles, presenting an issue at the beginning of the instruction, or relating what students learn to their existing knowledge (Presley *et al*., 2013). In addition, they refrain from presenting facts about a given subject but rather, function as a learner and allow their students to contribute ideas and knowledge to the classroom (Dolan, Nichols, & Zeidler, 2009). In addition, teacher provide their students with opportunities to better understand the scientific and social aspects of an issue and become aware of the social considerations associated with it (Presley *et al.*, 2013).

The role of students, on the other hand, tends to differ from that in traditional approaches. Students should collect and/or analyze scientific data related to a given issue and accordingly, negotiate the social (political and economic) dimensions (Presley *et al*., 2013). Argumentation is key in SSI-based learning classrooms (Zeidler & Nichols, 2009). Students must prioritize methods of inquiries while interpreting issues; making decisions on the basis of moral judgments; solving problems; and engaging in various forms of discourses such as argumentation, negotiation, and challenging the assumptions of dominant knowledge (Serpell, 2011). Conducting research and making arguments on the basis of a given SSI facilitate the learning of scientific content (Klosterman & Sadler, 2010).

In addition, moral perspective is one of the most important components of SSI-based learning (Zeidler & Keefer, 2003). Presley *et al.* (2013) suggested that students should consider the ethical dimensions associated with an issue. Furthermore, they should explore the benefits and risks of an issue and further explore them and their probabilities (Ratcliffe & Grace, 2003); doing so is crucial to identify and understand SSIs (Crick, 2001). When discussing risks and benefits, teachers should also be aware of the students' learning environment.

4.4. Learning environment

SSI-based learning requires both a collaborative and interactive environment in science classrooms. In addition, students and teachers should demonstrate a mutually respectful relationship (Presley *et al*., 2013). Few studies have examined the effect of SSI contexts on students' epistemologies of science. For example, Eastwood *et al.* (2013) analyzed whether SSI-based learning environments affect university students' epistemological understandings of scientific inquiry differently from traditional science educational contexts. Their results showed that both undergraduate human biology students and biology students held generally adequate understandings of inquiries combined with numerous misconceptions. In addition, teachers can use SSI to learn specific science content (Nuangchalerm & Kwuanthong, 2010; Sadler *et al.*, 2007), encourage analytical thinking (Nuangchalerm & Kwuanthong, 2010), enhance the nature of science (Nuangchalerm & Kwuanthong, 2010; Sadler *et al.*, 2007), learn satisfaction (Nuangchalerm & Kwuanthong, 2010), address citizenship education (Sadler *et al*., 2007), improve argumentation skills (Erduran *et al*., 2004), and promote decision-making skills (Sadler, 2009).

5. Strategies and models for SSI-based teaching

There are several strategies and methods to teach and learn SSI, such as role play, scenarios, debate, group work, jigsaw discussions, forums, conferences, vignettes, oral presentations, debates, and written reports (Conner, 2002; Dawson, 2001; Jarvis *et al*., 1998; Van Rooy, 2004). Similarly, there are numerous models that have been developed by science educators and can be used to bring SSIs into the science classroom (Table 1).

Table 1. Models for SSI-based teaching

Models	Details
1) Decision-making models (Ratcliffe, 1997)	**Options**: Identify alternative courses of action for an SSI **Criteria**: Develop suitable criteria to compare alternative actions **Information**: Clarify general and scientific knowledge/evidence for the criteria **Survey**: Evaluate pros/cons of each alternative against criteria selected **Decision making:** Make a decision on the basis of the undertaken analysis **Review:** Evaluate decision-making processes identifying feasible improvements
2) Bioethical model (Van Rooy, 2000; Dawson , 2001)	- Observe situations related to SSI concerning bioethics - Question and hypothesize - Gather information - Analyze and ethical deliberation
3) Model for decision making in practical contexts using moral case issues (Keefer, 2003)	- Identify SSI-related moral issues in question - Identify relevant knowledge and unknown facts - Offer solutions - Provide justification - Consider alternative scenarios that argue for different conclusions - Identify and evaluate moral consequences - Offer alternative solution
4) Instructional model for SSI-based education (Eilks, 2010)	**Problem analysis**: Students are presented with an issue using media reports and other strategies that highlight the reality and relevance of the issue **Clarification of science**: Teachers help students understand the basic science underlying the issue **Refocus on socioscientific dilemma**: Students refocus their attention on the issue and associated social problems or controversies **Role play**: Students assume roles to engage in the negotiation of the SSIs, which include parties of the issue debate or creators of media related to the issue **Meta-reflective activity**: Students are encouraged to reflect on their overall experiences with the issue and underlying science.

