

A Science Teacher's Reflections and Knowledge Growth About STS Instruction After Actual Implementation

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ABSTRACT: The major purpose of this study was to describe a science teacher's views of STS (Science–Technology–Society) instruction and what she acquired after implementing a two-semester STS-oriented science course in a high school of Taiwan. Upon analysis of the teacher's journals, interview data, concept maps, and relevant student questionnaire responses, this study revealed the following findings. The teacher believed that STS instruction was a potential way of practicing so-called “constructivist” teaching and her pedagogical knowledge about STS showed a considerable growth. As a result of STS instruction, her epistemological views of science seemed to progress toward more constructivist-oriented views of science. The heavy content load of Taiwan's national curriculum, regular cross-class standard tests, the lack of peers' or administrative support, the resource limitations in Chinese language, and the cultural impacts were identified as major factors that inhibited her implementation of STS instruction. © 2001 John Wiley & Sons, Inc. *Sci Ed* **86**:23–41, 2001.

INTRODUCTION

Science educators always search for more potential ways of instruction to help students learn science. In recent years, science educators have suggested various directions for the improvement of science education. For example, science instruction should present scientific knowledge in more authentic contexts (McGinn & Roth, 1999; Roth, 1995, 1997). To promote students' meaningful learning, science educators need to encourage students' discussion, argumentation, social negotiation, and cooperative learning (Newton, Driver, & Osborne, 1999; Springer, Stanne, & Donovan, 1999). Science education should help students develop problem-solving skills and apply scientific knowledge in solving everyday problems (National Research Council, 1996; Slack & Stewart, 1990). In addition, science curriculum needs to address more about the nature of science (Driver et al., 1996;

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Duschl, 1990, 1994; Lederman, 1992; McComas, 1998) and science education should prepare for future citizenship. (Hoffman & Stage, 1993; Yager & Weld, 1999).

Although STS instruction is not a new idea, its content and the instructional modes, clearly, fulfill the directions above. For example, the content of STS instruction addresses the active interplay among science, technology, and society; hence, science does not stem from a vacuum. In this way, it may shape a more authentic image of science for students. Moreover, the inquiry-oriented activities of STS instruction can develop students' problem-solving skills and encourage their social negotiations and cooperative learning. STS instruction provides a broader view of science learning that integrates the features of major reforms in science education. Hence, STS instruction has been proposed as a way of reforming the practice of science education since 1980. Until now, it still can be viewed as one of the major trends in science education research. Moreover, the features of STS instruction are consistent with those elaborated as examples of constructivist practices (Yager, 1995). Also, although constructivism is still a controversial topic in science education (Matthews, 2000; Osborne, 1996; Phillips, 1995), the position of this paper, as that proposed by Staver (1998) and Tobin (1993), believes that constructivism is a sound theory to help science educators understand how students learn science as well as to explicate the practice of science and science teaching. The constructivist perspective in this paper, as that suggested by Taylor, Dawson, and Fraser (1995), and Tsai (1998a), asserts that knowledge acquisition is a cognitive constructive activity of an individual learner which occurs within, and is constrained by, a socio-cultural context.

Basically, there are two sides of research on STS instruction, one is about students and the other is about teachers. In the past decade, a plentiful literature has revealed that STS instruction generally is helpful in enhancing students' knowledge achievement, process skills, creativity, scientific attitudes, decision making, and epistemological views about science (Pedretti, 1999; Solbes & Vilches, 1997; Yager & Tamir, 1993; Tsai, 1999a, 2000a). Aikenhead's review also revealed that although different researchers explored various outcomes of STS instruction because of the researchers' different views of STS, students could benefit from learning science through STS and they benefited quite consistently (Aikenhead, 1994a). On the other side of research, educators have widely explored teachers' views about STS instruction and intentions to implement STS instruction (e.g., Lumpe, Haney, & Czerniak, 1998; Mitchener & Anderson, 1987; Rubba & Harkness, 1993). However, not much research explored teachers' views about STS instruction after *actually* implementing STS instruction and what they acquired as a result of conducting STS instruction. In other words, much earlier research work may ask teachers to reflect their views about STS instruction without real practice. Researchers may agree that it will be more realistic to examine teachers' views about STS instruction if the teachers really practice some STS teaching activities. The purpose of this paper was to report a case of a science teacher's views about STS instruction and what she acquired after actually implementing 8-month STS instruction on a female 10th-grade science class in Taiwan.

This study also investigated an important research issue, that is, the case teacher's *scientific epistemological views* (SEVs). Teachers' SEVs are often considered as an important factor that frames their teaching beliefs, and these views may be related to instructional practice (Hamrich, 1997; Lederman, 1992; Nott & Wellington, 1995). The studies by Brickhouse (1989) and Hasweh (1996) showed that teachers' SEVs, to a certain extent, were consistent with their teaching. For example, Hashweh (1996) found that teachers holding constructivist SEVs tended to be more likely to detect student alternative conceptions and to use potentially more effective teaching strategies for inducing student conceptual change. However, the research by Mellado (1997) and Lederman (1999) revealed that the correspondences between teachers' SEVs and actual teaching practice were more

