The Integration of Science-Technology-Society/Science-Technology-Society-Environment and Socio-Scientific-Issues for Effective Science Education and Science Teaching

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Abstract

This article explores Science-Technology-Society (STS), Science-Technology-Society-Environment (STSE) and Socio-Scientific-Issues (SSI) in science education, and critically examines their contributions to science education and science teaching, and how they are underpinning values and ethics in society. The article presents rationales for the integration of STS/STSE and SSI education under a unified platform which can deliver an enriched, powerful, and organised pedagogy, and can be well accepted for the advancement of science education and science teaching. The benefits, projected outcomes and implicated issues surround the integration of STS/STSE and SSI are discussed. The STS/STSE and SSI integrated approach may effectively contribute to the development of scientific and technological literacies, and provide an impetus for the re-emergence of values in science education; foster values and ethics in students' minds, and benefit the societies.

Keywords**:** Pedagogy, STS, STSE, SSI, epistemology, science education, teaching, values, ethics, society

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Introduction

Science is multidimensional which includes not only the factual but also the historical, sociological, technological and humanistic dimensions (Jablon, 1993). Technology affects society in ubiquitous fashion and sometimes in unexpected ways. While the technology is a powerful force in modern society, both science and technology are also influenced by the society in which they exist (Marker, 1992). Science and technology have become an integral part of our economic, social, and political life (Hurd, 2000). Science and societies are facing increasing complexities in the technologically advanced and globalised world, where socio-economic, cultural, and political changes are constantly occurring and influencing our lives.

The National Science Education Standards (NRC, 1996) prescribed that the most important duty for teachers is to help their students to build a solid ground in science content, and gain an understanding of ethical implications of science and the human context in which science occurs. The standards recommended that students should be able to understand and evaluate costs and benefits associated with technological advancement. Students should understand the basic concepts and principles of science and technology, and active debates should be encouraged with their economic, political, and ethical issues (NRC, 1996). Recently the National Research Council (2012) presented *A Framework for K-12 Science Education* as a guide to standards developers, curriculum designers, assessment developers, state and district science administrators, professionals responsible for science teacher education, and science educators working in informal settings. The framework is based on three major dimensions such as, the major practices, crosscutting concepts, and disciplinary core ideas. The council expected that by the end of high school all students should be familiar with the contents and requirements of the framework suggested. The outline of the framework presents how these practices, concepts, and ideas should be developed across the grade levels. If these three dimensions are integrated into standards, curriculum, instruction, and assessment, students can gain meaningful learning in science and engineering (NRC, 2012).

Scientific and technological literacy explores societal values, beliefs, and influence on the way scientific and technological developments take place. A clear understanding of the nature of science and technology offers enormous opportunities to appreciate the embedded values, ethics, and world views while learning science. The major visions of scientific literacy emphasise ‘scientific skills development’ and ‘structure of science’, students’ way of conceptualising and dealing with situations within a scientific context, and different views of what it means to be scientifically literate or developed knowledge, skills and attitudes consistent with public understanding of science (Roberts, 2007).

The Science-Technology-Society and Socio-Scientific-Issues Movements

The Science-Technology-Society (STS) and Socio-Scientific-Issues (SSI) movements have a rich history of trying to address issues related to the developments of scientific and technological literacy. During the 1960s, an enormous effort was made to distinguish between science and technology, and the STS was presented as a connector between science and society with the use of technology. In the early 1970s and 1980s, there have been numerous attempts in the USA to initiate the STS programs in the secondary schools (Yager, 1993). One example is the BONGO program. In 1977 an interdisciplinary and project oriented BONGO program was introduced in the USA to address the high rates of drop-out, conceptual understanding and process skill acquisition of at-risk urban students. Various issues of social conscience were embedded in the interdisciplinary themes which led the students to act upon their beliefs. Students were motivated to create projects that had an impact on their communities. Due to the introduction of BONGO program, gains were shown in increased attendance, academic performance, critical thinking abilities, science reasoning skills, and STS awareness over the course of one term. The significant success of the program inspired other educators to run similar program in other parts of the country. The underlying success of BONGO was attributed to the contribution of interdisciplinary approach, team teaching effort, and the effective integration of traditional science with social sciences and humanities rather than infusing STS in subject area classes (Jablon, 1993). The STS educational practice was initially proceeded independent of an established research base upon which extant precollege STS educational practice could be directly based (Rubba, 1987).

Despite significant support and established research bases, the STS or Science-Technology-Society-Environment (STSE) programs did not progress well in reaching out to mass educators around the globe. In contrast, SSI programs that noticeably differs from STS/STSE programs have been successful in gaining momentum, and SSI is attracting science educators (Zeidler, Herman, Ruzek, Linder, & Lin, 2013). The teacher’s role in an STS or SSI program is quite different than it is in a traditional science course which requires different curriculum emphases and instructions. For example, in an STS program, the teachers need to act as a facilitator, an organiser, a leader, an arbitrator, and a guide. The student evaluations are focused on students and their ability to use high-level thinking skills (Yager, 1986). Both STS and SSI offer advantages in their corresponding teaching outcomes.

However, due to lack of clear definition and understanding of STS and SSI, different mode of course organisations, curriculum emphases, differentiated teaching approaches, and a lack of widely accepted and established curriculum, teachers find it difficult to implement them. This is especially true for the new teachers who cannot excel compared to the experienced teachers (Yager, 2007).

