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Science-Technology-Society (STS)

A New Paradigm in Science Education

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Changes in the past two decades of goals for science education in schools have induced new orientations in science education worldwide. One of the emerging complementary approaches was the science-technology-society (STS) movement. STS has been called the current megatrend in science education. Others have called it a paradigm shift for the field of science education. The success of science education reform depends on teachers' ability to integrate the philosophy and practices of current programs of science education reform with their existing philosophy. Thus, when considering the STS approach to science education, teacher beliefs about STS implementation require attention. Without this attention, negative beliefs concerning STS implementation and inquiry learning could defeat the reform movements emphasizing STS. This article argues the role of STS in science education and the importance of considering science teachers' beliefs about STS in implementing significant reforms in science education.

Keywords: *science-technology-society (STS); science teachers' beliefs; STS aims*

What Is STS?

Science, Technology, and Society (STS) is an interdisciplinary field of study that seeks to explore and understand the many ways that modern science and technology shape modern culture, values, and institutions, on one hand, and how modern values shape science and technology, on the other. Ziman (1980) identified STS as a kind of curriculum approach designed to make traditional concepts and processes found in typical science and social studies programs more appropriate and relevant to the lives of students. According to Yager (1990), STS may be defined as an integrated approach to science teaching; however, Wraga and Hlebowitsh (1991) have defined STS as a topical curriculum that addresses a broad range of environmental, industrial, technological, social, and political problems. According to Heath (1992), STS can be referred to as an instructional approach that incorporates appropriate STS knowledge, skills, attitudes, and values.

Hofestein, Aikenhead, and Riquarts (1988) define STS as teaching science content in the authentic context of its technological and social milieu, whereas the National Science Teachers Association (NSTA) views STS as the teaching and learning of science in the context of human experience. It also means determining and experiencing ways that basic science and technology concepts and processes are handled in

society. In other words, it means starting from the real-world problems included in the students' perspectives, instead of starting with the basic concepts and processes (NSTA, 1990). According to Yager (1996), STS means "dealing with students in their own environments and with their own frames of reference" (p. 10). Therefore, it means starting with students and their questions, using all resources available to work for problem resolution, and advancing to take actual actions individually and in groups to resolve actual issues.

STS as a Paradigm Shift on Science Education

Based on the view of science as knowledge and the traditional educational view of cognitive learning, science education focused for a long time on imparting knowledge in the different branches of science. Teachers continued to use teaching methods that involved the memorizing by students of the largest amount of knowledge, and the science curricula continued to view the human cognitive heritage as the aim to which one should adhere. This traditional paradigm of the science curriculum began to take shape in the 19th century, and its form was highly influenced by the social and political realities of that time (Kliebard, 1979). This social and political influence on the institution of science

had, in turn, a dramatic effect on the structure of our present-day science curriculum.

In addition, the traditional paradigm of science education is characterized by the professionalization of science. School science has been a collection of specific disciplines, such as astronomy, biology, chemistry, geology, and physics (Aikenhead, 1994; Yager, 1996). In this respect, Blades (1997) further describes how the revamping of the science curriculum was influenced by the "structure of the discipline" movement. From the perspective of curriculum theorists, the rationale of this movement was to have subject specialists creating curricula. Furthermore, the best method to encourage students' interest in a particular subject such as science was to "render it worth knowing, which means to make the knowledge gained usable in one's thinking beyond the situation in which the learning has occurred" (Bruner, 1960, p. 31).

With the famous space technology revolution embodied by Sputnik in Russia in 1957, a similar revolution began to occur in school curricula, as educationists started to criticize the science and mathematics curricula. Blades (1997) described how, within the United States, this scientific feat in space technology created a national fear of the Soviets and a perceived crisis in education. One of the results of the crisis was the effort to revamp the science curricula in the United States and the United Kingdom, which in turn influenced science curricula throughout the entire world. Following the Soviet launch of Sputnik, as Yager (1996) points out, even though the artificial satellite was more of a technological than a scientific achievement, attention and funding were directed toward reform that illustrated and emphasized basic science.

