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Teaching Socio-Scientific Issues Through Evidence-Based Thinking Practices

Dr. K. Tirumalamba[1], Dr. Y.Sridevi[2], Dr. Madasu Vasantha Rao[3], Kongara Neelima[4]

[1]*Assistant professor, Institute of Advanced Studies in Education (IASE), Andhra University, Visakhapatnam, A.P. India.*
[2]*Asst. Professor, Institute of Advanced Studies in Education (IASE), Andhra University, Visakhapatnam, A.P. India.*
[3]*Faculty, Department of Education, Acharya Nagarjuna University, Nagarjuna Nagar, Guntur, A.P. India.*
[4]*Assistant Professor, Department of English, B.V.Raju College (A), Bhimavaram, West Godavari District, A.P. India.*

One of the main goals of science education is to develop scientific literacy and improve the understanding of scientific practices. Argumentation, critical evaluation, and evidence-based thinking are important elements of scientific practices (Mugaloglu, Can, & Ceyhan, 2017). Argumentation mainly refers to constructing an argument, which consists of pieces of evidence and a claim (Simon, Erduran, & Osborne, 2006). The term critical evaluation refers to evaluating evidence and argument to make a decision. Both argumentation and critical evaluation require evidence-based thinking. In a nutshell, to fulfill the aim of scientific literacy in general and understanding scientific practices in particular, students need to develop argumentation; critical evaluation and evidence-based thinking skills. Moreover, argumentation and critical evaluation are recommended as an effective method in teaching science (Ministry of National Education in Turkey, MONE 2013, 2017).

Key Words: *challenges, education, knowledge, methods, progress, socio-scientific issues.*

Introduction

During teaching practices, teachers guide their students to construct an argument and make a critical evaluation based on arguments and shreds of evidence. Experiencing argumentation, critical evaluation and evidence-based thinking can also contribute to understand nature of science and to appreciate the scientific knowledge. Especially while teaching socio-scientific issues such as global warming or genetically modified organisms, evidence-based thinking is vital in students' attainment and taking decisions as an informed citizen. These issues are complicated since they contain various aspects such a social, political, economic. Teachers have difficulties in teaching socio-scientific issues because the related arguments and evidence may have social controversies. This study focuses on science teachers' views about the challenges and the difficulties that come with teaching socio-scientific issues, specifically global climate change. It also explores the teachers' views about teaching global climate change with evidence-based thinking approach. Moreover, one of the difficulties in teaching socio-scientific issues through argumentation is a limited source of teaching materials (Kara, 2012). Therefore, the present study also investigates the benefits and the challenges of using an instructional scaffold, which aims at promoting scientific thinking and critical evaluation of the relationship between data and model considering alternative explanations of the issue at hand (Lombardi, Sinatra, & Nussbaum 2013).

This study contributes to the literature on teaching socio-scientific issues, especially through argumentation, evidence-based thinking and critical evaluation. Besides, the investigation of the science teachers' views of teaching socio-scientific issues by using the instructional scaffold, Model-Evidence Link (MEL) Diagram, contributes to science teacher education literature. With this goal, the purpose of this study is to investigate science teachers' views about teaching socio-scientific issues through evidence-based thinking practices.

The research questions are: What are science teachers' views about- the appropriateness of using MEL diagram in science classrooms?- the benefits of using MEL diagram?- the challenges of using MEL diagram?

Literature Review

Critical evaluation in scientific reasoning has been studied in many fields such as developmental psychology, educational psychology, and science education research. According to Kuhn (1999), critical evaluations are judgments about the quality of explanations based on "criteria of argument and evidence" (p. 23). Central to our theoretical framework is the idea that evaluations about knowledge and how knowledge is constructed involves judgments from scientific reasoning, acquisition of scientific knowledge and scientific practices. Since the early 1990s, science education reform efforts have focused on the notion that science teaching should be consistent with the nature of scientific inquiry (MONE, 2004). The National Research Council (NRC, 2015) has recently promoted this idea, saying that science teachers should express "knowledge, skill, and competencies associated with scientific practices, disciplinary core ideas, and crosscutting concepts; and the pedagogical content knowledge and teaching practices that support students in rigorous and consequential learning of science" (p. 95). In response to the need of promoting scientific practices in science classrooms, Erduran and Dagher (2014) developed the Benzene Ring Heuristic to define the dynamic nature of epistemic, cognitive, social components of scientific practices, which are the real world, prediction, explanation, model, data and activities. All of these components are related to each other and include social practices of science such as argumentation and social certification.