In the 21st century, science education is enriched since the pedagogies involved in science education actively relate to issues of culture, identity, multiple social meanings of science education, teacher-student relationships, students' desires and expectations, and values in science education. Both STS and SSI approaches have contributed to the advancements in science education and science teaching. Despite the enrichment of science education and improved science teaching practices, science education is still facing great challenges as students' motivation and interest in sciences are decreasing (Batterham, 2000; Chowdhury, 2013, 2014; Kiemer, Gröschner, Pehmer, & Seidel, 2015; Tytler, 2007). Current science education does not provide adequate inner orientation and bases for students required to their developments, and uphold values and ethics as responsible future citizens. Perhaps due to individual and parallel contribution, both STS and SSI are not able to make expected impacts on students' motivation and active engagement in the sciences. Thus a coherent and consolidated approach of STS and SSI may help to meet these expectations.

In recent years students' interest and motivation in STEM (Science, Technology, Engineering and Mathematics) subjects has dropped significantly throughout secondary education (Kiemer, Gröschner, Pehmer, & Seidel, 2015). Many elementary school students do not find science as encompassing the world around them. The almost desperate state of undergraduate education in many countries, particularly in enabling sciences such as, physics, chemistry and mathematics is concerning for future science education and science teaching. The brightest students are not attracted to scientific careers in part because the poor rewards in science, and the experiences they endure in schools, do not help to motivate them (Batterham, 2000). Apart from students' lack of motivation and disengagement in sciences, the influence of rapid technological advancements and enhanced complexities in social life are perhaps making it more difficult to underpin the importance of values and ethics, and to present them appropriately through the curriculum. If students are engaged in science lessons in a way that provides social, cultural, and productive learning environment then students can reflect on the values embedded in science and science teaching. Such a learning environment may enhance students' interest in science and help them become informed citizens in society (Corrigan, Dillon, & Gunstone, 2007). The critical and important role of value-laden science education essentially can address the important issues such as, the increasing non-engagement of students in science education past the compulsory levels (Gunstone, Corrigan, & Dillon, 2007).

Main Focus

This article defines STS, STSE, and SSI, and discusses their missions, objectives, and progressions over time. The inherent strengths and limitations of both STS/STSE and SSI education found in research, and how STS/STSE and SSI education are contributing to and reflecting in society are provided. The implementation of individual STS/STSE and SSI approaches in real-life situations are presented to derive their benefits and drawbacks. The rational basis for the integration of STS/STSE and SSI are discussed and established the arguments. The implications of cultural aspects in science education and science teaching are elaborated in the context of STS/STSE and SSI education that affect students motivation and learning of science properly. The article critically analyses the propositions and potential reasons as to why the STS is not making adequate impact on societies after decades of its movements as it was expected. I provide rationales and discuss the necessity to achieve better outcomes from both STS/STSE and SSI which can mitigate the inherent limitations found in the STS, and suggest an STS/STSE and SSI integrated approach through their unification in one platform.

Although both STS/STSE and SSI have strengths and limitations but these approaches can complement to each other. Thus it is expected that the unified approach of STS/STSE and SSI will be coherent with a strong basis as they are consolidated. Science education research evidently shows that the large majority of high school students respond well to science courses if they promote the applications of science, foster human values, and show connectedness with personal and societal issues (Aikenhead, 1994; 2005). Hence it is expected that the STS/STSE and SSI integrated approach may effectively contribute to the development of scientific and technological literacies, and provide an impetus for the re-emergence of values in science education; and foster values and ethics in students' minds, prepare them as informed future citizens and benefit the societies.

STS and STSE

Education

Aikenhead studied STS education quite extensively. He defined the STS as: 1) a technological artifact, process, or expertise; 2) the interactions between technology and society; 3) a societal issue related to science or technology; 4) social science content that sheds light on a societal issue, and is related to science and technology; and, 5) a philosophical, historical or social issue within the scientific or technological community (Aikenhead, 1994). The STS dimension in science education contains an important component of the broad field of nature of science (Vázquez-Alonso, García-Carmona, Manassero-Mas, & Bennàssar-Roig, 2013). STS helps develop students' ability to apply and connect their learning to new contexts or situations. STS teaching helps improve students' understanding of the philosophy, history, and sociology of science (Yager, 2007). However, many educators find difficulties in dealing with STS as it is not a curriculum based education but a context for a curriculum. Thus a widely accepted STS curriculum with basic concepts, goals, and assessment instructions is required (Yager, 1993; Rubba, 1987).

STSE education is a form of STS education which greatly emphasises environmental consequences of scientific and technological developments, and the understanding of the interface between science, technology, society, and environment. STSE education is an umbrella term that supports a vast array of different types of theorising about the connections between science, technology, society, and environment. It contains a vast ocean of ideas, principles, and practices that overlap and intermingle one into the other. STSE presents an opportunity to learn, view, and analyse science in a broader context while recognising the diversity of students and classrooms (Pedretti & Nazir, 2011).

In defining the goals of STS and science curricula, Aikenhead (1980, 1994) focused on the following points: 1) characteristics of science, including its aims and values, human character, and its strategies for decision making, and extending knowledge; 2) limitations of scientific knowledge, values, strategies, and techniques including the recognition of science in society; 3) an examination of boundaries between science and politics, economics, religion, technology, and ethics; and, 4) characteristics of science and its place in society with science-related problems.

While describing the inception of STS approach, it was mentioned (Aikenhead, 2005) that the STS approach to science education was actually introduced from a particular vision of school science motivated by three major evidence-based failures of traditional approach to teaching science, i.e., crises in student's enrolment, myths conveyed to students, and a widespread failure of school science content to provide clear meaning for most students (Aikenhead, 2005). In this context, other researchers expressed similar views in multiple occasions with their evidences on traditional school science having limitations of making science relevant to everyday life, and unable to make expected impacts on students learning science properly (Osborne & Collins, 2000; Reiss, 2000).