complicated than originally assumed. For instance, Lederman (1999) found that teachers' level of experience, intentions, and perceptions of students were more important factors related to classroom practice. Moreover, given the fact that science educators often show much dissatisfaction with the levels of teachers' SEVs (Duschl, 1990; Lederman, 1992), another area of relevant interest is how to change teachers' SEVs. Abd-El-Khalick and Lederman' study proposed that there were two major approaches of changing teachers' SEVs: one was implicit, using science-based inquiry activities, and the other one was explicit, utilizing elements from the history and philosophy of science in the instructional process (Abd-El-Khalick & Lederman, 1998). The study by Abd-El-Khalick and Lederman (2000), which assessed the influences of history of science courses on preservice science teachers' SEVs, clearly, employed the explicit approach. Palmquist and Finley's research (Finley, 1997), which showed that some preservice teachers could progress toward constructivist SEVs when conceptual change, inquiry-oriented, and cooperative learning were taught, can be viewed as using an implicit approach. The present study further hypothesized that STS instruction may change the case teacher's SEVs. The use of STS instruction as a means of changing teachers' SEVs can be regarded as both implicit and explicit, because the STS instruction, at the methodological level, conducts science-based inquiry activities, while, at the content level, it may include historical cases and discuss some epistemological issues.¹ Consequently, one of the main foci of this study was to document the case teacher's possible SEV change as a result of implementing STS instruction.

METHODOLOGY

The Teacher and Study Context

The case teacher was a female high school science teacher in Taipei, Taiwan. The teacher is called as Sherry (pseudonym) in this paper. Sherry's school was a 7–12 high school near the central area of Taipei City. The 10th graders in the school were selectively admitted on the basis of their testing scores on a Joint High School Examination of Taipei City. The 10th-grade had about 800 students, with eight classes of (single-sex) male students, and eight classes of female students. In general, they were top 40–15% students, in comparison to all same-aged student population in Taiwan. The administrative systems and the cultures of the school (10th–12th-grade) represented a typical city-oriented high school in Taiwan, a traditional-oriented school setting. Sherry's Dean identified her as an outstanding teacher who enjoyed teaching and showed enthusiasm for enhancing science instruction. Sherry reflected herself as a teacher with high intentions of helping students and she believed that every student could learn science well and confidently.

With a bachelor in physics and three years of teaching, Sherry taught 10th-grade "fundamental physical science" course and 11th-grade "physics" course during the conduct of this study. Sherry's "fundamental physical science," a two-semester course required for all 10th graders in Taiwan, was the place for practicing STS instruction, and the class for study included 52 female students. Sherry began her actual practice of STS instruction in the 2nd month of the course. Although Sherry had attended several workshops about STS instruction, in the beginning of this study, STS instruction still remained as "paper work" for her. Some of the STS materials used in this study came from Sherry's collection from the workshops. The author and some other STS researchers in Taiwan also wrote or gave relevant documents to facilitate the instruction. Many STS-related projects directed by the National

¹ Tsai's paper has provided more discussion about how STS instruction may help people develop relatively more mature (in this paper, constructivist-oriented) SEVs (Tsai, 1999a). Readers of interest can refer to the article.

Science Council and Ministry of Education, Taiwan, ROC also offered useful modules for this study. This was Sherry's first time to actually practice STS instruction on her students, and the study lasted two semesters or 8 months. Tsai (1999a, 2000a) has reported Sherry's students' cognitive structure gains and scientific epistemological view change derived from STS instruction.

Data Sources

The research data of this study mainly gathered from a series of interviews and Sherry's journals. Formal interviews were conducted five times from the time just prior to the STS course implementation to the time immediately after it. The interval between any two consecutive interviews was about 2 months. The interview mainly explored Sherry's views about STS instruction, the gains and difficulties she experienced from the instruction. The first and final interviews also explored her epistemological views of science (described later). In addition, the teacher was asked to keep a journal every 2 weeks to reflect her experiences of implementing STS instruction. As a result, about 15 biweekly journals were collected in this study.

Moreover, Sherry was asked to draw two concept maps (Novak & Gowin, 1984) on the topic of STS instruction to represent her pedagogical knowledge. One concept map was completed prior to the actual implementation, while the another one was constructed immediately after the two-semester STS instruction. The use of concept map as a way of exploring teachers' pedagogical views or pedagogical growth was recommended by several researchers (Morine-Dershimer, 1989, 1993; Morine-Dershimer et al., 1992; Raymond, 1997). The concept maps in this study did not intend to provide quantitative analyses or make comparisons with some other teachers; rather, the maps were considered as an alternative way that showed Sherry's possible knowledge growth about STS instruction resulting from actual implementation.

In addition, as proposed earlier, this study viewed the implementation of STS instruction as a possible means of changing teachers' SEVs. The exploration of Sherry's SEVs was one of the major foci in this study. Sherry's SEVs were mainly explored through interviews. To document Sherry's possible view change, SEV interviews were conducted both before and after STS instruction practice (i.e., the first and final formal interviews described earlier). The interview framework was based on the assertions summarized in Tsai's (1998a) paper, which discussed a contrast between empiricist epistemology and constructivist epistemology. The framework is presented in Table 1.

The interview was conducted to explore five major aspects of Sherry's SEVs and these aspects were called "interview dimensions" in Table 1 and also throughout this paper. These interview dimensions, which were also used to explore the SEVs held by Sherry's students (Tsai, 1999a), included the following major interview questions.

1. The invented reality of science (e.g., Do scientists "discover" or "invent" scientific knowledge? Why?)
2. The theory-laden quality of scientific exploration (e.g., Does theory play a role on scientists' exploration or observations? How? Do scientists have any expectation before conducting the exploration? Why?)
3. The conceptual change of scientific progression (e.g., After scientists have developed a theory, does the theory ever change? What kind of change may occur in the development of scientific knowledge, e.g., accumulation or shift?)
4. The role of social negotiations in science community (e.g., Do other scientists influence one scientist's research work? Or science is a process of individual exploration, mainly depending on personal efforts? How?)