The mentioned SSI-based teaching models highlight that teachers should introduce SSI at the beginning to drive their lessons. They can infuse scientific content with moral and ethical perspectives regarding SSIs by allowing students to engage in higher-order practices such as questioning, generating hypotheses, gathering information, analyzing data, problem solving, and decision making.

6. Examples of SSI-based teaching

From this study, we found that teachers use two patterns to discuss SSIs in their classrooms. First is a one-period SSI-based teaching, as shown in the case of Nancy (pseudonym) and second is SSI teaching for an entire unit, as in the case of William (pseudonym) (Pitiporntapin & Sadler, 2015).

We examined Nancy's biology class for tenth-grade students. In this class, Nancy was teaching her students about food webs. She brought newspaper articles about using chemicals in rice fields to increase production and asked her students to read and discuss their opinions concerning the SSI. To facilitate the discussion, she grouped her students' responses under "Agree" and "Disagree." She then conducted an activity to elaborate on a particular response or opinion about the food web and food chain. For the activity, she asked her students to work in groups of five or six. Each group received pictures of living things (e.g., rice, trees, shrimps, birds, frogs, rats, eagles, grasshoppers, and human beings), which they had to place on a large paper and indicate "what eat what" using arrows; the arrow head had to point to the eater. Once the students finished their task, she asked a representative from each group to present it in front of the class. On the basis of their presentation, she asked questions to further explain the concept. Before finishing the class, the students reviewed the pros and cons of using chemicals in farms, although the discussion was limited due to time constraints.

On the other hand, for his tenth-grade students, William selected the SSI of protesting against the construction of a coal-fired power plant as an introductory topic for the entire unit of natural resources. In the first period, he began the lesson by asking them to read related newspaper articles and watch videos. Then, he asked each group of students to identify and present their pros and cons of constructing a coal-fired power plant in the environment. At the end of this period, he asked his students to search for evidence to support their claims and bring them to class in the next period for a discussion. In the second period, he began by reviewing what the students learned in the previous period. He then asked questions that were based on the quality of evidence the students found to support their claims and warrants. Thereafter, he asked each group of students to create criteria to assess their evidence. Examples of their criteria include validity, clarity, and reasonability of evidence to support their claims and warrants. When the students finished their assessment, a representative from each group presented their conclusion in front of the class. He also asked his students to conclude their claims, warrants, and evidence while accounting for the pros and cons of constructing coal-fired power plants. Finally, he asked his students to identify the types of natural resources utilized in constructing coal-fired power plants and then informed them that they were going to learn more about natural resources in the next period.

In the third period, William discussed the types of natural resources such as water, soil, air, animal, and human beings and asked questions about natural resources utilized in the construction of coal-fired power plants. Then, he took his students to the library to search for information and discussed natural resources in relation to the construction of coal-fired power plants. Finally, he asked his students to list the pros and cons of constructing coal-fired power plants and informed them of a debate on the topic in the next period.

In the fourth period, he divided his students into two groups: one side agreed with the construction of coal-fired power plants, whereas the other disagreed. Thereafter, he asked each group of students to discuss and prepare their information for a debate on the topic of "*Construction of a coal-fired power plant improves the lives of people in Krabi.*"

In the fifth period, he asked a representative from each group to present their information and discuss their points of view. Next, the supporters of the group who agreed or disagreed with the issues had to alternately present their data and make supportive or counterarguments. In the second round, the head representative of the group who disagreed with the construction was the first to present, followed by the head representative of the group that agreed; the same order applied for the supporters of both groups. At the end of his class, he asked his students to discuss the components of argumentation observed during their debate such as their claim, warrant, evidence, counterargument, counterclaim, and supportive argument.

In the final period, he asked the students to write about their decisions regarding the construction of a coal-fired power plant in their communities in their worksheets, which was then presented by 4–5 students. Before the class ended, he asked each group of students to present their decisions regarding the issue. Finally, William and his students together concluded the lesson on natural resources, after which he asked the students to re-take the argumentation test.

However, we found that teachers may find it difficult to implement SSI-based planning or teaching if they view lesson content mainly from an evaluation viewpoint (Sadler & Donnelly, 2006). Some teachers are concerned about the lack of related materials, time constraints (Lee, Abd-El. Khalick, & Choi, 2006), and insufficient support to discuss SSIs in their classrooms (Saunders & Renni, 2011). In addition, teachers often do not have faith in their ability to perform teaching of this nature in which the students engage in argumentation (Newton *et al*., 1999). Pedretti *et al.* (2007) found that teachers in the early years of teaching felt confident in teaching material with controversial issues but were reluctant to do so.