Saribas and Ceyhan(2015) introduced BRH to pre-service science teachers in order to investigate their perceptions of scientific processes and improve their understanding of science and scientific practices. Findings of their study revealed that in order to increase understanding of the scientific practices, science teachers should deepen understanding about the nature of science, including the idea that "scientific explanations are based on logical and conceptual connections with evidence validated through evaluative processes" (the NGSS Lead States, 2013, p. 98). Therefore, providing explicit and purposeful professional development to science teachers about designing lessons on evidence-based scientific explanations is one crucial component needed to increase the likelihood that science teachers will effectively engage their students in critical evaluation and evidence-based explanations (Mugalo glu et al.,2017; Saribas, Ceyhan, & Lombardi, 2019).Our perspective on critical evaluation draws upon evidence-based thinking and application of scientific practices. The Model-Evidence Link (MEL) Diagrams used in this study are instructional scaffolds that focus on the connections between the components of scientific practices through evidence-based explanations. Specifically, MEL Diagrams aimed at promoting critical evaluation through making connections between pieces of evidence and alternative explanations (Lombardi et al., 2013). Chinn and Buckland (2012) first designed the original version of the MEL diagram in order to use in middle school science lessons. Lombardi and his colleagues (2013) developed a MEL diagram for climate change to investigate students' ability to critically evaluate arguments and develop their understandings of fundamental concepts about climate change.

The results of their study showed that use of MEL diagram increased students' knowledge about fundamental scientific principles related to climate change that was sustained six months after instruction (Lombardi et al., 2013). Lombardi and his colleagues (2013) suggest that teachers can use MEL diagrams to help students evaluate evidence and explanations by promoting collaborative scientific argumentation. Using argumentation as well as scientific evidence has long been considered to be beneficial in teaching and learning science. Teachers' use of argumentation as an instructional strategy as well as students' argumentation skills develop over time and with professional development (Osborne, Erduran, & Simon, 2004). If teachers are to engage students in argumentation that promotes coordination and critical evaluation of scientific evidence and explanations, we assume they should experience similar activities with professional development based upon our understanding of the literature on the scientific practices, critical evaluation, and scientific argumentation. In the present study, we investigated how a professional development program on evidence-based thinking practices shaped the teachers' views about the benefits and challenges of teaching socio-scientific issues, specifically climate change.

Teachers are expected to improve their students' analytical thinking and decision-making skills through evidence-based thinking and critical evaluation processes. In this study, a three-hour workshop was conducted to investigate science teachers' views about teaching socio-scientific issues through argumentation and introducing an instructional scaffold, Model-Evidence Link diagrams to promote the use of argumentation and critical evaluation in science classrooms. 125 science teachers, who were working in public schools in an urban area in Visakhapatnam participated in the workshop. Findings revealed that 90% of the participants stated that the use of MEL diagram is appropriate for science teaching. Promoting higher-order thinking skills was the highest benefit, whereas the need for time for the development and implementation of the material was the greatest challenge for the use of the MEL diagrams in science classrooms. This study contributes to the literature on teaching socio-scientific issues, especially through argumentation, evidence-based thinking, and critical evaluation.

Introduction to Socioscientific Issues

Socioscientific issues (SSI) involve the deliberate use of scientific topics that require students to engage in dialogue, discussion, and debate. They are usually controversial in nature but have the added element of requiring a degree of moral reasoning or the evaluation of ethical concerns in the process of arriving at decisions regarding possible resolution of those issues. The intent is that such issues are personally meaningful and engaging to students, require the use of evidence based reasoning, and provide a context for understanding scientific information (Sadler, 2004a; Zeidler, 2003). This paper describes the theoretical model for using SSI in the classroom, while our companion article, which will be published in the summer issue of this journal, describes practical examples of SSI use in a 5th-grade classroom. Rationale Of course, the idea of teaching via controversial topics and more recently, SSI has been recognized in the international science education community and by the national documents of many countries in one form or another (Kolstø, 2006; Levinson, 2006; Ratcliffe & Grace, 2003; Ratcliffe, Harris, & McWhirter, 2004; Zeidler & Keefer, 2003). However, missing from most science classrooms are engaging activities that focus on contemporary social issues that require scientific knowledge for informed decision-making. While certain scientific principles require specific instruction, the development of pedagogical models dealing with contemporary issues in general, and SSI in particular, must necessarily include students' active participation in developing argumentation skills, the ability to differentiate science from non-science issues, and the recognition of reliable evidence and data.