In the past STS education was able to outreach and influence other disciplines of education such as, social science. STS issues have foundational components rooted in the natural and social sciences, and hence science and social studies courses are logical premises where STS education can be incorporated at the precollege level (Rubba, 1987). The social science disciplines that form the basis for social studies curriculum already contains topics and units that describes technology and society. However, Marker (1992) suggested further that if the social studies curriculum is studied from an STS perspective, it can help students grasp important concepts and generalisations about the STS. Thus infusing an STS perspective into social studies curriculum is both realistic and desirable to gain effective outcomes (Marker, 1992). This reflects the attestation of the validity of STS from other disciplines due to its necessity, positive impact, and capability to influence the students of social sciences on their understanding of science, technology, and society, and gain public awareness.

The essence of the discourse of STS education encourages students to become critical investigators and engage in dialogue with their teachers. It does not dichotomise teachers and students activities. In classroom setting, constructivist teachers design the instructions from their experiences which provide an opportunity for students to develop their own understanding of the data at hand. Teachers encourage students to use the information of an area in a way that will deepen their understanding. Students apply their own intelligence and information they have at hand to construct their own understanding of an event they witnessed themselves, and students' personal understandings are then moved forward (Hinchey, 1998). Currently many countries have embraced social constructivist pedagogy to incorporate into curriculum.

It is apparent that science is now becoming more holistic in nature which blends natural and social sciences that deal with both science and social problems through trans-disciplinary approach. Another changing face of science today is found as strategic research in science. The strategic research in modern science occurs with a team spirit and focuses on functional aspects of science and technology, relates to human welfare, economic development, social progress, and quality of life (Hurd, 1998). In this context, technology can be utilised in variety of ways in science education, and therefore, it is important to have clear conceptions of both the nature of science and the nature of technology. When technology is viewed as applied science it is assumed that there is a linear relationship in which science creates technology, and in this case, technological development is projected through the lens of science. Thus the argument lies in the fact that *technology as applied science* approach is only representative of science programmes that does not take into account the human contribution and its effect on scientific discoveries (Jones, 2007). From this point of view, this approach appears as a dehumanised focus, and such a dehumanised focus does not allow the full development of learners' scientific and technological literacies. Hence this may be detrimental to the development and, for the inclusion of values and ethics in science education and science teaching, and for the advancement of scientific and technological literacies. The introduction of STS and technological applications can enhance the learning of science concepts and increase students' interest and motivation. If technology is taught as a subset or subservient to science, then it can be counterproductive as students will be unable to gain a clear understanding of technology present in society (Jones, 2007). Thus an expanded view of technology is required to be introduced to students with wide range of ideas and values that both constrain and promote scientific and technological developments. Jones (2007) argued that developing a good understanding of the nature of technology can provide powerful opportunities for values, ethics and other world-views in learning of sciences (Jones, 2007).

The STS approach to science education helps to develop a student-centered orientation that inspires students' cultural self-identities, students' future contributions to society as informed citizens, and their interest in translating personal and practical meaning of scientific and technological knowledge (Aikenhead, 2005). Recently a reported case-based study (Chowdhury, 2013) focused on a student-centered approach. It was demonstrated that combining chemistry classroom learning and industrial case study, and with the use of appropriate teaching methods and instructional tools may enhance students' motivation and engagement, and increase the awareness of social implications. The case-study helped increase students' motivation to learn chemistry; helped students to learn through real-life situations as to how science and technology contribute to society; exposed students to problem solving issues, and improved their decision-making abilities (Chowdhury, 2013). Thus the approach and outcomes of the case-study strongly supports the proposition which focuses a student-centered orientation rather than a scientist-centered approach. It is because a student-centered approach helps students to reflect on the norms of values and ethics, and the expectations of wider society.

Real-Life Implementation of STS/STSE

When STS/STSE approaches are implemented in real-life situation, both benefits and drawbacks can be derived. This also help us to understand and assess their position, and the necessity for any further improvements. Based on the STS/STSE approaches 3 examples are presented below where the STS and STSE were practically implemented.

Tsai (2002) reported knowledge growth about STS instruction, improvements of teaching approaches, and scientific epistemological views of a female science teacher who implemented an eight month STS instruction in Taiwan. After actual implementation of STS instruction, teacher's knowledge about STS was enriched which helped her to conceptualise the rationales and strategies of STS instruction. She acquired more authentic images of science, and consequently showed a considerable pedagogical knowledge growth about STS. It was found that teacher's scientific epistemological views were shifted considerably toward constructivist-oriented view than the orientation of empiricism which she used to hold before the STS was implemented. Students in the STS instruction group viewed that their learning environments placed more emphasis on social negotiations, prior knowledge, and autonomy. The STS instruction promoted students' scientific knowledge, process skills, citizenship behaviours, and decision-making abilities. Teacher experienced that her cultural experiences caused some difficulties of implementing the STS instruction, and as such, she expressed her opinion that students should be provided a broad vision about "science," and not just the "Western science." This research also pointed out some important factors that may impede the success of STS instruction such as, heavy loaded syllabus outlined by national curriculum, standard tests, lack of administrative or peers' support, and resource limitations in local context.