For effective SSI-based teaching, teachers require an array of teacher resources, subject-matter knowledge, and pedagogical content knowledge (Magnusson *et al.*, 1999). However, the question remains whether science teachers are willing to practice SSI-based teaching in science classrooms. In sum, since SSIs are crucial in promoting scientific literacy and an important component of science curricula, we suggest integrating SSI-based instruction in current science teacher education programs for pre-service teacher and professional development courses for in-service science teachers.

7. Acknowledgements

The research was financially supported by the Faculty of Education, Kasetsart University, Thailand and TUBITAK (The Scientific and Technological Research Council of Turkey) under the International Post-doctoral Research Fellowship Programme. We thank our advisor, Prof. Dr. Troy D. Sadler, who is also the director of the ReSTEM Institute: Reimagining & Researching STEM Education, University of Missouri, USA, for his providing us with meaningful insight into SSI-based teaching.

References

21st Century Science Project Team (2003). 21st Century Science-a new flexible model for GCSE Science. *School Science Review*, *85*(310), 27–34.

Aikenhead, G. S. (1980). *Science in social issues: implications for teaching. A Discussion Paper, D-80/2.* Ottawa, Canada: Science Council of Canada.

Aikenhead, G. S. (2006). *Science education for everyday life. Evidence-based practice.* New York: Teachers College Press.

Conner, L. (2002). *Learning about social and ethical issues in a biology class* (Unpublished Doctoral dissertation) Monash University.

Dawson, V. (2001). Addressing controversial issues in secondary school science. *Australian Science Teachers Journal*, *47*(4), 38–44.

Dolan, T. J., Nichols, B. H., & Zeidler, D. L. (2009). Using socioscientific issues in primary classrooms. *Journal of Elementary Science Education*, *21*(3), 1–12.

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.

Eilks, I. (2010). *Making chemistry teaching relevant and promoting scientific literacy by focusing on authentic and controversial socio-scientific issues*. Paper presented at the Annual Meeting of the Society for Didactics in Chemistry and Physics, Potsdam, Germany.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPing into argumentation: developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education*, *88*(6), 915–933.

Evagorou, M. (2011). Discussing a socioscientific issue in a primary school classroom: The case of using a technology supported environment in formal and nonformal settings. In T. D. Sadler (Ed.), *Socio-scientific issues in science classrooms: Teaching, learning and research* (pp. 133–159) New York: Springer.

Hodson, D. (2008). *Towards a scientific literacy: A teachers' guide to the history, philosophy and sociology of science*. Rotterdam: Sense Publishers.

Jarvis, S., Hickford, J., & Conner, L. (1998). *Biodecisions*. Lincoln: Crop and Food.

Keefer, M. W. (2003). Moral reasoning and case-based approaches to ethical instruction in science. In D. L. Zeidler (Ed.), *The role of moral reasoning on socioscientific issues and discourse in science education*. Dordrecht: Kluwer Academic Press.

Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*, *85*(3), 291–310.

Kolstø, S. D. (2006). Patterns in students' argumentation confronted with a risk-focused socioscientific issue. *International Journal of Science Education*, *28*(14), 1689–1716.

Klosterman, M. L., & Sadler, T. D. (2010). Multi-level assessment of scientific content knowledge gains associated with socioscientific issues based instruction. *International Journal of Science Education*, *32*(8), 1017–1043.

Klosterman, M. L., Sadler, T. D., & Brown, J. (2012). Science teachers' use of mass media to address socio-scientific and sustainability issues. *Research in Science Education*, *42*(1), 51–74.

Lee, H., Abd-El-Khalick, F., &Choi, K. (2006). Korean science teachers' perceptions of the introduction of socioscientific issues into the science curriculum. *Canadian Journal of Science, Mathematics and Technology Education*, *6*(2), 97–117.

Levinson, R. (2006). Teachers' perceptions of the role of evidence in teaching controversial socio-scientific issues. *The Curriculum Journal*, *17*(3), 247–262.

Magnusson S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome, & N. Lederman (Eds.). *Examining pedagogical content knowledge: the construct and its implications for science education* (pp. 95–132) The Netherlands: Kluwer Academic Publishers.

National Research Council (NRC). (2001). *Classroom assessment and the National Science Education Standards*. Washington, DC: National Academy Press.

NRC (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education*, *21*(5), 553–576.

Nuangchalerm, P., & Kwuanthong, B. (2010). Teaching "Global Warming" through socioscientific issues-based instruction. *Asian Social Science*, *6*(8), 42–47.

Oulton, C., Dillon, J., & Grace, M. (2004). Reconceptualizing the teaching of controversial issues. *International Journal of Science Education*, *26*(4), 411–23.

