Keith Courville

Louisiana State University

Science, Technology, and Society: A Perspective on the Enhancement of Scientific Education

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Abstract:

(Purpose) This literature review discusses the history and application of science, technology, and society (STS) teaching methodologies. **(Findings)** Topics addressed in this paper include: (1) developmental history of STS; (2) fundamental beliefs of STS practitioners; (3) STS methodology in the classroom; (4) Difficulty in implementing STS; (5) STS as reducing content based knowledge in students; (6) STS as increasing student motivation; (7) STS as increasing student involvement in community issues; (8) STS as increasing science content knowledge and mastery; (9) Current findings within the research field; and (10) Future directions in STS implementation within the educational system. **(Conclusions)** After an overview of the literature, a general trend of STS increasing student motivation and community involvement was observed, while the effects of STS in terms of content mastery has long been a subject of debate, with more recent research presenting data in favor of STS in terms of general student knowledge acquisition.

Developmental History

Science, Technology, and Society (STS) is a novel approach to science education that is now being used to implement scientific understanding while at the same instance deal with broader issues and implications in the world of science. STS as a learning approach encompasses many different methods of student instruction. Students taught by teaching techniques that incorporate societal issues and/or active learning, defined as science, technology and society approach, exhibit greater interest in science, more positive attitudes towards scientific professions, and increased concept mastery than students taught in traditional, textbook, or non-active manners. Once we evaluate these teaching methods, we can delve into classroom examples and teaching philosophy, followed by research results on STS effectiveness in meeting its proposed goals. Furthermore, both current issues in the classroom and future directions in STS will be examined.

Before STS was a defined teaching method, educational philosophy dealing with a societal focus on science had already began in many countries, to a certain extent, with societal issues of the day, such as the pollution. Educational reform that explored the connections between science and society came to prevalence in Britain, during the 1970s, where the phrase would eventually enter the language and gain international attention through an educational reformer named John Zinman (Dogan, Kaya, Kilic, Kilic, & Aydogdu, 2004). The first definite usage of the phrase Science, Technology, and Society did not occur until the beginning of the 1980s when the phrase for this type of teaching was given by Zinman in a book on science education methodology (Meyer & James, 2002). At this time STS was still more of a name in a textbook than a reform movement within the American educational field.

STS as a movement within the educational field started in the late 1980s, primarily in the state of Iowa, by the urging of the National Science Teacher's Association (NSTA) (Hollenbeck, 1998). The initial focus of the movement was to bridge the gap between scientific knowledge and the needs of the society, i.e. to foster students who were aware of the needs of the community as well as the effect that science has on community issues, particularly through the use of developing technology. At this time in the 1980s there was not a significant level of research done on STS within the classroom, probably due to the lack of national prominence of the method.

Further statements in the 1990's such as the document entitled Science for All Americans from the American Association for the Advancement of Science (AAAS) in 1994 and the National Science Education Standards from the National Research Council (NRC) in 1996 also illustrated the growing desire for reform in science education (Dass, 1999). As Dass (1999) notes, these organizational reports demanded a science education that manifests the ability to critically examine problems, apply science to real-world problems, and to foster a greater interest in science. All of these educational organizations later endorsed STS as a means to enhance our nation's science education. Besides the endorsements from the AAAS and the NRC, the NSTA also has endorsed STS as "essential components of American science programs (Meyer & James, 2002, p.4).

As the needs of science education grew and endorsements came in from science and teaching professional organizations, so did the prevalence of STS in American classrooms.

According to survey research from the early 1990s from Berlin and Kumar (1993), 45 states and over 3,000 school districts utilized the STS approach to science education to some degree; however, the extent of that degree was not defined by the researchers. As STS techniques began to be used in more and more classrooms, researchers began to follow case studies on how to integrate STS modeled learning and the difference between STS classrooms and regular classrooms (Jackson, 1993).