A recent study (Vázquez-Alonso et al., 2013) was conducted with a large number of samples (613) of Spanish pre- and in-service secondary science teachers through the responses to a 30 items questionnaire of opinions on Science, Technology and Society, and then analysed science teachers' beliefs in STS and other Nature of Science themes. The results showed that teachers' understanding of STS–Nature of Science was clearly asymmetric, and both negative and positive beliefs in STS–Nature of Science were coexisted among the teachers. Teachers' positive beliefs pertain to STS–Nature of Science issues were found to be social responsibility concerning environmental pollution; interaction between science, technology, and society; definition of science; scientific and humanistic knowledge as part of a single culture; gender equality in science and technology; and interdependence of science and technology. Teachers' negative beliefs pertain to STS–Nature of Science issues were ethics in science and technology; role of science and technology in dealing with everyday affairs; and scientific observations. The study showed that the practice of teaching science under STS instruction produced some improvement in teachers' understanding of certain aspects of STS–Nature of Science. But the improvement was neither systematic nor extensive. Based on the research outcomes it was suggested that due to lack of experience to apply STS-Nature of Science in the practice of teaching, it is necessary to design and implement training activities for both pre- and in-service teacher education programs that will involve the teachers in an explicit and reflexive analysis of STS–Nature of Science topics. It was also commented that the practical experience of teaching science cannot be considered as a decisive factor for the improvement of science teachers' conceptions of STS–Nature of Science, and their subsequent implementation in classroom.

A recent review (Pedretti & Nazir, 2011) on the STSE education mapped out a typology of the STSE education in the form of six currents or contemporary issues such as, application/design, historical, logical reasoning, value-centered, sociocultural, and socio-ecojustice, and provided a heuristic view that can be useful for critical analysis of the STSE discourses and practices. The authors critically analysed and criticised all the currents they considered. Although each current has its own strengths and limitations, however, some have a longer history than others, whereas others reflect more on recent concerns. Some currents can also coexist, overlap, and can be utilised in harmony. At a macro level, the STSE education situates science in rich and complex tapestry which draws attention from politics, history, ethics, and philosophy. Although it was found that various models of sociocultural STSE education exist, however, the STSE, in its many forms and currents showed success as it was able to bring relevancy, interest, and real-world connections to science classroom.

From above examples where the STS and STSE were practically implemented it is found that the implementation of STS improved pedagogical knowledge and epistemological views, and promoted students scientific knowledge, process skills, citizenship behaviours and decision making abilities. However, cultural issues may cause confusion or difficulties in implementing STS instruction. Teachers' understandings of STS–Nature of Science were found asymmetric, who expressed both negative and positive beliefs in STS–Nature of Science issues. At a macro level, the STSE education has the ability to draw attention from politics, history, ethics, and philosophy. And the implementation of STSE can bring relevancy, interest, and real-world connections to science classroom.

The STS/STSE approach has been changed over a period of time, and varies in context within countries. In fact, a number of STS-based science curricula are now found worldwide (Aikenhead, 2005). Although the issue of making science relevant to everyday life is the major impetus of STS science curriculum and instruction and as such, the STS had shown success and proven its credibility which is clearly evident. However, the STS approach is not effective enough yet as to the extent of its well acceptance on a global scale. Although the STS emphasises the connection of science and technology with society, and addresses societal issues, however, the STS approach is still lacking a coherent connection with other issues related to science education such as, personal, emotional, historical, morals, values, ethical, character education, civic, cultural, political, economics, and understanding the nature of science.

SSI

Education

The SSI education is open-ended, and involves multifaceted social issues with conceptual links to science (Sadler, 2011). SSI deals with controversial social matters related to science; it promotes scientific literacy, and emphasises the ability to apply scientific and moral reasoning to real-world situations (Zeidler, & Keefer, 2003). The conceptual framework of SSI is related to STS education, and both STS and SSI connect science to societal issues. However, the SSI differs from the STS because of its emphasis on the development of content knowledge, character and virtue (Zeidler, Sadler, Simmons, & Howes, 2005), and moral reasoning in scientific education (Zeidler, & Keefer, 2003; Zeidler & Schafer, 1984). Similarly the SSI differs from the STSE because of its emphasis on psychological and epistemological growth of the child, and the development of character or virtue (Pedretti & Nazir, 2011).

The SSI utilises real societal issues and scientific education to develop functional scientific literacy, and increases students’ retention of science knowledge. The SSI is essentially constituted of questions that are philosophical as well as empirical in nature. The SSI exists at the intersection of differing human interests, values and motivations, and are therefore necessarily socially-constructed (Robottom, 2012). The nature of SSI is usually controversial and characterised by dilemmas, and is debatable from various perspectives. As such, they are usually inextricably linked with morality and ethics (Yap, 2014). Research in the area of SSI has been growing, and in recent years, it created significant attraction from science education community because of its utility in providing a theoretical framework for epistemological beliefs, supporting pedagogy consistent with that framework, as well as providing a context for public understanding of science (Zeidler et al., 2013). The SSI helps to develop critical thinking strategies with an emphasis that includes both affective and cognitive aspects in science learning. In socio-scientific education the use of ethical frameworks as a teaching and learning tool reinstates the importance of incorporating values in science education, and establishes a tangible link between moral considerations and scientific literacy (Yap, 2014).

Real-Life Implementation of SSI

Based on the SSI education 3 examples are presented below where the SSI education was practically implemented. Britt et al. (2011) reported teaching and learning experiences when they worked with socio-scientific issues in secondary school with the engagement of both students (students aged from 13 to 16) and teachers. Teachers were satisfied with working under SSI instruction, and found that the learning goals were appropriate in relation to syllabus, but not as much to students' prior knowledge. Students learned more than they usually do in science as they were exposed to critical thinking. Students searched information, applied scientific knowledge, and understood scientific facts and argumentations. Although students representing the multicultural schools expressed a higher interest in working with SSI compared to their normal science classes, however in overall, the SSI could not make expected impact on raising students' interest in science. But it strengthened the generic skills such as, team-work, problem-solving, and media literacy. Many teachers lacked strategies to work with discussions and argumentations. Teachers understood that the structure and information they provided to students challenged their previous knowledge which were the major aims of SSI work, and hence the SSI instruction effectively contributed to achieve positive, affective and cognitive outcomes. The SSI also found to be most efficient for 'particular students' who believe that they learn from presenting and discussing their knowledge and focusing on "the bigger picture". And those particular students acknowledged their own responsibility for learning, and they consequently found that school science was personally relevant and self-efficacious (Britt et al., 2011).