American educators demanded curricula that could help Americans achieve excellence. Therefore, viewing science as inquiry was central to most of the major curricula of the 1960s (Welch, 1981). This movement was rich in new ideas and in views of science and mathematics curricula. Thus, the aims of science education were changed from emphasizing cognition to ways of acquiring and developing knowledge. Accordingly, the roles of the teacher and the learner changed. The teacher was no longer seen as a store of knowledge, and by the same token, the student was no longer seen as a passive recipient of knowledge. The main role of the teacher changed and became the designing of students' thinking and activities, while the role of the student became the active search for knowledge. This was the so-called "discovery" or "inquiry" trend (Schwab, 1966), which called for developing science curricula that

could make the students into young scientists who practiced science processes like old scientists. According to this, students performed the activities of identifying problems, collecting data, setting hypotheses, designing experiments, experimenting, deducing, generalizing, and other mental and experimental skills (Carin & Sund, 1989).

With this new trend, too, it was expected that learners would develop the skills of observation, classification, measurement, communication, prediction, deduction, identifying problems, setting hypothesis, designing research plans, and organizing and analyzing. It was also expected that they would develop positive scientific qualities such as curiosity, objectivity, and deliberate judgments (Carin & Sund, 1989). However, this emphasis did not affect teaching practice in any appreciable way (Welch, 1981).

Schools in America and in other countries around the world continued for a long time to use curricula built in the light of the inquiry approach. Yet the outcomes of such education disappointed the educationists and did not seem worthy of the efforts that had been exerted for a decade or more to build the curricula (Yager & Tamir, 1993). In this respect, Yager and Tamir (1993) maintained that those process-centered curricula did not lead to the desired effects on teaching. It seems, therefore, that teachers were also to blame for the failure of the inquiry trend.

Specialists confirmed that despite the great efforts exerted to build curricula based on the inquiry approach, the classrooms remained the same as they had been before the inquiry trend. Emphasis continued to be placed on memorization and performing experiments that proved previously taught facts. Thus, many students, especially adolescents, began to turn away from education (Yager & Tamir, 1993, p. 638). Yager and Tamir (1993) also noted that the 1960s curricula were based on an assumption that there was a pattern of discipline that would make the learners acquire scientific inquiry skills as well as knowledge. It was also assumed that the learners would employ knowledge and skills in the future and that they would apply what they had learned in solving the problems that faced them in their everyday life. This would require continuous deduction and positive attitudes toward science and inquiry.

After the Second World War and the dropping of the nuclear bombs on Nagasaki and Hiroshima in Japan in 1945, which killed more than 150,000 individuals, the negative effects of science and its applications began to be evident. At that time, scientists called for directing science and technology toward the

welfare of mankind rather than to its destruction. From that time on, organizations and societies concerned with the wise use of science and technology began to be set up, including, for example, the Society for Social Responsibility in Science, the Scientists and Engineers for Social and Political Action, the British Society for Social Responsibility in Science, United Scientists for Environmental Responsibility and Protection, and the Society for Social Responsibility in Engineering.

These organizations and societies aimed to alert scientists of the social role of science and their social responsibility. More and more organizations seeking to humanize science began to come into being. Such organizations began to shed light on the destructive effects of science and technology on the environment, which began to suffer severely as a result of science and technology (Martin & Beder, 1993; Solomon, 1993; Yager, 1996). Furthermore, many publications tackling the social problems of science and technology appeared, like Rachel Carson's *Silent Spring* in 1962 (Carson, 1962), Barry Commoner's *Science and Survival* in 1967 (Ehrlich, 1971), Paul Ehrlich's *The Population Bomb* in 1978, and Barry Commoner's *The Closing Circle: Nature, Man and Technology* in 1971 (Commoner, 1971). Those publications sought to spread environmental awareness among citizens of the international society, with the intention that they would protect the environment (Solomon, 1993).