Today, STS has been established as a distinct educational philosophy and classroom method. Presently, researchers are attempting to further define this technique, as well as evaluate its effectiveness in the classroom. In order to discuss the present research on STS approaches, the methodology must be distinctly defined in terms of classroom practices and basic beliefs underlining its tenets.

Practices and Beliefs

With increased classroom practice, STS developed into a concrete teaching method, complete with its own defined educational philosophy and goals. According to Dass (1999), STS is a science approach that goes far beyond traditional methods because it focuses on a holistic approach to science education. Since its inception in the 1980s, STS has had time to develop from an overarching principle to a more substantially defined method. During their national surveys Berlin and Kumar's (1993) simplistic definition of STS as focusing on the interaction of science, technology, and society, garnered not a single objection from any state science supervisor that was surveyed. Furthermore, Berlin and Kumar (1993) noted that nine states also required that personal responsibility in decision making was an additional focus of STS implementation in that state’s school districts. This augmentation goes along with the trend for

STS to foster responsible citizens who are able to make decisions on scientific matters that effect their communities and world at-large.

Later definitions of the STS approach combine both the interaction between fields and the effect a proper science education has on the lives and community of the students. In the operational context some focus on defining the STS approach as one that can "teach science to ALL students" (Meyers & James, 2002, p18). The premise that STS may be a technique that can communicate to students of different abilities, interests, and cultures is an advantage often claimed by STS educators.

The aforementioned definitions are simply constructed definitions, lacking an operational context or an analysis of the beliefs that STS stems from as a learning technique and the philosophy of implementation that enables STS to be adopted for classroom use. Lawrence, Yager, Sowell, Hancock, Yalaki, and Jablon (2001) gives an extremely detailed discussion of the practices and beliefs instrumental to teaching using STS in today's classroom. According to Lawrence et. al (2001), the overall scope of STS orientation in a classroom relies on students actively seeking information to utilize, seeing science as a means of solving problems in everyday life, identifying problems in their community, and seeking to solve these problems through science. In this manner, the techniques and practices that a student first learns in the classroom, i.e., the seeking and utilizing of information to solve problems, is placed in a broader context of societal engagement. In this broader context, it is the hope that the students assimilate the tools necessary to seek information and solve problems scientifically in the scope of their own lives. In terms of sustained learning development STS should result in engagement of the students in "long term inquiry, discovery, or research-based approaches to learning with real world applications" (Carroll, 1999, p. 7) Thus, you truly have students learning science techniques and abilities that they can utilize throughout their entire lives, instead of mere facts and figures they would be forced to memorize and apply to very specific problems.

Further analysis by Lawrence et. al (2001) differentiates between the traditional science approach and that of the STS approach in terms of content. Whereas in a traditional science education course problems are considered void of their ethical or moral dilemmas or effect on the community an STS approach engages students in terms of the societal as well as scientific issues concerning a problem or that result from a proposed solution (Lawrence et. al, 2001). In this manner students may learn the full weight of their actions within their communities and the possibility that science, especially through emerging technologies, may be the means to resolve certain value based issues.

Robert Yager, one of the foremost researchers in the STS field, has focused some of his research on the effect that the STS technique has on classrooms as a whole, including both the students and the teachers. Yager provides an additional perspective on STS teaching philosophy, besides the focus of the methodology with community and societal issues. The STS classroom to Yager (1995) is a classroom that is organized from the perspective of the students; in this classroom the students are viewed as active partners in the learning process instead of merely as recipients of instruction and lecturing as in a traditional science classroom. There is the underlying philosophy within the literature as a whole that STS is a science specific implementation of constructivist, student focused teaching techniques. Yager (1995) furthers this theme by detailing the effects of STS instruction on the teachers themselves where he explains how proper instruction and training can lead to an increased use of STS approaches by teachers.