The epistemological orientations to SSI were investigated by Zeidler et al. (2013) from a cross-cultural perspective to examine students' epistemological patterns of reasoning about the SSI, and identify potential interactions of cultural and scientific identity. The designed investigation included over 300 students from Jamaica, South Africa, Sweden, Taiwan, and the USA. The chosen topic was the allocation of scarce medical resources relative to distributive justice. The results of the study showed that all students displayed a high degree of congruence with respect to how they frame their reasoning on the SSI issue, and provided justifications for their epistemological beliefs. While answering questions relative to a SSI issue the students from all countries other than Taiwan noticeably demonstrated lower levels of epistemological sophistication in their justifications, and expressed their views about the structure of scientific knowledge and the nature of knowing and learning science. However, the Taiwanese students' epistemological sophistication was found beyond that of a certain qualitative threshold, which allowed them to better assume utilitarian epistemological orientations across contexts, and thus engaged them more holistically in the SSI decisions. It was attributed that the reasoning about such issues might have excellently influenced the Taiwanese students and, in a manner that sensitised them to think about the structure of scientific knowledge and the nature of knowing and learning science in more personal epistemological ways. This contrasting outcome of epistemological patterns of reasoning and explaining was evidently reflected in the study and was considered to be an influence of culture in which the culture contributed to epistemic practices of socially constructed knowledge (Zeidler et al., 2013).

A recent study (Yap, 2014) evaluated the effectiveness of using ethical frameworks as a pedagogical strategy to facilitate students' critical thinking, informal reasoning, argumentation and decision-making skills. The investigation and data analysis were based on the collation of reasoning approaches from three selected SSI issues: genetically modified food, genetic screening, and reproductive technologies. The results of the study found that moral reasoning and implied religious values remained at fairly similar levels. Students used variable reasoning approaches based on the context of socio-scientific issues presented to them. Students were able to use ethical frameworks which helped them to develop critical thinking abilities. This study demonstrated that the students displayed significant progression in their perception and appreciation of socio-scientific reasoning from unaffected position to concerned and informed judgment. Based on such observations the author argued that the use of ethical frameworks can be an effective means to explore the socio-scientific issues.

From the above examples where the SSI was practically implemented it was found that students' learning of science were improved as they engaged in critical thinking, searched information, applied scientific knowledge, and understood the scientific facts and argumentations. The implementation of SSI improved students' generic skills such as, team-work, problem-solving, and media literacy. However, many teachers had lack of understanding to imply their strategies with discussions and argumentations. From cross-cultural perspectives, students' epistemological beliefs and abilities to justify the SSI issues varied across different cultures. Students used ranges of reasoning approaches based on the context of SSI issues presented to them, students gained the ability of using ethical frameworks, and consequently these aspects improved their critical thinking and judgment capabilities.

The SSI approach may be well utilised for the improvement of decision making abilities and connecting science to any contemporary societal issue. In this case, a myriad of other multidimensional aspects (e.g., laws, public opinion, economics, environment and politics) may add to that issue, and create more complexities. It is quite rationale that someone may ask, how students will be able to cope with such complexity while they deal with the SSI. When the students are introduced to SSI, they are allowed to see the strengths and limitations to gain sound scientific evidence to argue a viewpoint, and at the same time, students experience that how their arguments are based on other type of values that may also be legitimate in decision making process. Thus through the evidence-based discourse, students are able to learn to formulate their own informed decisions and understand those views that differ from themselves. As an example, Jorde and Mork (2007) demonstrated that when a web-based curriculum was introduced to students it helped students to successfully deal with the socio-scientific issues presented to them. And effectively the curriculum created a learning environment where students learned and applied scientific concepts. As a result students comprehended the strengths and limitations of scientific evidence through their arguments; and, were able to understand their own values and other associated values in their decision making process (Jorde & Mork, 2007).

Integration of STS/STSE and SSI

The fundamental aims of education are in need of more emphasis despite enormous advancements in science education observed over the last several decades. The modern science education requires organised, enriched, powerful, and holistic conceptual and pedagogical tools that can effectively reflect on the way students construct their scientific knowledge and learn science without error, how students can apply science in real-life situations, how the learning of science can increase the awareness of social implications and help eradicate any misconceptions in the process of learning science; how students can be motivated which will enhance their interest in science, meet their adaptive needs, improve their decision making abilities, and help students to become informed citizens and take responsibilities. The STS/STSE and SSI integrated education may help to achieve these goals, and improve students' effective science learning and science teaching outcomes.

In the following discussion I try to reconcile, and suggest with my opinion and plausible explanation for the integration of STS/STSE and SSI to bring them on a unified platform of pedagogy which can be more effective and realistic for the advancement of science education and science teaching. The implicated issues around the cultural aspects in science education and science teaching are also discussed.

Rational Discourses for the Basis of STS/STSE and SSI Integration

Strengths and Limitations of STS/STSE

The validity of the inception of STS/STSE is well accepted by science educators, and has shown credible achievements. In the past several decades, the STS movement tried to bridge the gap between science, technology and society, and fostered societal values. However, the apparent disparity in the uniform acceptance of STS/STSE on a global scale is raising questions to re-consider and reflect on the initial objectives of STS/STSE and science curricula as Aikenhead (1980, 1994, 2005) described.