In the early 1970s, educational experts observed that science and technology led to many passive social, economic, and environmental changes. They therefore called for science programs that related STS to make students aware of the importance of the effects of science and technology on their lives (Agin, 1974). Ziman called for teaching science to students in all grades according to the interaction between STS, while in the 1980s the American NSTA (1982) considered the interaction between STS to be the basis of science education, as it emphasized the importance of scientific and technological education and teaching the interactive relationship between STS.

It was suggested in the Keil discussions at the Fourth International Symposium on World Trends in Science and Technology Education in August 1987 that STS programs had the greatest potential for enabling students to attain the goal cluster of Project Synthesis (Hofstein et al., 1988). Project Synthesis, a comprehensive research project conducted in the United States, considered four goal clusters (Kahl & Harms, 1981):

Personal needs. Science education should prepare individuals to use science for improving their own lives and for coping with an increasingly technological world.

Societal issues. Science education should produce informed citizens prepared to bear responsibility with science-related societal issues.

Career awareness. Science education should give all students an awareness of the nature and scope of a wide variety of science-related careers open to students of varying aptitudes and interests.

Academic preparation. Science education should allow students who were likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate to their needs.

In one sense, STS efforts are seen as responses to the first three goal clusters of Project Synthesis. STS means focusing on the personal needs of students—that is, science concepts and process skills that are useful in the daily lives of students. It focuses on societal issues—that is, issues and problems in homes, schools, and communities, as well as on the global problems that concern all humankind. STS also means focusing on the occupations and careers that are known today (Yager, 1996, p. 7).

Solomon (1993) mentioned another push toward a new kind of science education that came indirectly from an influential report by a group of the world's top intellectuals, economists, and businessmen in the Club of Rome. The report on *The Limits to Growth* quoted a debate that included items such as the exponential growth in fuel use and the finite nature of the fossil fuel reserve, the world population explosion, and its limited production of food.

STS and Aims of Science Education

A major goal of education is, or should be, to improve the quality of human existence. An essential part of this goal is the promotion of rational ways in which citizens can influence the conduct and direction of human affairs and can live in a democratic society (Longbottom & Butler, 1999; Quicke, 2001). In democratic societies, the quality of the decision made by the laity is of fundamental importance. Lay people's abilities to promote their point of view on socioscientific issues are therefore significant. In this respect, Longbottom and Butler (1999) argue that these assumptions link education in general and science education in particular. Quicke (2001) argues that the primary justification for teaching science to all children is that it should

make a significant contribution to the advancement of a truly democratic society. In other words, the changes in current society lead to changes in the role of education in general and science education in particular.

Science education is the production of citizens who are creative, critical, analytical, and rational. For this reason, science for citizenship has been discussed as an important goal of science education (Kolstoe, 2001). In this respect, Longbottom and Butler (1999) refer to science education that should be designed for the general population rather than for a specialist group of future scientists, and that should lead to empowerment in some general sense of giving citizens more control or decision-making ability. To do this, Price and Cross (1995) infer that science education should give pupils a basis for understanding and for coping with their lives. They should be given applications and effects of science in their personal and social life.

The National Science Foundation Advisory Committee for Science Education recommended that the traditional approach to science education in science be rethought with more "emphasis on the understanding of science and technology by those who are not and do not expect to be professional scientists and technologists" (Hurd, 1998, p. 409). The implication is that notions of scientific literacy should be embedded in contexts that promote a socially responsible and competent citizen (Hurd, 1998). For Jenkins (1999), citizens need to be "scientifically literate" in order to be able to contribute to decision making about issues that have a scientific dimension, whether these issues are personal (e.g., relating to medication or diet) or more broadly political (e.g., relating to nuclear power, ozone depletion, or DNA technologies).

Science for citizenship is an important educational goal (Duggan & Gott, 2002; Hurd, 1998; Jenkins, 1999; Kolstoe, 2001; Longbottom & Butler, 1999). This is a challenge for school science education. Therefore, this raises questions regarding how science education can prepare students as citizens.