TABLE 1
The Dimensions of Interview Framework of Exploring the Teacher's Scientific Epistemological Views

Interview Dimension	Constructivist SEVs	Empiricist SEVs
The invented reality of science	Scientific knowledge is invented	Scientific knowledge is discovered
Theory-laden quality of scientific exploration	Scientific exploration is theory-laden	Scientific exploration is theory-neutral, mainly from objective observations
Conceptual change of scientific progression	The progress of science encounters a series of conceptual change	The progress of science is a process of conceptual addition
The role of social negotiations in science community	The development of science relies on the social negotiations in science community	The development of science is a process of individual discovery
The cultural impacts on science	Science is culture-dependent	Science is culture-independent

5. The cultural impacts on science (e.g., Do different cultural groups of people have different types of “science”? How? Does culture influence the development of scientific knowledge? How?)

Table 1 shows that constructivist-oriented SEVs assert that scientific knowledge is an invented reality, which is developed through the use of agreed upon theories, shared forms of evidence, and social negotiations in the scientific community. These views also emphasize the role of conceptual change in the development of science, and cultural impacts on science are also well recognized. The empiricist-aligned SEVs tend to support opposing views.

All of the formal interviews in this study were conducted in Chinese by a trained research assistant. The interviews were audiotaped, and were later transcribed by the assistant. Then, the author analyzed and interpreted the interview data. The author translated the interview and journal data cited in this paper. The translated data were further examined by a second independent Chinese speaker, who actually listened to the interview tapes and read Sherry's biweekly journals.

Finally, to explore some possible linkages between STS instruction and constructivist learning environments, a CLES (Constructivist Learning Environment Survey) instrument was administered to students in the final month of this study. CLES was originally developed by Taylor and Fraser (1991) and it included the following four scales: social negotiation, prior knowledge, autonomy, and student-centredness. Each scale contained seven 5–1 Likert items and the score ranged from 7 to 35. This study used the “actual” form of CLES; hence, higher scores indicated that students perceived the actual learning environments as more close to constructivist-oriented ones. The following four questions are sample items:

1. In this class, I ask other students about their ideas. (social negotiation scale)
2. In this class, I get to think about interesting, real-life problems. (prior knowledge scale)
3. In this class, I find my own way of doing investigations. (autonomy scale)
4. In this class, the teacher expects me to remember important ideas I learned in the past. (student-centredness scale, scored in a reverse manner)

The Chinese version of CLES was used in another study with 1176 Taiwanese 10th graders (Tsai, 2000b). Tsai (2000b) reported the reliability of CLES to be around 0.75 for each scale. In this study, CLES was administered to Sherry's students and a comparable group of students in the same school who received traditional approaches of science instruction. That is, the instrument was administered to the students of the STS group ($n = 52$) and those of the control group ($n = 49$) reported in Tsai's papers (Tsai, 1999a, 2000a). In this way, this study can examine whether STS instruction can create more constructivist-oriented learning environments.

The Researcher's Role

The author was the main researcher conducting this study. The author played a role of a researcher and a facilitator on Sherry's STS instruction. Although Sherry had some STS materials gathered from the workshops she had attended before, the author provided additional literature and teaching modules for her. The author also offered some guidance if requested by Sherry. Moreover, Sherry herself regularly videotaped the STS classes (almost once a week). The author viewed the videotapes and then discussed with Sherry for possible instructional assistance. In order to avoid the interruptions of the teaching and pressures caused, the author, however, did not conduct any participant observations in the STS classes. In this way, the STS instruction was assumed to be implemented in a more natural way. In addition, the researcher gave continual moral support and encouragement throughout the whole process of the STS implementation.

This study does not suggest that the findings derived from Sherry's reflections are representative; however, it provides initial insights for STS teachers' possible knowledge growth, SEV change and factors which may influence the actual implementation of STS instruction.

FINDINGS AND DISCUSSION

The Practice of Constructivism

First, after two-semester STS instruction, Sherry believed that STS instruction is a clear and appropriate way of practicing so-called "constructivism." In the fourth interview, she stated that

In the workshops I participated before, I heard a lot of concepts and ideas about constructivism. I always thought that it was too vague or I got an image that everything in science education was related to constructivism. But there are no clear rules or guidelines to follow when trying to practice it. In recent months, I gradually understand what is "constructivist-oriented" science teaching.

In other words, STS instruction helped Sherry obtain a clear picture about how to practice the theory of constructivism. Constructivist-oriented science teaching emphasizes learners' prior knowledge and social negotiations. These features were reflected at Sherry's journals. For example, she wrote the following:

In today's class, I presented a discrepant event about electricity to students and asked to discuss its possible outcomes and then give reasons. Students' ideas are far from my expectation. They are creative, though in many cases, not scientifically correct. I now realize the importance of prior knowledge and group discussion Now, I recognize the merits of constructivism. My students try to "construct" their knowledge. (the 4th month, 4th week's journal)

Group discussion really can be implemented in my class, although, until now, it is not very successful for some students. However, in the past, I always thought that small group discussion could be effective for much higher-aged students or for students in US television programs, but definitely not my students. It, now, seems O.K. for my students. (The final month, 2nd week's journal)

Sherry, through the observations of students' activities, realized the major feature of constructivism that students did "construct" their own knowledge. The STS instruction also encouraged group work and discussion and it gave Sherry a chance of practicing some examples of constructivist-oriented teaching. Students' responses on the CLES instrument, which was administered at the final month to both Sherry's students and a comparable group of students receiving traditional teaching, revealed a similar finding. The *t*-test analyses on examining the CLES score differences between two groups indicated that Sherry's students perceived their learning environments as more constructivist-oriented than did their counterparts in three of the four CLES scales, shown in Table 2. Students in STS instruction group viewed that their learning environments placed more emphasis on social negotiations, prior knowledge and autonomy.