The declining support of STS approach from wider education community is readily apparent. This is because STS approach is not considering the epistemological foundations, students' moral and ethical developments, and not focusing the emotional aspects of learning science (Zeidler et al., 2005). In respect to the underlying causes that are impeding the overall success of STS, Zeidler et al. (2005) described, although STS principally emphasises the impact on society for the decisions that are derived from science and technology, it actually does not warrant any particular attention to ethical issues involved; and STS does not consider students' moral or character developments. STSE also does not directly address students' moral and ethical developments on their personal level. This is because the theoretical framework of STSE lacks a focus on ethics and morals. Instead, it is found that the traditional STSE education only points out ethical dilemmas or controversies. Furthermore, the STSE education showed its inability to fostering reasoned argumentations and considerations about the distinct nature of science; along with emotional and cultural aspects, and epistemological connections within the issues (Zeidler et al., 2005). Thus it is appeared that the STSE is insignificant to its reflection in science curriculum and practices.

Strengths and Limitations of SSI

The targeted principal objectives of SSI are aimed at providing sound theoretical framework and, focuses on essential personal aspects of learning science. SSI provides a series of connections that bring various contributing forces to the development of scientific knowledge such as, epistemological bases, emotional, moral, and ethical development (Zeidler et al., 2005). SSI can reflect on a unified stage of organised pedagogy which is based on a sound theoretical framework (Zeidler et al., 2002).

Currently the missing part in science education and science practices is not just a connection of science to daily life experience only, but also to relate to the objective studies of science that is based on mental or spiritual strength and internal values of individual which are linked to powerful ethical relationship (Witz, 1996). This view is fully conformed to, supports and resonates the SSI approach (Zeidler et al., 2005). Because this may help increase the awareness of inner values and higher ideals that have historically played a role in science (Witz, 1996); and such awareness may encourage to link social and cultural aspects of life more closely with science. This is the way students are able to reflect more actively of how science can make a difference in their lives and society.

Although SSI has significantly contributed to the development of content knowledge, moral reasoning, psychological and epistemological growth of the child, however, it is also apparent that SSI has not been able yet to show any success on the development of character or virtue among students. Despite that a majority of teachers and educators strongly support the inclusion of character education in the science curriculum, however, the reality is that there is no common agreement on the frontiers in character education as it is a broad area, and many educators view it quite differently. Moreover a myriad range of obstacles are found in implementing character education in the sciences (Chowdhury, 2016). Thus SSI needs to consider all such aspects to address.

In a practical sense, it is quite difficult to identify the most appropriate SSI options and subsequently organise them into a coherent and theoretically justifiable curriculum. It is also highly unlikely that all students will be motivated by the same issues, problems, experiences, situations or to make any substantial changes to their daily behaviours and routines (Hodson, 2010). Again, the non-alignment of environmental, social and economic interests in SSI may give rise to community debates. Moreover, the use of SSI in the school curricula may present challenges in the prevailing organisational culture of schooling (Robottom, 2012) due to lack of understanding of the potential implications of SSI in science education and science teaching as well as resource limitations.

Logical Premise for STS/STSE and SSI Integration

The development of scientific and technological literacy helps in understanding various matters such as: distinct nature of science, and connecting science and technology to society; connecting epistemological, moral, emotional, ethical, and cultural issues; how the dehumanisation aspects of science education and scientific practices are inhibiting the inclusion of values and ethics, and students' character development; and, on students' decision making process. All such aspects require careful attention to science educators.

Hodson (2010) described that both STS/STSE and conventional forms of SSI oriented science education are inadequate in current situation to meet the needs and interests of students faced with the demands, issues, and problems of contemporary life. He argued that since the consideration of the nature of science is more prominent part of regular science curricula, hence more emphasis given on STSE education has shifted the situation in a state of confrontation with SSI. It was also advocated a more radical and politicized form of SSI-oriented teaching and learning where students are able to address complex and controversial SSI, formulate their own position and engage in socio-political actions that they believe will make a difference (Hodson, 2010).

Thus it becomes evident that both STS and STSE have shown more success compared to SSI as both STS and STSE have been able to bring relevancy, interest and real-world connections to science classroom. Both STS/STSE and SSI complement to each other. Thus considering the strengths and limitations of both STS/STSE and SSI, and the inherent nature and capability of both approaches (STS/STSE and SSI) of complementing to each other toward more sustainable improvement than the individual and parallel progression of STS/STSE and SSI, it can be rationally postulated that the SSI may be complemented with the STS/STSE if successful linking and integration can be made bridging the gaps between two approaches toward an enriched, powerful and organised pedagogy under a unified platform; and, effectively this integrated approach can be well accepted from wider education community around the globe.

Implications of Cultural Aspects in Science Education and Science Teaching in the Context of STS/STSE and SSI Integrated Education

Students success in science depends on: the degree of cultural difference that students perceive between their life-world and their science classroom; how effectively students move between their life-world culture and the culture of science or school science; and, the assistance students receive in making those transition easier (Costa, 1995; Jegede, 1995; Jegede & Aikenhead, 1999; Phelan, Davidson, & Cao, 1991). Aikenhead (2001) described that in the pursuit of cross cultural border crossing, students make their transition like a traveller, and some students experience some unfamiliar culture. Students thus require a degree of guidance from a travel-agent type of teacher who can provide incentives for them to travel smoothly into the culture of science. The incentives may include any scientific topic, scientific issues, events or scientific controversies. Providing incentives to students may create the need to know more about the culture of science (Aikenhead, 2001).