As future citizens, students have the enormous responsibility of making decisions that require an understanding of the interaction of science and technology and its interface with society. The STS movement has been strongly identified with meeting this goal, but despite its benefits, putting theory into practice has so far been difficult (Mansour, 2007a).

In response to the pressing needs of modern societies, it has been argued that science education should pay more attention to the STS interface (Eijkelhof & Lijnse, 1988). In all science programs that have been

identified as "exemplary" in the NSTA "Search for Excellence Programme," there was an overt effort by science teachers to help students develop into scientifically literate citizens. One of these programs accepted by NSTA was the Project Synthesis (Ost & Yager, 1993). Scholars have argued that inclusion of socioscientific issues through the STS movement in the science curriculum will help in developing the scientifically literate citizen (Bybee, 1987; Dimopoulos & Koulaidis, 2003; Hart & Robottom, 1990; Kolstoe, 2001; F. P. Ramsey, 1993; Wiesenmayer & Rubba, 1999; Yager, 1993). Moreover, NSTA refers to STS issues as the best way of preparing young people for citizenship. This is clear in NSTA's definition of STS:

Basic to STS efforts is the production of an informed citizenry capable of making crucial decisions about current problems and taking personal actions as a result of these decisions. STS means focusing upon current issues and attempts at their resolution as the best way of preparing people for current and future citizenship roles. (as cited in Ost & Yager, 1993, p. 282)

The primary objective of an STS education is to present contextual understanding of current science and technology and provide students with the intellectual foundations for responsible citizenship (Waks, 1987). In their study, J. Ramsey and Hungerford (1989) and Wiesenmayer and Rubba (1999) showed that an STS issue investigation with an action instructional model that addresses each of the four STS goal levels is crucial in promoting citizenship actions on STS issues. Within STS in science education, the emphasis on the interconnections between science and society has entailed a focus on science-related social issues. It has been argued that to empower the students as citizens, there is a need to emphasize STS (Kolstoe, 2001). It is clear that the science education community values the inclusion of a STS approach in science education programs. Therefore, it is worth raising the question: What are science teachers' beliefs concerning the STS issues? This is the focus of the next section.

STS and Science Teacher

The Association for Science Education (ASE, 1981) in its policy statement "Education Through Science," argued that in planning and developing the curriculum, teachers should show that science can be explored from the viewpoint of its applications, leading to development of an appreciation and understanding of

the ways in which science and technology contribute to the worlds of work, citizenship, leisure, and survival. To implement STS in science education, the training and psychological preparation of the teaching force must be considered (Jegede, 1988). According to Za'Rour, the unfamiliarity of teachers with the required teaching models and approaches could hinder the introduction of STS education in schools. Similarly, Rubba (1991) suggests that STS has not attained the level of implementation recommended by NSTA because the majority of the science teachers are not prepared to teach STS. Therefore, before STS teaching practices can be fully developed and put into practice appropriately, science teachers' beliefs and values about science education must be restructured in such a way that they can fully appreciate the notion of responsible citizen action on STS issues as a goal of a school science education.

Another barrier for implementing STS in the class, as Aikenhead (1984) suggests, is the socialization process that science teachers go through during their preparation in the university. When studying science at university, teachers experience a process of socialization into a discipline (B. Barnes, 1985; Ziman, 1994). From experience, teachers develop deep-seated values about science teaching (Aikenhead, 1984; Pedretti & Hodson, 1995). Aikenhead (2000) mentions that pre-service education socializes science teachers to believe that their responsibility is to socialize their students into a specifically scientific discipline. Therefore, to implement an STS science course successfully, from a teacher's point of view, the best way to initiate students into a discipline is the same way the teacher was initiated (Aikenhead, 1984). Aikenhead (2000) emphasized change in the deep-seated, personally cherished values of a number of teachers. In addition to that change, teachers must add new methods to their repertoire of instructional strategies. A new routine of instruction is best learned from fellow teachers who have practical credibility. A successful plan of action will involve few cleverly selected teachers chosen to go through an intense in-service experience. These teachers then become in-service leaders in their own regions of the country, passing on their leadership expertise to other teachers who repeat the in-service process in their own communities. An example of this approach in preparing STS teachers is presented by Pedretti and Hodson's (1995) study. Pedretti and Hodson conducted a 1-year study with six science teachers who were positively predisposed to STS science. The aim was to produce usable curriculum materials through teacher ownership and understanding, all organized