Two central presuppositions of the SSI framework that provided a rationale and direction for how the learning process unfolded informed our approach. First, our selection of many moral and ethical scenarios throughout the academic year had to do with our recognition that students' interests, more times than not, are not isomorphic with our educational objectives. Generally, students tend not to think about the structure of the cell, the periodic table, or the laws of thermodynamics. Students do not typically think about any topic that is not personally relevant. This begs the question, "What is personally relevant to students?" Phrased differently, "What do students think about?" The answers, so it seems, are not surprising. Generally, students think about themselves, whatever affects them personally, and what other people think. We do not imply this represents the sum total of their world, but it is a good starting place to get their attention. Second, our framework has suggested that contextualized argumentation in science education may be understood as an instance of education for citizenship. It follows that it is essential to present the humanistic face of scientific decisions about moral and ethical issues, and the arguments and evidence used to arrive at those decisions. Separating the learning of the content of science from consideration of its application and its implications is an artificial divorce (Sadler & Zeidler, 2005; Zeidler & Sadler, 2008b). Distinction from Science, Technology, and Society It is important to note that the SSI framework goes "above and beyond" past notions (at least how typically practiced) of science, technology, and society (STS) education. While STS education emphasizes the interrelationships among science, technology, and society, it seems to lack a theoretical framework that informs teachers and those involved in program development of pedagogical strategies that acknowledge the social development of children's identity as part and parcel with the curriculum. We have stated previously that "Socio-scientific Issues, then, is a broader term that subsumes all that STS has to offer, while also considering the ethical dimensions of science, the moral reasoning of the child, and the emotional development of the student" (Zeidler, Walker, Ackett, & Simmons, 2002, p. 344).

The SSI framework, as my colleagues and I have conceptualized it, is informed by developmental and sociological research that acknowledges the epistemological growth of the child and the development of character (Zeidler & Sadler, 2008a; Zeidler, Sadler, Simmons, & Howes, 2005). SSI and Scientific Literacy A conceptual SSI model of "functional scientific literacy" has been suggested elsewhere (Zeidler, 2007; Zeidler & Keefer, 2003; Zeidler et al., 2005). The theoretical framework was proposed both because of its utility in addressing SSI in terms of the psychological, social, and emotive growth of the child and its flexible sensitivity to multiple perspectives of science education research as it relates to scientific literacy (SL). In this conceptualization, functional SL, in contrast to more traditional notions of SL that are more technocratic in nature, is dynamically mediated by personal cognitive and moral developmental considerations. These considerations include factoring in character and cognitive and moral development and include the use of (but may not be limited to) cultural, discourse, case-based, and nature of science issues.

Our realization of functional SL lies in how these areas are orchestrated together with an eye toward providing developmental conditions necessary for the formation of responsible, evidence-based reflective judgment, conscience, and character. Hence, shaping students' epistemological belief systems may be a bit of a novel consideration in contemporary science education practice, but it is central to the advancement of an SSI approach to science education. Other researchers have acknowledged the connection between SSI and SL (Aikenhead, 2006; Pouliot, 2008). As the three examples in the companion piece will show, Pouliot (2008) strikes a chord in this regard that obviously resonates with us. It is now commonplace in science education that the study of SSI by students constitutes a prime avenue for fostering SL of a kind that will prompt young people to familiarize themselves with science in action, to develop their capacity for evaluating the information made available to them on a daily basis, to make decisions concerning controversial socio-technical issues, and to take part in debates and discussion on socio-technical controversies of concern to them (Pouliot, 2008, p. 545).

SSI and Pedagogy Role of the Context (SSI Context) Teachers looking to the Web for SSI fodder may recognize that Internet and issues-based learning activities can also be an invaluable resource in terms of exposing students to diverse perspectives on current scientific reports and claims. Again, current research can suggest important ideas to inform practice. With scaffolded learning interfaces (e.g., Walker & Zeidler, 2007), students can spend their time reading and evaluating the multiple perspectives of a given socio-scientific issue instead of "surfing" through a plethora of sometimes misleading information. Of course, this requires that teachers invest the time upfront to find both reliable as well as potentially unsound sources of scientific data and perspectives, so students may be confronted with mixed evidence and learn to assess the validity of varied claims and data.

Role of the Teacher While encouraging students to consider evidence-based alternative arguments is of primary importance, it is equally important that teachers who are interested in using debate or discussion-focused activities also consider the match between their own pedagogical expectations and the theory base guiding the research. For example, a teacher engaged in SSI would need to rely on research and current information about a given topic to better direct classroom debates through various lines of questioning (e.g., epistemological, issue-specific, role reversal, and moral reasoning probes). The importance of exposing students to discursive activities in the science classroom cannot be overstated if our goal is to increase SL. Putting together an SSI module does not simply mean selecting a scenario where science or technology can “save the day.” Role of the Students Moving SSI from theory to practice is essential in contemporary classrooms.

Science education that includes SSI offers unique opportunities to challenge students’ moral reasoning and, in the process, presents concepts that seem to make sense because of the relevance and individual interest. Consistently, we have found that the main competition to understanding and coherence are core beliefs, pseudoscience, and lack of personal experience in moral decision-making (Zeidler, Sadler, Applebaum, & Callahan, 2009). The challenge to science teachers is to allow students to discredit their own belief system by having opportunities to formulate new perspectives. Our experiences have allowed us to identify several areas that are potentially problematic for students when engaging in SSI.