The notion of STS as constructivism in the science classroom is echoed by other researchers in the science education field. Freedman (1998) defines STS as a constructivist practice in his assessment research, noting that teachers recognize “doing and thinking about science is more important than being able to recite facts” and “students can be responsible for their own assessment and learning" (p. 3). Thus it should be noted that STS is not only distinguished from more traditional methods of science education by its focus on scientific impacts on societal problems, but also by the student centered learning focus through which STS classrooms are organized.

Concerns in the Field

Given the inherent difference in terms of philosophy, practice, and focus between a traditional textbook approach and the learner focused Science, Technology, and Society method of science education, there are bound to be many conflicts between proponents of the respective methodologies. In terms of concerns dealing with education through an STS method, there are several educational concerns primarily regarding academic achievement and content mastery.

Before addressing these concerns it should be noted that there are several underlying assumptions regarding the effectiveness of STS. First, it is assumed that the instructor has the training necessary and an educational philosophy that is congruent with success in a student focused constructivist classroom environment. Previous research demonstrates that without teacher training and belief in the STS method, the proper implementation of STS within the classroom in placed in severe jeopardy (Carroll, 1999). This sentiment is echoed by Akinoglu and Tandogan (2006), who note that it is often difficult for teachers to transition into STS techniques from their previous teaching styles.

Even with the assumption of complete and flawless classroom implementation of STS from teacher and active participation from students, there are still concerns regarding STS in the classroom. The primary criticism against STS as a teaching method is that students will actually learn less of the relevant scientific facts that many deem are necessary to successfully master scientific concepts (Yager &Akcay, 2008). This criticism is very logical as it addresses the possible disadvantage of the valuing of problem solving and societal applications over directly addressing scientific laws and facts that are learned within a traditional textbook lesson. Furthermore, observations in early STS case studies by Jackson (1993) echo the sentiment of a lack of raw scientific information in the STS classroom. In describing one teacher's classroom, Jackson states that "the student-centered, interactive structure of Bob's unit made it enjoyable for most all the students, but it seems to have produced a familiar result -- largely inert, low-level, factual knowledge" (pg. 13).

Some educators even fully embrace this shift in focus from facts to application, increasing the criticism by traditional methods towards the STS method. As Hollenbrook (1998) explains regarding teaching using the STS approach, “This approach does not follow the traditional classroom model, in which we present the information, expect the students to memorize the information, and then recite it to us, so we can determine if they learned” (p. 3). Thus, the amount of information learned by students taught by the STS method has become a constant and consistent source of criticism levied against this educational method.

Despite these criticisms against the method, as previously noted, STS has spread throughout American classrooms. The prevalence of the method in the science classroom, however, does not mean the criticism against STS has ceased. Currently, researchers in the science education field are trying to assess the validity of these charges, as well as the positive results garnered from STS.

Perceived Successes

Supporters of STS in the classroom have their own claims pertaining to the advantages of the constructivist teaching technique. Most of the perceived successes are difficult to measure in a quantitative manner by researchers as they consist of attitudinal and behavioral changes that extend beyond the scope of the traditional learning environment. As Akinoglu and Tandogan (2006) directly state in regard to the attitude changes towards learning science through an STS method, “it motivates learning for both students and teachers" (p. 73). Yager and Akay (2008) explain the learning advantage of STS as one that extends learning beyond the school. Indeed, the ultimate goal of STS methods seems to be the effect the student has on the world, not merely the learning of isolated information.

Other proponents of STS focus on its perceived ability to incorporate multiple learning styles and/or cultures into the learning process. With students able to have more control over their learning environment, proponents expect the students will naturally choose the methods and scenarios advantageous to themselves, instead of an instructor forcing all students to learn by the same method and participate in problems that a student might not relate to culturally. Not only is STS an applicable method across cultures and learning styles, but it might also be a means in which to meet the needs of certain subgroups within the American educational system, such as learners in an urban culture and environment (Meyer& James, 2002). As such from a constructivist learning method, allowing students to build on their own experiences and culture should be expected to interest and motivate more students than a lesson devoid of culture or experience which students can relate to in their everyday lives. Other researchers point out that the dynamic nature of the STS classroom is one that can meet the interactive needs of the middle school student (Jablon & Van Sickle, 2003).