around an action research group. Pedretti and Hodson documented teachers' increased understanding in terms of the nature of science, developing curriculum materials, personal and professional development, and collaboration. In addition, participants reaffirmed many of their personal theories and practices.

Fensham (1988) reports that science teachers state that the science disciplinary background has not prepared them for STS. An undergraduate education in a science discipline rarely allows students to be aware of the controversy in pure science itself, and its patterns of teaching and learning do not usually include discussion of the merits of arguments or debating about the quality of the empirical evidence or the concepts on which this is based. Through the findings of his case study with five science teachers in the Prairie high school to explore the personal reasons, beliefs, and dilemmas underlying their decision, Aikenhead (1984) suggested three requirements so the teacher could reflect the NSTA's 1982 position statement supporting a STS approach to science teaching. These requirements are (a) an alteration in the teachers' values concerning valid science content, (b) an evaluation of socializing function of their new courses, and (c) a reformulation of the practical holistic decision-making system that currently supports and sustains them on a day-to-day basis.

STS teaching requires new models for pre- and in-service teacher education. Yager (1996) argues that the greatest problem associated with shifts in STS teaching is the failure of most teachers to have experience studying and learning themselves as STS (i.e., learning in the context of human experiences). In its policy statement "Education Through Science," the ASE (1981) argued that in planning and developing the curriculum, teachers should show that science can be explored from the viewpoint of its applications, leading to development of an appreciation and understanding of the ways in which science and technology contribute to the worlds of work, citizenship, leisure, and survival.

To implement STS in science education, the training and psychological preparation of the teaching force must also be considered (Jegede, 1988). According to Za'Rour (1987), the unfamiliarity of teachers with the required teaching models and approaches could hinder the introduction of STS education in schools. Similarly, Rubba (1991) suggests that STS has not attained the level of implementation recommended by NSTA because the majority of the science teachers are not prepared to teach it. Therefore, before STS teaching practices can be fully developed and put into practice

appropriately, science teachers' beliefs and values about science education must be restructured in such a way that they can fully appreciate what the notion of responsible citizen action actually is on STS issues as a goal of school science education.

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Aikenhead (2000) also emphasized the need to change the deep-rooted, personally cherished values of a number of teachers. In addition to such change, teachers must add new methods to their repertoire of instructional strategies. A new routine of instruction is best learned from fellow teachers who have practical credibility. A successful plan of action will involve a few cleverly selected teachers who are chosen to go through an intensive in-service experience. These teachers then become in-service leaders in their own regions of the country, passing on their leadership expertise to other teachers who repeat the in-service process in their own communities. An example of this approach in preparing STS teachers is presented in the study by Pedretti and Hodson (1995), who conducted a 1-year study with six science teachers who were positively predisposed to STS science. The aim was to produce usable curriculum materials through teacher ownership and understanding, all organized around an action research group. Pedretti and Hodson documented the increased understanding among teachers in terms of the nature of science, developing curriculum materials, personal and professional development, and collaboration. In addition, participants reaffirmed many of their personal theories and practices. (Pedretti and Hodson, 1995).