In the acquisition of science culture, different cultural processes are involved. Many less industrialised or non-Western regions of the world import the Western science to teach at school which is often regarded to be more superior knowledge to local culture. When students study the science in a formal Western type educational setting, they also experience the culture of school science and the culture of their life-world, which may lead to a clash between these two cultures. The inevitable cultural clashes between students' life-world and the world of Western science can create potential hazards. To eliminate such hazards, students try to invent ways avoiding the construction of proper scientific knowledge which is foreign to them; or students try to store conveniently the constructed scientific knowledge in their minds in order to avoid the interferences with their own life-world experiences. Within the Western or Non-Western cultural setting, the cultural clashes between students life-worlds and the world of Western science is not only posing challenge to science educators, it is a great obstacle for the advancement of science education reform movements which are based on *science for all* ideology. The cultural clash between students' life-world and the culture of science or school science is also making the science teaching extremely difficult and, for students, learning their science meaningfully (Jegede & Aikenhead, 1999). Thus it requires to underpin this cultural issue globally for the advancement of *science for all* based education.

In classroom practices when few students perform poorly, then many teachers often classify them as overall low achievers but teachers are often unaware of their successes. This actually reflects the teachers view due to their low expectations and pessimism about those students. The underlying reason is that these teachers rarely suspect that classroom features, pedagogical style, or their own attitudes may profoundly influence on student's ability to succeed and connect with school environment (Phelan, Davidson, & Cao, 1991). Thus it is important that schools and teachers create the necessary environment where students can acquire skills and strategies that will lead them to work comfortably with different people in divergent social and cultural settings. This is how schools and teachers can contribute to uphold values and ethics of the culture of science, and help students to learn science.

Both STS/STSE and SSI recognise the importance of cultural aspects in science education and science teaching, and accordingly address the cultural issues based on their own views and mission perspectives. However, based on *science for all* ideology, and as a comprehensive approach, the integrated STS/STSE and SSI education can focus strongly, and deal more effectively with these cultural issues in science education and science teaching compared to individual or parallel contributions from STS/STSE and SSI.

Benefits and Projected Outcomes from the Integrated STS/STSE and SSI Education

The major benefits and projected outcomes that can be derived from the integrated STS/STSE and SSI education are as follows:

1. In the 21st century, technology has become a powerful force in society which is constantly influencing the society and is being influenced by the society. Under this situation, the successful STS/STSE and SSI integrated approach can offer enormous opportunity to adequately explore the ethical and ontological issues of science, society, culture, and the person in the context of humanity live in technological society.
2. The integration of STS/STSE and SSI can provide an enriched, powerful and organised pedagogy under a unified platform; and, effectively can act as a holistic approach, and use either STS/STSE or SSI as deemed to be appropriate. In such way the integrated approach can afford more opportunities for the construction of science curriculum in better ways that differ from traditional arrangements of teachers, students, subject matters, and the contexts within which science learning occurs.
3. The presence of STS/STSE and SSI is more than half a century with wealth of knowledge and established research experiences. Now it is timely and appropriate to look at the provision of integrating STS/STSE and SSI based on the rationales presented which can benefit the STEM education. As a result of successful integration it can gain a critical mass to rigorously address the issues pertained to students' lack of motivation and engagement in sciences especially in higher secondary school compared to individual and parallel contributions from STS/STSE and SSI. And effectively this can help to reverse students' demotivation and disengagement in learning sciences.
4. The successful outcome from STS/STSE and SSI integrated education may provide an impetus for the re-emergence of values in science education; and may foster values and ethics in student's minds, and benefit the societies. Then value-laden science education can effectively contribute to building the bridges and linkages between science and society, and achieve scientific and technological literacy for all students.
5. The STS/STSE and SSI integrated approach and its epistemological basis will be more enriched and aligned with social constructivist philosophy, and can be easily adapted with any science curricula around the globe, hence will be well accepted from wider education community.
6. The unified approach will be more coherent as both STS/STSE and SSI will complement to each other. Thus it is likelihood that the curricula derived from such integrated approach will be coherent. And because of solid foundation, it is less likely that these curricula will be changed frequently over period of time unlike the individual STS and STSE approaches which experienced such changes.
7. Under the united umbrella, the STS/STSE can be reinvigorated as it can actively look back the original aims and missions embedded prior to inceptions, and were subsequently overlooked over period of time.
8. The STS/STSE and SSI integrated approach will be able to coherently connect a myriad range of issues related to science education and science teaching such as, personal, emotional, historical, morals, values, ethical, character education, civic, cultural, political, economics, and understanding the nature of science.

9. The STS/STSE and SSI integrated approach will be able to help better way to connect science and technology with society and culture, and connect the epistemological issues to science education.
10. The STS/STSE and SSI integrated approach will be enriched and able to actively contribute to develop the generic skills among the students such as, problem-solving, team-work, and media literacy. This will also help students to develop critical thinking, formal or informal reasoning, argumentation, and decision-making skills.