Although some science educators do not agree there exists a consistency between STS pedagogy and the constructivist-oriented teaching (Roth, 1989), STS instruction is viewed as practical applications of constructivism from Sherry's perspective. Yager (1995) shares a similar belief and he stated, "The features of STS teaching are congruent with those elaborated as examples of constructivist practices" (p. 40). Heath (1992) summarized some effective teaching strategies of STS instruction, which included exploration of real life problems, cooperative and collaborative teacher-student approach, debates and small group discussions, and clearly, these are examples of constructivist-oriented instructional activities. Although some workshops on STS and constructivist philosophies may be helpful on developing teachers' views about constructivist teaching (e.g., Cho et al., 1997), this study believes that actual implementation of STS instruction may be a more effective way.

Views and Knowledge About STS Instruction Shown in Concept Maps

Sherry's views and knowledge about STS instruction were also collected through concept maps. Figures 1 and 2 show the concept maps she drew about STS instruction prior to and after the actual implementation respectively.

TABLE 2
A Comparison of CLES Scores Between Traditional Teaching Group and STS Instruction Group

Scale	Traditional Group (<i>n</i> = 49)		STS Group (<i>n</i> = 52)		<i>t</i>
	Mean	SD	Mean	SD	
Social negotiation	20.12	4.23	21.98	4.11	-2.24*
Prior knowledge	18.98	4.06	20.81	4.34	-2.18*
Autonomy	18.41	4.41	22.60	4.28	-4.85***
Student-Centered	17.98	4.23	18.44	4.48	-0.53

p* < .05, **p* < .001.

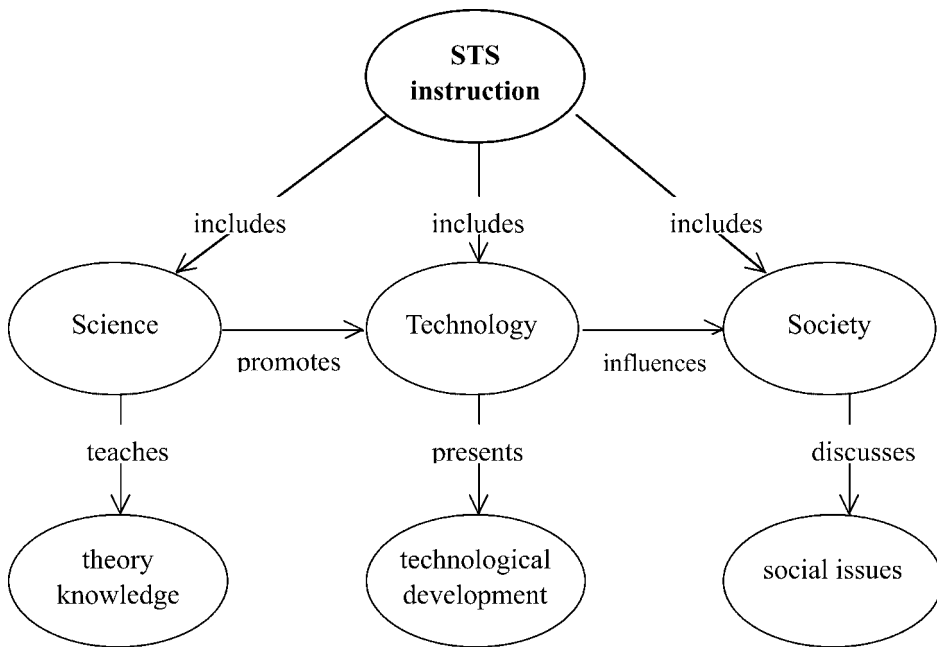


Figure 1. Sherry's concept map about STS immediately before this study.

It is clear that Sherry's knowledge about STS were enriched after actual implementation. Before actual implementation, Sherry's ideas about STS only included a simply interplay among scientific knowledge, technological development, and social issues. Although she had attended some workshops of STS, her initial ideas of STS implied a linear linkage existing among science, technology, and society that science promoted technology and technology influenced society. This is a naive view identified by Rubba and Harkness (1993). However, after practicing STS instruction for two semesters, she perceived STS instruction from various perspectives. For example, she viewed STS as an integrated curriculum that promoted students' scientific knowledge, process skills, citizenship behaviors, and decision-making abilities. Also, constructivism was clearly in her frameworks of STS instruction, and many constructivist-oriented teaching approaches recommended by science educators, for instance, cooperative learning, discussion activities, and conceptual change strategies, were displayed in her postconcept map. It is plausible to conclude that the actual implementation clearly helped her conceptualize the rationales and strategies of STS instruction and then showed a considerable pedagogical knowledge growth about STS.

Epistemological Views of Science

How STS instruction may change Sherry's SEVs is another important concern in this study. Sherry's students seemed to progress toward constructivist-oriented SEVs as a result of STS instruction (reported in Tsai [1999a]). It is interesting to explore whether Sherry showed a similar change.