Pedretti, E. (2003). Teaching science, technology, society and environment (STSE) education: Preservice teachers' philosophical and pedagogical landscapes. In D. L. Zeidler (Ed.). *The role of moral reasoning on socioscientific issues and discourse in science education* (pp. 219–239). Dordrecht, Netherlands: Kluwer Academic Press.

Pedretti, E. G., Bencze, L., Hewitt, J., Romkey L., & Jivraj, A. (2007). Promoting issues based STSE perspectives in science teacher education: problems of identity and ideology. *Science & Education*, *17*(8–9), 941–960.

Pitiporntapin, S., & Sadler, T. D. (2015). Pre-service science teachers' perceptions and practices of socioscienceetific issue-based teaching. *Journal of Science and Mathematics Education in Southeast Asia*, *38*(2), 102–125.

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

Ratcliffe, M. (1997). Pupil decision-making about socioscientific issues within the science curriculum. *International Journal of Science Education*, *19*(2), 167–182.

Ratcliffe, M., & Grace, M. (2003). *Science education for citizenship: teaching socio-scientific issues*. Maidenhead, England: Open University.

Roberts, D. (2007). Scientific literacy/science literacy. In S. Abell, & N. Lederman (Eds.). *Handbook of research on science education* (pp. 729–780). Mahwah, NJ: Lawrence.

Sadler, T. D. (2004). Informal reasoning regarding SSI: a critical review of research. *Journal of Research in Science Teaching*. 41*:* 513–536.

Sadler, T. D. (2009). Situated learning in science education: socio-scientific issues as contexts for practice. *Studies in Science Education*, *45*(1): 1–42.

Sadler, T. D. (2011). Socioscientific issues based education: what we know about science education in the context of SSI. In T. D. Sadler (Ed.). *Socio-scientific issues in science classrooms: teaching, learning and research*. New York: Springer.

Sadler, T. D., & D. L. Zeidler. 2005. Patterns of informal reasoning in the context of socioscientific decision making. *Journal of Research in Science Teaching*, *42*, 112–138.

Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? *Research in Science Education*, *37*(4), 371–391.

Saunders, K. J., & Rennie L. (2011). A pedagogical model for ethical inquiry into socioscientific issues in science. *Research in Science Education*, *43*(20), 1–22.

Serpell, R. (2011). Social responsibility as a dimension of intelligence, and as an educational goal: insights from programmatic research in an African society. *Child Development Perspectives*, *5*(2), 126–133.

Stradling, B. (1985). Controversial issues in the curriculum. *Bulletin of Environmental Education*, *170*, 9–13.

Tal, T., & Kedmi, Y. (2006). *Teaching socioscientific issues*: *classroom culture and students' performances*. *Cultural Studies of Science Education*, *1*(4), 615–644.

The Institute for Promotion of Teaching Science and Technology (IPST). (2002). *The Manual of Science Learning Management under the Basic Education Curriculum B.E. 2544*. Bangkok: Karusapa Press.

Topcu, S. M. (2008). *Preservice science teachers' informal reasoning regarding socioscientific issues and the factors influencing their informal reasoning*. (Doctoral thesis). Middle East Technical University, Turkey.

Topcu, M. S., Muğaloğlu, E. Z., & Güven, D. (2014). Fen eğitiminde sosyobilimsel konular: Türkiye orneği. *Educational Sciences: Theory & Practice*, *14*(6), 2327–2348.

Van Rooy, W. (2000). Controversial issues within biology: enriching biology teaching. *Australian Science Teachers' Journal*, *46*(1), 20–27.

Van Rooy, W. (2004). Bringing controversial issues into science teaching. In G. Venville, & V. Dawson (Eds.). *The art of science teaching* (pp. 194–208). Crows Nest: Allen and Unwin.

Vipoosanapat, W. (2014). *Mae Wong dam EHIA 'deeply flawed'*. The Nation. Retrieved from http://www.nationmultimedia.com/ national/Mae-Wong-dam-EHIA-deeply-flawed-30247284.html.

Wipatayotin, A. (2015). *Jambo attacks spur Khao Yai road rethink*. Bangkok Post. Retrieved from http://www.bangkokpost.com/news/ general/456385/jumbo-attacks-spur-khao-yai-road-rethink.

Zeidler, D. L., & Keefer, M. (2003). The role of moral reasoning and the status of socioscientific issues in science education: philosophical, psychological and pedagogical considerations. In D.L. Zeidler (Ed.), *The role of moral reasoning on socioscientific issues and discourse in science education*. The Netherlands: Kluwer Academic Press.

Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: theory and practice. *Journal of Elementary Science Education*, *21*(2), 49–58.

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, *89*(3), 357–377.