Fensham (1988) notes that science teachers state that the science disciplinary background has not prepared them for STS. An undergraduate education in a science discipline rarely allows students to be aware of controversies in pure science itself, and its patterns of teaching and learning do not usually include discussion

of the merits of arguments or debate about the quality of the empirical evidence or the concepts on which this is based. Through the findings of his case study exploring the personal reasons, beliefs, and dilemmas underlying the decision of five high school science teachers to teach, Aikenhead (1984) suggested that there were three requirements for enabling a teacher to reflect the NSTA's 1982 position statement in support of a STS approach to science teaching. These requirements were (a) an alteration in the teachers' values concerning valid science content, (b) an evaluation of the socializing function of their new courses, and (c) a reformulation of the practical holistic decision-making system that currently supported and sustained them on a day-to-day basis.

The success of science education reform depends on the teachers' ability to integrate the philosophy and practices of current programs of science education reform with their existing philosophy (Bybee, 1993). After reviewing the research, Fang (1996) pointed out that practice could be consistent with a teacher's beliefs. Pajares (1992) supported the notion that teachers' beliefs influence their perceptions, which in turn affects their behavior in the classroom. Thus, when considering the STS approach to science education, teacher beliefs about STS implementation require attention (Carroll, 1999). Without this attention, negative beliefs concerning STS implementation and inquiry learning could defeat the reform movements emphasizing STS.

Carroll (1999) argues that teachers must be involved in the actual development of the STS curriculum so they can build their knowledge concerning STS teaching and learning themes and must reform their beliefs along the way. Teachers must also have the opportunity to develop their views and beliefs about STS. In this respect, Thirumarayana (1998) suggests that before STS instruction can be implemented, teachers must first build on their interests and use that knowledge to develop conceptual understanding. Central to the realization of any curriculum implementation goal is the need for information concerning the beliefs that teachers hold about curriculum implementation and the origins of these beliefs. As Munby (1984) has clearly and articulately argued, "teachers' beliefs and principles are contextually significant to the implementation of innovations" (p. 28). Research supports the idea that teachers are crucial agents of change for educational reform and that teachers' beliefs are precursors to change (Fishbein & Ajzen, 1975; Pajares, 1992).

From this point, implementing STS in science curricula is based on the contribution of teachers and their

convictions or beliefs about such innovations. Noss and Hoyles (1996), for instance, argue that the implementation of any innovation that neglects to take account of the teachers and their work situation as mediators of the innovation is bound to fail. Therefore, it is essential to take science teachers' beliefs and practices into account and also the factors that shape or influence their beliefs and practices in order for them to be dealt with (Mansour, 2007b). Thus, to genuinely understand teachers' beliefs and practices, the next section of this article clarifies the different views about the nature of teachers' beliefs, teachers' beliefs about teaching and learning, and the relationship between beliefs and practice.

Teachers' Beliefs About Teaching and Learning Science Through STS

Researchers often categorize teacher beliefs as either behaviorist (transmissionist) or constructivist. It should be noted from the start, however, that such a dichotomy, while useful in terms of being able to clearly categorize beliefs, may be simplistic and misleading. Theories of learning, such as constructivism, are so diverse (Ernest, 1994) that it is questionable whether we can possibly categorize sets of beliefs in terms of a behaviorist/constructivist dichotomy. Not only are these theories of learning complex and open to a variety of interpretations, but teachers' beliefs themselves are also complex and sometimes contradictory and therefore resist a concise classification.

In his review of literature on teachers' beliefs and knowledge, Calderhead (1996) summarized beliefs related to teaching and learning. He placed teachers' beliefs into two categories by arguing that some teachers view teaching as a process of knowledge transmission, while others view it as a process of guiding children's learning or as a process of developing social relationships. He also distinguishes between teachers' beliefs based on their experience. Preservice teachers start with control-oriented belief systems that emphasize the importance of maintaining order and good discipline and guiding the activities of the children. During training, these attitudes become more liberal and child centered. However, when teachers enter full-time teaching, they revert to a control-oriented belief system.