In the dimension of "the invented reality of science," Sherry, in the beginning of this study, believed that science was discovered, existing there for scientists to discover. She stated that

Science is obviously discovered. Scientific knowledge comes from our observations around the world. It is already there for us to find out. (first interview)

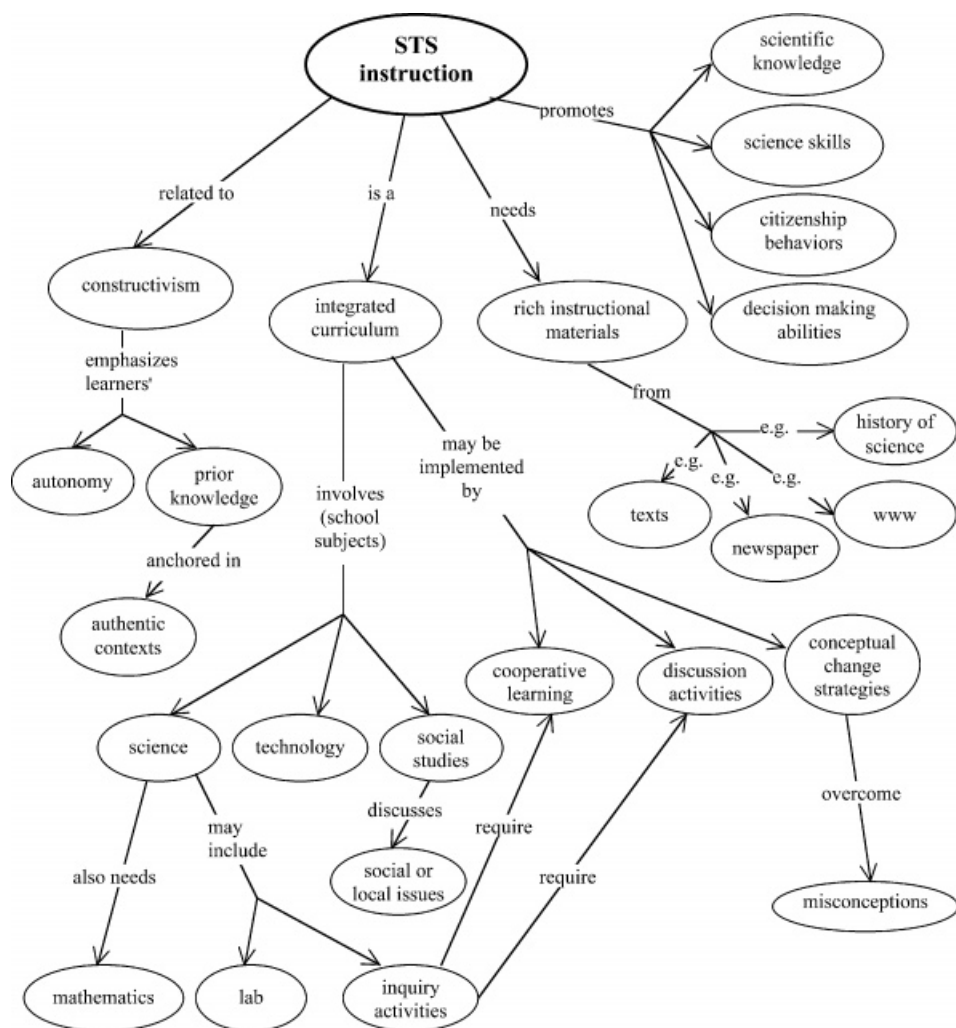


Figure 2. Sherry's concept map about STS after this study.

This view is similar to that held by many science students and teachers in other studies (e.g., Lederman, 1992; Ryan & Aikenhead, 1992; Tsai, 1998b). However, after the STS instruction of this study, Sherry herself developed a simple framework of viewing scientific knowledge. She expressed that

I think there are two kinds of scientific knowledge; one is descriptive while the other is explanatory. For me, the descriptive knowledge is discovered, but the explanatory knowledge is invented The explanatory knowledge requires scientists' creativity and imagination. For example, Hook's law is discovered, while theory of relativity is invented. (final interview)

Although Sherry did not clearly state the idea source of this framework, she gradually appreciated the creative aspects of scientists' work and accepted the view that not all of scientific knowledge was discovered. Furthermore, in the dimension of "theory-laden quality of scientific exploration," Sherry, in the beginning of this study, seemed to hold a position like "blind idealism" described by Nadeau and Desautels (1984) that the scientist

is a totally objective human being. She stated that

Scientists need to be objective. Their theoretical perspectives do not affect their observations and research interpretations. They report what they really observe. (first interview)

However, after actual implementation of STS instruction, her views exhibited a clear change.

I think, scientists' personal theories will affect the processes of conducting exploration and their experiments . . . They do not have blank minds when doing research. They have some expected results about their research . . . In many cases, I think they may choose to report some findings that favor their personal theories. (final interview)

Although Sherry reflected that her SEV change might come from some reading drawn from the history of science (reported later), Tsai (1999a) has hypothesized that the inquiry activities conducted in STS instruction can help people understand the theory-laden quality of scientific exploration. In the dimension of "conceptual change of scientific progression," Sherry, both in the first and final interview, showed a mixed view. She stated that

Science is cumulative. It tries to replace incorrect knowledge discovered in the past. However, in some special cases, it takes some leaps. (first interview)

Science develops mostly through accretion, but in special cases its perspectives shift a lot. (final interview)

Sherry's SEVs in this dimension did not display an apparent change. Science educators may find more effective ways of changing people's SEVs about this dimension. Moreover, Sherry, in contrast to the teachers in Abell and Smith's study who placed little emphasis on social dimensions in scientific community (Abell & Smith, 1994), emphasized the importance of scientists' social communication and debates for the development of scientific knowledge. In the dimension of "the role of social negotiations in science community," Sherry, both at the beginning and the end of the STS instruction, expressed constructivist-oriented SEVs. For example, She stated that

Scientists' research work is influenced by other scientists. The development of science relies on many scientists' validation; otherwise, it can not become accepted knowledge. Other scientists' comments and verification are important in increasing the power of the knowledge. (first interview)

Sherry, at the final interview, further attributed the significance of scientific knowledge to the social aspects of scientific community.