Additionally, educators believe that if students become more interested or have a higher attitude towards science, the students will ultimately learn more about science. This premise however, is without a doubt, the most highly contested advantageous claim made by proponents of STS. Current research methodology holds STS students to the same standard of scientific content knowledge, which in turn yields surprising results in relation to the academic performance of STS classrooms versus traditional science classrooms.

Current Findings

In terms of the most current research findings regarding the effectiveness of STS methodology, the research is focused on the two aforementioned purported advantages of the STS classroom. Proponents actively believe that students taught by STS methods learn more content than traditional students, while at the same time having a greater appreciation and attitude towards the subject of science. The comparative hypothesis that STS students have greater content mastery and greater attitude towards science than traditional textbook approaches has already been tested many times by researchers and the results have been fairly consistent.

In regard to the greater appreciation of STS students towards science, many researchers have found that STS promotes a greater appreciation of science. Some researchers demonstrate this greater appreciation for science in the form of “encouraging students to enjoy and experience science" (Yager & Ackay, 2008, p.4). Others, such as Hollenbeck (1998), report that from the teacher's perspective students are motivated by the variety of learning assessments that can be provided in an STS classroom. However, adjustments in attitude in the Akinoglu and Tandogan (2006) study were conflicting with other research, showing a negative adjustment for all participants in the study, with STS students having less of a negative change than their traditionally taught counterparts. Another perspective on the issue of student attitude can be found from Tal (2001), who lists general appreciation for education from all community members as a by-product of STS's focus on community issues.

In terms of concept mastery, STS students have been found to actually learn more content than their traditionally taught peers. It should be noted that it is the norm of the research field that STS students are evaluated using the same test as their traditionally taught peers in order to truly compare the difference in the amount of content learned and mastered. Yager (1995), in his comparison of sixth grade science classrooms found that STS classrooms have advantages in the retention of scientific information. A measurement of retention in regard to scientific information helps demonstrate that students learned a concept instead of merely memorizing facts and figures. A higher level of retention also serves to bolster the argument that STS classrooms facilitate students becoming life-long active learners.

Early research by Yager (1995) also presented data that students taught by STS techniques exhibited a significant positive difference in application on concepts in new situations, creativity in regards to questions and suggestions, attitude towards science careers and classes, and the underlying philosophy or worldview of science. Yager’s (1995) differences between STS classrooms and traditional classrooms were so significant that his research was held to a 0.01 level of confidence. Research from Akinoglu and Tandogan (2006) also found results that correlated well with previous findings in the realm of concept mastery, as the researchers showed that students taught in STS classrooms at the middle school level mastered more content in a post-test analysis than their traditionally taught peers.

Yager and Akcay (2008) collaborated on an extensive comparative study of textbook versus problem based learning in middle school science classes, specifically using the methods developed by Marmara University within the context of an American middle school. Utilizing experienced science teachers within the same middle school teaching separate classes through two different classroom techniques, this study is an extensive real world test of the STS approach. On the subject of content mastery Yager and Akcay (2008) found a small, but statistically significant, increase in STS students as compared to traditionally taught students. However on the subject of attitudes towards science Yager and Akcay (2008) found that not only did STS methods increase student interest and reverence for the sciences, but a traditional textbook approach actually decreases student attitudes towards science. Furthermore, the researchers took the novel approach of also surveying community involvement of students in both groups, finding that students taught by STS were more involved in their communities through such issues as attending local government meetings, volunteering, and participating in public debates (Yager & Akcay, 2008).

Thus, in terms of the most recent and well executed research procedures, STS has been found to be as good as or even better in terms of content mastery than traditional science classroom teaching methods. Even more significant, is the drastic increase in student attitude, motivation, and social involvement when taught with a science method that focuses on societal problems. According to the research, STS classrooms achieve the goal of STS advocates in such that the classrooms foster a long term learning motivation and scientific inquiry in the students.