Bell and Gilbert (1996) outline two extreme positions concerning the nature of teaching that can take place in a given classroom. The first states that the predominant belief is that the role of a teacher, as an expert in this knowledge, is to present such knowledge

directly to students in a logical sequence. The second position is based on the belief that knowledge is constructed by individuals and that the role of the teacher is to be a facilitator who allows students to reconstruct, extend, or replace their existing knowledge. Teachers' beliefs about science teaching are therefore extremely varied. Some teachers believe in teaching students by lecturing or direct teaching. Others reflect constructivist views of learning and teaching by using cooperative learning or inquiry. However, the majority of science teachers are more likely to mix features of science teaching methods. A teacher's belief about science teaching is more likely to include various aspects of several modes of teaching than it is to fit perfectly into the description of a single model (Mansour, 2007b).

Tsai (2002) argues that the beliefs of many teachers who hold traditional views of teaching science, learning science, and the nature of science may stem from the problem of their own school science experience. Science classes, laboratory exercises, and relevant activities in teacher education programs may have reinforced these "traditional" views. In the same way, Trumbull and Slack (1991) believe that teachers fail to develop constructivist-oriented ideas about teaching and learning because they have all experienced success in the existing (i.e., traditionally oriented) educational environments. Therefore, they may not perceive potential insights about constructivist conceptions of learning and teaching.

Teachers' beliefs about learning science refer to their conceptions of the process of learning science, what behaviors and mental activities are involved on the part of the learner, and what constitutes appropriate and prototypical learning activities. The central question of enquiry is, "How and in what way should students learn science?" An underlying feature of a particular view of learning, which can be seen to be implicit in some science teaching, has been described by D. Barnes (1973) as a "transmission view." He describes the teacher who adopts this view as operating a "speaking tube" down which he or she sends knowledge when he or she asks pupils questions or tells them to write. He considers that it is primarily in order to test whether they have in fact received the knowledge transmitted by the teacher. A teacher who follows a transmission mode is one who:

- believes knowledge to exist in the form of public disciplines, which include content and criteria performance (this often means that they see themselves as "authorities" in a subject)

- values the learner's performances in so far as they conform to the criteria of discipline
- sees the teacher's task to be the evaluation and correction of the learner's performance, according to criteria of which he or she is guardian
- sees the learner as an uninformed acolyte for whom access to knowledge will be difficult since he must qualify himself through tests of appropriate performance. (D. Barnes, 1973; Bell & Gilbert, 1996; Trumbull & Slack, 1991)

According to Scott (1987), within the "transmission view," a tacit assumption being made by the teacher is that the students do not bring relevant ideas of their own to lessons and that they act simply as recipients of knowledge, adding the information to their "memory store." Thus, chunks of information are transferred from teacher to pupil during teaching.

This view is reflected in a variety of ways: through the teacher's approach to the curriculum, in the type of teaching strategies adopted by the teachers, and in the way students are assessed (Scott, 1987). As for the "transmission view" of learning, the curriculum is seen as the list of things to be taught. Science is thus presented as a catalogue of "facts." Also, the emphasis is on "closed" teaching strategies, which support the flow of information from teachers to students. Moreover, the interactions between the teacher and students in the class have the traditional characteristics of the classroom, with the teacher asking a series of closed questions and students playing the game of "guess what the teacher is thinking." According to a "transmission view," evaluation of learning emphasizes summative assessment; knowledge has either been transferred or it has not. The teacher is seen as being the active transmitter of knowledge. The pupil is initially empty headed and plays an intellectually passive role in adopting that knowledge.

As for a behaviorist perspective, the transmission of information from teacher to learner is essentially the transmission of the response appropriate to a certain stimulus. Thus, the point of education is to present the student with the appropriate repertoire of behavioral responses to specific stimuli and to reinforce those responses through an effective reinforcement schedule. An effective reinforcement schedule requires consistent repetition of the material; small, progressive sequences of tasks; and continuous positive reinforcement. Without positive reinforcement, learned responses will quickly become extinct. This is because learners will continue to modify their behavior until they receive some positive reinforcement

(Skinner, 1976). Fox (1983) uses the term *transfer theory* to refer to teachers within the transmission mode. He suggests that teachers who adopt the transfer theory tend to express their view of teaching in terms of "imparting knowledge," "conveying information," "giving the facts," or "putting over ideas." Two of the teaching methods, the lecture and the "chalk-and-talk" approach, represent the classical ways of seeing the transfer or transmission theory in action (Bentley & Watts, 1989).