Science acquires its significant status mainly because of the frequent debates among contemporary scientists. The communication between competing ideas facilitates the progression of scientific knowledge. (final interview)

Similarly, in the dimension of "cultural impacts on science," Sherry, both at the beginning and the end of the STS instruction, expressed constructivist-oriented SEVs. She believed that

Science is influenced by cultures, and western science is a product of western cultures. (first interview)

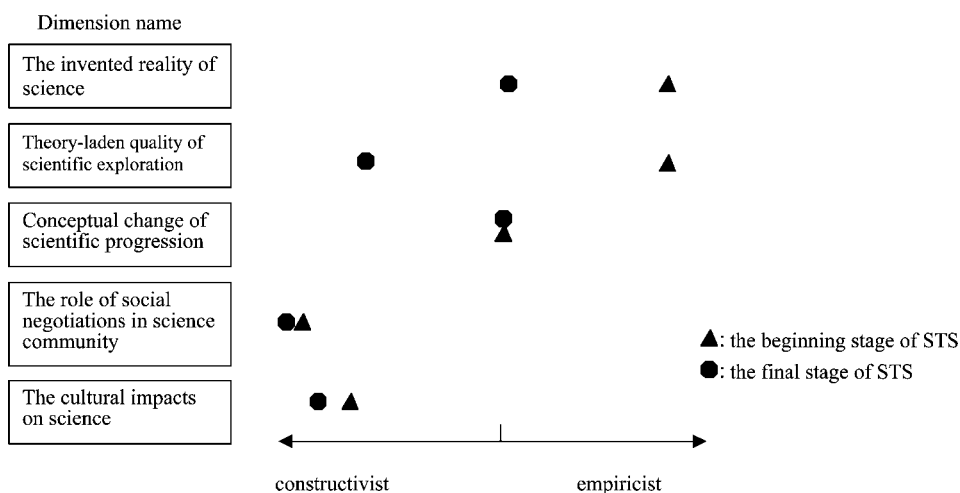


Figure 3. The change of teachers' scientific epistemological beliefs resulting from STS instruction.

Science is not only influenced by cultures. The politics and society may impose large impacts on it Certainly, the politics and society can be interpreted as a form of cultures. These cultures may facilitate or inhibit the development of science. (final interview)

Sherry seemed to have a broader recognition about cultural impacts on science after STS instruction. Sherry's SEVs in each interview dimension are summarized in Figure 3.²

In sum, at the beginning stage of STS instruction, Sherry's SEVs, in some interview dimensions, were oriented to empiricism, but some dimensions were oriented to constructivism. The study completed by Haidar (1999) has revealed a similar finding that many teachers' SEVs are mixed views of empiricism and constructivism. This also concurs with the conclusion drawn from Lakin and Wellington (1994) that teachers' SEVs may share some merits of empiricism, but their orientations are more complicated. However, after actual STS implementation, Sherry's SEVs, in each dimension, were labeled as constructivist-oriented or at least, mixed. Sherry herself recognized such a SEV change, and reflected the incentive of change from the following:

In the process of STS instruction, I collected some lessons from the history of science. I found that scientific knowledge is not developed in a straightforward way as I assumed before. It involves many theoretical, social and, even political issues. I guess that may be the major sources of my view change. (final interview)

This way of changing SEVs is categorized as an explicit mode by Abd-El-Khalick and Lederman (1998). The explicit mode of changing SEVs mainly utilizes elements from the history and philosophy of science.

This study indicated that Sherry's SEVs in some dimensions changed toward more constructivist-oriented ones. Tsai (1999a) reported earlier that Sherry's students progressed toward more constructivist-oriented SEVs after the 8-month STS research treatment.³

² The SEV orientations marked in Figure 3 were placed by the author after a discussion with Sherry. In other words, Sherry agreed such a representation about her SEVs.

³ To state more specifically, at the final stage of STS instruction, the SEVs held by Sherry and by her students shared similar orientations at least in the following three interview dimensions: theory-laden quality of scientific exploration, the role of social negotiations in scientific community, and the cultural impacts on science. In the remaining two dimensions, Sherry tended to have mixed views while her students tended to have more empiricist-aligned views.

Laplante (1997) and Lyons (1990) supported a claim that “teachers and students have interconnected and interacting epistemological perspectives, what might be called nested epistemologies, each influencing the other in learning” (Laplante, 1997, p. 279). This study may imply a similar assertion that teachers and students have nested epistemologies of science, each influencing the other in teaching and learning. This sustains a research assumption elaborated by Bell, Lederman, and Abd-El-Khalick (1998) and Hammrich (1997) that teachers’ SEVs are related to their students’ SEVs.

Ryder, Leach, and Driver (1999) further suggest that science teachers, as mediators of the cultures of science, need to incorporate epistemological views of science (or the images of science) into curriculum, and communicate these ideas either explicitly and implicitly in their teaching. Bianchini and Colburn (2000) also recognized the teachers’ pivotal role on discussing the nature of science for students. They also encourage teachers to explicitly engage students in discussions that connect instructional activities (e.g., hands-on inquiries) to the ideas related to the nature of science. In particular, a series of Tsai’s research work revealed that students having constructivist-oriented SEVs tended to employ more meaningful approaches to learning have more integrated knowledge frameworks, and prefer constructivist instructional environments (Tsai, 1998b, 1998c, 1999b, 1999c, 2000b). This paper indicates that STS instruction may illuminate a potential way of exploring the epistemological views of science for both science students and teachers, and the STS instruction itself may help them progress toward constructivist-oriented SEVs.