Future Directions

Given the success of STS in the science classroom in motivating students to learn more content, it is no surprise that STS would have impacts and implications in other educational fields, as well as new extensions within the science field. Within the science field, educators are continuing to create and develop lessons that utilize STS philosophy and techniques to engage students in local community issues. In particular, STS has been used to demonstrate the connection between classroom science, the environment, and the society at large, with such lesson issues as water quality, greenhouse gases, and recycling (Papadimitriou, 2001). In the state of Iowa, one of the first states to adopt STS methodology, focusing on the environment is one of the primary means to first introducing students into the STS classroom (Hollenbeck, 1998).

Other uses of STS have spurred development of entirely new science courses based on STS methodology, that offer students additional science learning on subjects not traditionally taught at their educational level. For example, the STS classroom can be used to actively engage students in research and teach students about scientific research methods, which may not be as extensively taught in traditional high school courses on biology, chemistry, and physics (Daas, 1999). Science teachers are also coming together at science education conferences to share their experiences on teaching through STS, as well as sharing their lesson plans on scientific subjects that utilize STS techniques (Dolgos & Elias, 1995).

In addition to success in the science classroom, STS is beginning to be used in other classrooms. This time, instead of taking scientific information and relating it to the larger society through the effects of technology, the focus is the reverse. Students learning in the social sciences are being referred back to science content or explained how science directly effected a particular social period or event; it should be noted, however, that the infiltration of STS into social studies is not significant to have affected the majority of curriculum (Marker, 1993).

STS has also made its way into the educational classroom at the university level. King and Milson (2002) provide direct participant feedback from university students in an education methods course, where students are taught by the STS methodology and asked to provide feedback. The feedback from King and Milson (2002) from undergraduate elementary science education majors showed a wide range of feelings toward STS assignments, ranging from disgust at having to do complete the assignments to an appreciation of how STS can affect learning. At the least, future educators are now gaining an understanding and knowledge of STS that previous generations of college students lacked. Perhaps the prevalence of STS in American classrooms will continue to rise given the increased exposure of future teachers at the college level.

Conclusion

STS has truly undergone the test of time since its inception and initial definition in the 1980s, to its implementation and endorsement in American schools in the 1990s, and finally withstanding the field of educational research. STS has been a proven success within the science classroom, where it has been shown that students taught by STS methods perform better than their peers in a variety of academic avenues such as content mastery, appreciation of science, and future academic success.

However, there are serious issues within the body of research on STS methods. First, within America, the initial use of STS was in the state of Iowa, and it follows that much of the early research is from individuals residing in Iowa and based on schools within the state. Only much later did studies on the use of STS within American classrooms of different cultures, such as urban, emerge. Furthermore, in terms of publication date and the history of STS, there was an obvious flurry of research in the early 1990s during the initial endorsement by national science organizations, while more recently STS has become more of an accepted method, and classroom research on the method has significantly slowed. However, given the serious arguments from both advocates and critics of STS on the success of the technique, there is clearly a justification for additional research on STS.

With the future holding greater opportunities for further development and innovation, STS may see its prevalence in all levels of science education increase. Furthermore, many subjects and classroom environments may benefit from the methodology of STS, where learning is focused on the student and on the effects of the academic subject being taught in their daily lives. Of course, if society focused learning is to be implemented into other subjects; it must be followed by rigorous research in order to assess the success of any implementation. Some of the same criticisms levied against STS, such as a deficit of factual learning, may be even more relevant in subjects such as mathematics or history. Also, some strengths of the STS classroom, such as the increased interest in a subject or societal involvement, may not necessarily be achieved in the classrooms of other subjects. So while the extension of STS methodology seems to be one avenue of future application of the technique, it is also is yet another avenue for future research.

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