In contrast to the transmission view, there is a constructivist view about teaching/learning science though STS. What we call a constructivist approach in science education is a proposal that contemplates active participation of students in the construction of knowledge and not the simple personal reconstruction of previously elaborated knowledge provided by the teacher or by the textbook (Gil-Perez et al., 2002). As Hodson (1992) has stated, students develop their conceptual understanding and learn more about scientific inquiry by engaging in scientific inquiry, provided that there is sufficient opportunity for and support of reflection.

From a constructivist perspective, learning is viewed as the active construction of knowledge in gradually expanding networks of ideas through interaction with others and materials in the environment (Marshall, 1992). The goal of science teaching might be to develop individuals who think for themselves (Newbrough, 1995). Such people have some measures of control over the meaning they make of their experiences and the ways in which they construct their lives and ideas. Constructivism places primary emphasis on the independence of each person's interpretation of his or her own experience (Roth, 1994). The implications of constructivist views for the science classroom include the ample use of hands-on investigative laboratory activities, a classroom environment that provides learners with a high degree of active cognitive involvement, the use of cooperative learning strategies, and the inclusion of test items that activate a higher level of cognitive processes. Also, the main pedagogical implication is that the active learner's construction of his or her own understanding can be facilitated by teachers who provide stimulating and motivational experiences that challenge students' existing conceptions and involve them actively in the teaching/learning process (Gil-Perez et al., 2002; Matthews, 1997, 2002).

Within the constructivist view, as mentioned by Watts (1994), science needs to be relevant to students' everyday lives, since this real context provides the

roots from which their studies should be drawn. It needs to be related to their hobbies and modern lifestyles, to current affairs and television news, to people and practices in the world. Watts (1994) also notes that the movement for relevance is not new and that it helped to shape school science in the United Kingdom throughout the 1980s so that schemes like SATIS (Science and Technology in Society) were motivated by the need to relate the "application" of science to current issues in society.

Constructivist teachers of science promote group learning, where two or three students discuss approaches to a given problem with little or no interference from the teachers. In contrast to traditional teachers who see that a given problem has only one solution, constructivist teachers would rather explore how students see the problem and why their paths toward solutions seem promising to them. Constructivist teachers also help students connect their own prior experiences to current situations (Yager, 1996). However, the teachers' roles are different in the behaviorist approach, where a teacher's task consists of providing a set of stimuli and reinforcements that are likely to make students emit behavior (Yager, 1996). In real science classes, science students seldom see anything they study as having any relevance or applicability in their own lives.

Conclusion

Science teachers are the most important key in shifting toward STS education. Therefore, for a successful shift to occur, a science teacher has to have a very complete understanding of what STS education is about and the philosophy behind it. They also need support and help from other people involved in education. According to Heath (1992), many good STS units and programs result from individual teachers striking out on their own, filled with enthusiasm, ability, and dedication to the importance of STS but with little support. Without support, it is difficult to expend or maintain the quality of ongoing STS instruction. Technology, interdisciplinary teacher teams, and university partnerships could be sources for support (p. 52).

The success of STS education reform depends on the teacher's ability to integrate the philosophy and practices of STS education reform with his or her existing philosophy. This article supported the notion that teachers' beliefs about STS education influence their behaviours in the classroom. Thus, when considering the STS approach to science education, teacher beliefs about STS implementation require attention.

Without this attention, negative beliefs concerning STS implementation could defeat the reform movements emphasizing STS.

Teaching science within the STS paradigm is derived by both the students and the teacher working cooperatively together or from suggestions offered by students based on their interests and life issues confronting them. So it is very important to consider students' views, interests, and attitudes when developing the science curricula.

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