This paper then approaches another important research question. That is, from Sherry’s perspective, what may be important factors affecting her implementation of STS instruction. According to her interview data and journal writing, this study concluded the following major factors: cultural influences, national curriculum, standard tests, peers’ or administrative support, and the availability of relevant resource.

The Cultural Influences

From the 1st month of this study, Sherry recognized cultural experiences may have caused some difficulties of implementing STS instruction.

My students are not well able to conduct inquiry activities. They do not know how to set questions, manipulate the variables, and analyze the data. This situation may come from the idea that they may not have such experiences from previous education. I suspect myself whether I could do that well at even a more mature age than their age. Maybe, our cultures do not exist such a way of inquiry. (The 1st month, 4th week’s journal)

Lee (1999) exactly noted this and argued that in some cultural contexts, inquiry is not part of their cultural experiences. These students and even their teachers need to be explicitly taught how to engage in the communication, discussion, and inquiry processes. As expected, the cultural influences were manifest in students’ group work and discussion activities. Sherry stated that

The students in Taiwan or the whole Taiwanese cultures do not enjoy discussion. The cultures do not encourage people to express their own ideas. The cultures do not value people expressing different ideas. These may cause some problems of implementing STS instruction. (the 2nd interview)

After several months, based on Sherry's reflections and the viewing of videotapes, many students seemed gradually to be easy in group work and discussion. Sherry reflected that

Through my encouragement, more and more of my students try to express their ideas. In the past, students were afraid of saying something wrong. It seems that, in our cultures, no idea is better than having a wrong idea. Or, having a wrong idea unrecognized by others is still better than having a wrong idea known by others. (the 4th month, 2nd week's journal)

It is impressive that at the end of this study, Sherry wrote that

This week, I asked students to discuss the possible causes of greenhouse effects. Some of my students were eager to express their views. Then, they were arguing which one was the most influential cause. I got a feeling that they were scientists, fighting for their ideas. I enjoyed the communication processes, although I often had difficulties in managing their argumentation. (the 9th month, 2nd week's journal)

Although cultural experiences may have imposed some obstacles on these students' inquiry and discussion activities, through the teacher's appropriate guidance and encouragement, students could gradually learn to do these. The cultural differences also imply that science education needs to explore science in other cultures and then give students a broad vision about "science," not just "western science." Lee (1999) asserted that recognizing the contributions of other cultures in science and technology can motivate diverse students to participate in these areas, and provide a broader view of science. This is particularly important for science educators in nonwestern countries. These educators are asked to teach western science in a nonwestern context. They may encounter some conflicts between school knowledge and cultural experiences. Cross (1999) pointed out similar tensions between "western" science and local cultures in nonwestern societies. It is, however, still not conflicting to integrate some theoretical perspectives derived from local cultures into science curriculum, and explain to students that they are different modes of thinking and reasoning because of historical and cultural developments. STS instruction may well present such an integrated curriculum, especially in nonwestern countries. In fact, Sherry, in the process of STS instruction, presented many cases from Chinese history of science. She responded that

My students often thought that Chinese or Taiwanese did not have "science." Through presenting some historical cases, they gradually found that we have our own science, although it is not the mainstream perspective. Students find that it is interesting, and gradually recognize that they are different sets of theories, not better or worse. (the 4th interview)

As a result, Sherry's students tended to perceive that the development of science was influenced by cultures. Hence, Tsai (1999a) reported that Sherry's students had a clear SEV progression on the dimension of "cultural impacts on science" (listed in Table 1).

Other Factors Influencing the Implementation of STS Instruction

Sherry's journals and interview data also revealed some other factors influencing the implementation of STS instruction. For example, she reflected that the heavy load of Taiwan's national curriculum and the regular cross-class standard tests caused serious time constraints in implementing STS instruction.

I feel that I cannot teach as many concepts as I taught before. It seems that students acquire a deep exploration about the selected concepts, but I worry how they will perform in the regular standard tests? (the 2nd month, 4th week's journal)

Group discussion really can be implemented in my class, although, until now, it is not very successful for some students. . . . It, now, seems O.K. for my students. But it takes time for me to negotiate students' ideas and reach conclusions for them. Especially, the teaching pressure of covering abundant scientific concepts caused by the national curriculum and the regular cross-class standard tests held by the school may somewhat hinder my incentive to implement similar activities. These difficulties exist in the whole processes of conducting STS instruction in these two semesters. (the final month, 2nd week's journal)

Obviously, there is a dilemma between STS instruction and the teaching load requested by national curriculum or the standard examinations held by the school. The experienced science teachers in Newton, Driver, and Osborne's study expressed similar concerns on argumentation in science lessons (Newton, Driver, & Osborne, 1999). Clearly, STS instruction involves some debates and discussion activities; hence, Sherry's reflections were well-founded. Moreover, Sherry's identified that the lack of administrative support or moral support from other colleagues may impede her implementation of STS instruction. She reflected that

Many of other science teachers question what I teach this for? Or, they think that my teaching methods are very strange. Although the Dean and other administrators in school did not say anything nor explicitly complained, I feel that they did not agree this way of instruction. (the third interview)

Some other science teachers talked to me why I chose such a complicated way of teaching the simple concepts. They seemed not to appreciate my ideas (the 5th month, 2nd week journal).