Curriculum and Teaching Instruction within an STS/STSE and SSI Integrated Education

Students can perceive their science knowledge as useful and relevant when the scientific topics such as, medical, health, environment, energy, material science, and industry-based matters (Chowdhury, 2014), value-oriented, moral and ethical issues related to science are presented to them in a plausible and intelligible manner (Chowdhury, 2016). There is a strong evidence that students like ethical issues that are more widely addressed in science education (Reiss, 1999). When certain types of curricula or traditional science curricula are unable to engage students in moral considerations where they can express views from own moral positions on a particular topic/issue related to science, in that case, the STS/STSE and SSI integrated approach can successfully utilise them. The rationale for the presence of moral, ethical and character education in science curriculum is that it contributes to students' development to become self-dependent individuals, who will be capable of recognising, accepting and internalising their roles as responsible decision-makers. Students will be able to reflect on their own moral positions that will help to handle various moral and ethical issues in the society (United Nations Educational Scientific and Cultural Organization, 1991). This rationale was authenticated by Hurd (2000) who also provided a similar outline for an effective science curriculum under present circumstances. Thus due to the inclusion of SSI, the STS/STSE and SSI integrated approach can make significant contribution to design an effective curriculum where the curriculum standards can principally focus on the utilisation of knowledge in science and technology, and meet students' adaptive needs. This curriculum can actively engage students in learning sciences; improve their decision making and judgement forming abilities; and help students to choose the right actions that involve the elements of risk, uncertainty, values and ethics. Thus all these arguments presented (Hurd, 1998, 2000; United Nations Educational Scientific and Cultural Organization, 1991) for the requirement of a reformed science curriculum stresses on the compelling reason and strong needs for emphasising morals, values, ethics and character education through science curriculum development and implementations (Chowdhury, 2016). The STS/STSE and SSI integrated education-based curriculum can meet these demands of a reformed science curriculum.

In the STS/STSE and SSI integrated approach, teacher can apply both STS/STSE and SSI education in a classroom setting depending on the content, context, allocated time-line and relevance. For example, when the teachers are engaged in teaching energy and environment where global warming issues are discussed, in that situation, with the application of STS/STSE approach students can use their ideas, concepts and skills to gain a clear understanding of the science behind and relate them to societal issues. However, using the same topic, the teacher can also apply the SSI approach. In that case, teacher may ask students to engage in debate and discussion in order to address a scientific approach to solve the current global warming issue. The debate and discussion can instigate students to explore the implicated components related to this issue, such as, cost effectiveness for the elimination of greenhouse gas emissions, and the social and ethical responsibilities of industrialised nations (Allchin, 1999) who are mostly responsible to cause such problem. This way student can develop their moral and ethical reasoning to address a real problem toward a solution. It is important to ensure that when students' are involved with own evaluation of an ethical-dilemma related to science, they have solid understanding of science behind the issue (Chowning, 2005) which they can gain from the STS approach discussed. While handling the SSI approach, teachers should be well aware of current scientific knowledge and emerging technologies which may further introduce new ethical and social dilemmas based on pre-existing values (Allchin, 1999).

In order to become future citizens and informed decision makers, students need to develop scientific skills, understand the nature and structure of science and technology; and, how science and technology have developed and grown intellectually. Students need to develop adaptability, apply their gained knowledge in understanding and controlling the environments; reflect on science, technology and decisions; and, how science and technology considerations differ from their personal and political values (Roberts, 1982). Thus it is expected that the STS/STSE and SSI integrated approach may help to holistically focus on the humanisation and socialisation aspects of science practices; and can increase the awareness of social implications among the students. Students can learn science properly as it motivates students, meet their adaptive needs, enhance their interest in science, students become future informed citizens and take responsibility. It is also expected that the STS/STSE and SSI unified approach may provide an impetus to emphasising values and ethics through the implementation of improved science education curriculum, and may effectively contribute towards the development of scientific and technological literacies, hence it can be well accepted from wider education community around the globe. The discussion presented in this article may be helpful to teachers, educators, scholars, researchers, policy makers, government and curriculum developers to address current and emerging issues in science education and science teaching.

Conclusion

The STS/STSE approach has proven the validity of its inception, and accordingly has shown credible progress. On a global scale, the STS/STSE approach has not yet been successful for its uniform acceptance. Thus the STS/STSE needs to reflect back on its initial aims and objectives, and how they are met and fulfilled. The STS/STSE has demonstrated success in connecting science and technology, and contributed to the development of scientific and technological literacy. The SSI approach has also shown success in connecting epistemological, moral, emotional, ethical, and cultural issues to science. The SSI contributed to understanding the distinct nature of science and personal aspects of learning sciences. It focused on the humanisation and socialisation aspects of science practices; and, emphasised on the understanding of the role and interactions of science and technology at the interface between society, politics, economics, religion, and ethics. Thus it becomes apparent that the SSI is filling the gaps or vacuum or connecting the missing parts to the STS/STSE where most of the aims and objectives were embedded prior to inception. Both STS/STSE and SSI have shown their credible success, and none can be superior to other. Henceforth it can be rationally postulated that the SSI may be complemented with the STS/STSE if successful linking and integration can be made bridging the gaps between the two approaches toward an enriched, powerful and organised pedagogy under a unified platform, which can be well accepted for the advancement of science education and science teaching. The benefits, projected outcomes and implicated issues related to the integration of STS/STSE and SSI are discussed. It is expected that the STS/STSE and SSI integrated approach may help to focus more holistically on the humanisation and socialisation aspects of science practices; and can increase the awareness of social implications. Students can learn science properly, motivate students, meet their adaptive needs, enhance their interest in sciences, and students become future informed citizens and take responsibility. The successful linking and integration between STS/STSE and SSI may provide an impetus for the re-emergence of values in science education, and foster values and ethics in societies. The STS/STSE and SSI integrated approach may effectively contribute to the development of scientific and technological literacies. The requirements to devise an integrated curriculum of STS/STSE and SSI integrated education are discussed in this article. An example of teaching instruction in a classroom setting is presented where teacher can utilise both STS/STSE and SSI education on the same topic of science to be taught. How the successful integration and unification can be achieved between the two approaches (STS/STSE and SSI) is out of the scope of this article discussion. But, it requires careful consideration, regular discussions among the science educators, scholars and researchers, regular debates and forum discussions, and some research evidences to validate this proposition.

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