Student impediments to success tend to include moral (core) beliefs, scientific misconceptions, lack of personal experiences, lack of content knowledge, underutilized scientific reasoning skills, and emotional maturity. In presenting this list, we do not mean to dissuade teachers from attempting an SSI approach. In fact, it is our position that insofar as students have such impediments, that we have a responsibility to provide them with opportunities to challenge their personal belief systems about the social and natural world in order to make connections. As the examples in the companion piece will show, the moral component of SSI is what triggers the students’ need for more (content) information, critical thinking, constructive argumentation, and compromise. SSI and Classroom Discourse Sociomoral Discourse Sociomoral discourse is a central necessity when issues of inquiry, discourse, argumentation, and decisionmaking become a focal point in an SSI classroom. It occurs when one student’s reasoning influences that of another, and, in return, a reciprocal relationship is forged. Such transactive discussions have been described in the literature (e.g., Berkowitz, 1997; Berkowitz, Oser, & Althof, 1987; Zeidler & Keefer, 2003) and have proven to enhance the quality of reasoning by providing varied viewpoints that require the use of counterpositions, evidence, and just solutions over the course of development. Students are apt to experience dissonance when ideas or evidence are presented that do not immediately fit into their past experiences. The dissonance compels students to negotiate, resolve conflicts, and enhance the quality of their own arguments.

Argumentation and Debate

The inclusion of argumentation and debate in the science classroom is a rising area of interest among science educators just as issues of social controversy in science are proliferating with the advancements of technology. Although there are a number of useful approaches to assessing student discourse (Bell & Linn, 2000; Sadler, 2004b; Zeidler, 2003), much work needs to be done in developing effective pedagogical approaches that pay particular attention to elementary, middle, and high school students' conceptual understanding of science content knowledge and the structure and function of sound argument. Using argumentation and debate, however, is a useful means to engage thinking and reasoning processes, and to mirror the discourse practices used in real life in the advancement of intellectual and scientific knowledge. For the purposes of the classroom practice, a focus on tolerance, mutual respect, and sensitivity must be modeled and expected.

Productive debate and argumentation is not always practical or even possible in every educational setting, particularly for educators with little experience managing it. Teachers may first consider guided discussions rather than debate. Such discussions can allow educators to address controversial socioscientific topics in a more controlled manner, which may be especially helpful in certain contexts. The unit involving the harp seal hunt in the companion piece, which can provoke strong emotions in children and adults, is a good example. Practicing by having a discussion before attempting a debate may also help both the teacher and the students to incorporate the behaviors that will ultimately make argumentation more productive. Critical Thinking Whether business, politics, or both motivate concerned citizens, calls for increased SL typically include a plea for the education system to produce students who are critical thinkers. One of the benefits of including an SSI curriculum is that the discussion and debate of controversial socioscientific issues necessitates that students develop many of the skills and dispositions associated with critical thinking. The core creative thinking skills of analysis, inference, explanation, evaluation, interpretation, and self-regulation (Facione, 2007) will all be encouraged by SSI units as will the dispositions associated with them. Incorporating SSI can therefore help to produce students who are truth-seeking, open-minded, analytical, systematic, judicious, and increasingly confident in their reasoning.

Conclusion

SSI and the Context for Evidence-Based Decisions Integrating Science Content Our working assumption within the SSI framework is that SSI units of study afford the context for students to understand, through carefully crafted experiences, that scientific knowledge is theory-laden and socially and culturally constructed. The extent to which students internalize this depends, of course, on their developmental readiness. The process of experiencing science "in the making" would look different across varied grade levels. However, our central approach remains essentially the same regardless of grade level. Appendix A reflects the teacher's role by illustrating the pedagogical relationships between the teacher and the students in the SSI discourse. The teacher's role becomes secondary (but not less important) in relation to the SSI, which provides the social context for understanding scientific content, and the inquiry methods and reasoning skills students bring to bear on working their way through the issues. The teacher must learn to direct, prod, orchestrate, and facilitate, but it is clearly the students' engagement in the issue that is of central importance. Cross-Curricular Connections One of the advantages of an SSI curriculum, particularly at the elementary level, is that it lends itself to interdisciplinary connections. Many educators feel there is not enough time for science in elementary grades. However, a carefully designed SSI topic can involve a mix of reading skills, science content, social studies, mathematics, and art, as well as providing students (and their teacher) with real experience involving moral reasoning, epistemological development, and peer debate. As students get older, their education becomes increasingly focused and insulated, a process many believe reduces the overall effectiveness of science education. SSI units encourage the integration of scientific and nonscientific disciplines rather than their separation, which helps provide students with real, believable context. That context, in turn, provides motivation to learn science content by making it seem more relevant and interesting.

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