I feel some kind of discouragement from other teachers. I do not ask for any assistance from them, but just for their moral support. If they could express more interest or encouragement about my teaching, I would definitely implement the lessons in a more easy way. (the 4th interview)

It is clear that Sherry needed some support from her colleagues to continue her STS instructional practice. Sherry, however, at the end of the study, stated that she would continue trying to integrate some STS materials into her instruction in the future, though the school cultures did not favor her teaching. She stated that

I feel that STS instruction enhances my scientific knowledge and knowledge of teaching. My students also like many activities we worked together. Many of them gradually enjoy this way of learning. There is no reason for me to totally give up what I proceeded so far. (final interview)

Finally, Sherry identified the resource limitations in Chinese language may cause some difficulties of implementing STS instruction in Taiwan.

I spent a week in two university libraries to find out some lessons about the history of electricity, either from the western history or from Chinese history. It took me so much time. If teachers need to spend so much time to find relevant course materials, most of them will give up, I think. (the third interview)

A lot of STS materials I found were translated directly from those developed in western countries, and many of them are not very useful in my class. (the fourth interview)

The lack of appropriate instructional content related to local contexts may lower teachers' motivation to practice STS. Similar situations may be applied to many nations whose

language is not English.⁴ Sherry expressed a need for support from others, and a need for more available materials. Some teachers in Lumpe, Haney, and Czerniak's study expressed a similar view that the lack of support from others, the lack of materials, and the lack of funding were factors that would discourage STS implementation (Lumpe, Haney, & Czerniak, 1998). In sum, Sherry pointed out that the national curriculum, standard tests, lack of peers' or administrative support, and resource limitations may impede the success of STS instruction. However, these factors are more related to the external environments or established rules and cultures. It may take a much longer time to resolve these difficulties.

IMPLICATIONS

STS instruction helped Sherry conduct constructivist-oriented learning activities, which were very different from how she had taught before. Through observations of students' STS activities, Sherry well conceptualized the main feature of constructivism that students "construct" their own ideas. The practice of STS instruction may challenge traditional views of teaching science held by many teachers that teaching science is simply a process of transmitting long lists of concepts and students are merely the recipients of knowledge (Yerrick, Parke, & Nugent, 1997). The actual practice of STS instruction also helped the teacher develop rich knowledge structures about STS. The STS instruction in the "paper work" version, as Sherry had received before, may not help teachers achieve the same level of knowledge frameworks. The STS workshops presented in the "paper work" format may include more practical experiences for teachers.

This study suggests that the teacher can, to a certain extent, progress toward more constructivist-oriented SEVs. That is, STS instruction may help teachers acquire more authentic images of science. Bencze and Hodson (1999) have argued that science curricula often deliver some images of inauthentic science; for example, science starts with observation, science is a value-free activity, and scientific inquiry is a simple, algorithmic procedure. Bencze and Hodson (1999) further described an attempt on changing teachers' inauthentic images of science. The involved teachers worked with a university-based researcher/facilitator educator for 5 months to design and implement more authentic science curriculum (e.g., conducting correlational studies in science and technology) for 7th graders. They suggested that the change of teaching practice helped the teachers acquire more authentic aspects of science. Similarly, the teacher in this study, through the practice of STS instruction in a long period of time, changed her SEVs toward more authentic ones. This implies that long-term actual implementation of more authentic science curriculum (e.g., STS instruction) is an effective way of changing teachers' SEVs. This may somewhat explain why the preservice teachers in Gustafson and Rowell's study had little change on their SEVs in 13-week elementary science education courses (Gustafson & Rowell, 1995). Although the courses provided rich discussion about constructivist views of teaching science and explored a variety of constructivist-oriented instructional strategies, their actual practice with elementary pupils lasted only 4 weeks (3 hrs. once a week). The teaching practice may also have been situated in a traditional instructional context. How the teachers, as the role of *preservice* teachers, could really implement more constructivist-oriented instructional activities in the context is still open to question. This shapes some insights for teacher education programs. The lecture-oriented short-term courses may not have great impacts on teachers' SEVs. More practice about authentic science, for example, STS instruction, or

⁴ The need for available materials was a major issue in STS in North America in the 1980s. The issue led to some major projects conducted in North America, such as that described by Aikenhead (1994b). Aikenhead's report may be helpful for science educators outside of North America wanting to produce STS materials for teachers (Aikenhead, 1994b).

more direct discussion about the philosophy and history of science, may be more promising ways of changing teachers' inauthentic views of science.

This study showed a teacher's pedagogical and epistemological developments as a result of practicing STS instruction. That is, the practice of STS instruction, itself, is a potential way of enriching teachers' knowledge of science and of teaching science. Research also suggests that teachers' views about STS strongly influence their ability and implementation in curricular innovation in science (Cunningham, 1998). However, many earlier studies indicated that science teachers did not hold adequate understandings about STS (e.g., Rubba & Harkness, 1993; Solbes & Vilches, 1997). How to help teachers acquire better understandings about STS and how to motivate teachers to actually implement STS instruction may be important research questions for further investigation.

Although the change in the case teacher's epistemological views and knowledge growth may mainly be attributed to the practice of STS instruction, some other factors may also contribute to such a development or change. For example, the researcher's encouragement and timely assistance may have helped the teacher continue her STS instruction in a unfavorable culture of the school. In addition, the teacher's high intentions of enhancing science teaching and her positive perceptions toward students and students' science learning may have facilitated the view change and knowledge growth.

This study also pointed out some factors that may impede the success of STS instruction, including the syllabus outlined by national curriculum, standard tests, lack of administrative or peers' support, and resource limitations in the local contexts. The implementation of STS instruction, clearly, is related to many aspects of existing political realities, situations, and cultures. Science education policy should try to resolve these if we do anticipate a high possibility of reforming science education.

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