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Chin-Chung Tsai

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RESEARCH REPORT

The progression toward constructivist epistemological views of science: a case study of the STS instruction of Taiwanese high school female students

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Chin-Chung Tsai, Center for Teacher Education, National Chiao Tung University, Hsinchu, Taiwan

Prior research revealed that having constructivist-oriented scientific epistemological views could be an important prerequisite for implementing so-called constructivist-based teaching strategies. How to help students acquire constructivist oriented epistemological views of science, then, becomes a major concern for practicing science educators. This study viewed STS (Science-Technology-Society) instruction as a promising means to help students progress toward constructivist oriented epistemological views of science. One hundred and one Taiwanese female 10th graders (16-year-olds) were assigned to either a traditional instruction group or a STS treatment group. Through an eight month research treatment it was found that STS group students, at the final stage of this study, tended to have scientific epistemological views more oriented to constructivist views of science than traditional group subjects. Further analyses revealed that, among STS group students, those originally having empiricist-aligned views of science tended to progress most in their epistemological views. Student in-depth interviews revealed that some STS group subjects, as a result of STS instruction, tended to accept the theory laden quality of scientific exploration and to perceive the importance of social negotiations in science community and cultural impacts on science. However, student interview data showed that such an epistemological progression seemed to be implicit, suggesting that students may not have the confidence to generalize what and how they learned about science in STS instruction to how scientists actually practice about science.

Introduction

Although science educators have not reached a consensus about the particular content or method for science instruction, there is agreement that science education should help students develop an adequate understanding about the nature of science, or acquire appropriate epistemological views of science (Hammrich 1998). Many countries have viewed a proper understanding of the nature of science as a major goal of science education and it is a key feature of numerous current science curricular reforms and research projects (e.g. American Association for the Advancement of Science 1989, National Research Council 1996, in the USA, or Department of Education and Science 1989, Driver *et al*. 1996, in the UK). However, earlier studies investigating students' epistemological views of science have repeatedly revealed that students have an inadequate understanding about

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science and that they generally have empiricist oriented views about the epistemology of science (Lederman 1992, Mellado 1998).

Educators have highlighted that epistemological beliefs affect the degree to which individuals are involved in and in control of their learning and their persistence in difficult situations. They could be viewed as an important factor influencing a higher order process that guides learning, conceptual change and cognitive operations (Pintrich *et al.* 1993, Hofer and Pintrich 1997, Tyson *et al.* 1997, Duschl and Hamilton 1998). Recently, the possible influences of students' Scientific Epistemological Views (SEV) on science learning, in particular, have received much attention among science education researchers. These researchers also view student SEV as higher order thoughts that guide the acquisition of scientific knowledge or shape their learning assumptions and orientations in science. Available research evidence supports (e.g. Edmondson 1989, Songer and Linn 1991, Tsai 1997, 1998a, 1998b, 1999a, 1999b, 1999c) that, when compared to students exhibiting the belief that science is discovered from completely objective observation and experimentation (i.e. empiricist-oriented SEV), students who believe that science is constructed based on scientists' agreed paradigm, evidence and negotiation (i.e. constructivist oriented SEV)[1] tend to: (1) employ more meaningful strategies when learning science; (2) have better attitudes and more appropriate learning beliefs toward school science; and (3) show greater preferences for constructivist-based learning environments. These findings suggest that having constructivist-oriented scientific epistemological views is possibly an important prerequisite for students' meaningful learning in science and for implementing so called constructivist-based teaching strategies. How to help students acquire constructivist-oriented epistemological views of science, then, becomes a major concern for practicing science educators.

STS (Science-Technology-Society) instructional approach has been proposed as a way of reforming the practice of science education since 1980. It presents science from various perspectives and discusses more epistemological issues in science (e.g. how and why scientists develop the scientific knowledge). STS instruction is very different from traditional teaching that emphasizes the fact or final version of science. This study, as proposed by Tsai (1998b), viewed STS instruction as a promising means to help students progress toward constructivist oriented epistemological views of science.[2] Yager and Lutz's (1995) article proposed a similar idea that STS instruction could alter learners' traditional (i.e. empiricist-oriented) views of science. Abd-El-Khalick and Lederman's (1998) paper could further support such an expectation. They proposed that there were two major approaches to improve people's conceptions of the nature of science: one was implicit, using science-based inquiry activities, and the other one was explicit, utilizing elements from the history and philosophy of science or addressing some epistemological issues in the instructional process. The use of STS instruction as a means of changing student SEV could be considered as both implicit and explicit, as 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 for students (Yager 1993, Yager and Lutz 1995).

Moreover, females were generally considered as relatively disadvantaged in learning science (Kahle and Meece 1994). Some educators even claim that normal educational practice in science is conducive to `epistemological marginalization' of

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females (Nichols *et al*. 1998: 968). It is plausible to predict that female students may have more inappropriate perceptions about learning science as well as about the nature of science (e.g. Speering and Rennie 1996, Kenway and Gough 1998). Therefore, this study chose high school female students as the target subjects for investigation. Through analysing questionnaire and in-depth interview data gathered from a group of Taiwanese female 10th graders (16-year-olds), this study was intended to explore how STS instruction may play a role in respect of student SEV.

Methodology

Subjects

A total of one hundred and one students from two female (single sex) 10th grade classes of a high school in Taipei City, Taiwan, participated in this study. These female students had been selectively admitted on the basis of their testing scores on a Joint High School Examination (of Taipei City) immediately prior to the conduct of this study. Through taking the Examination, about 400 female 10th graders were admitted to the high school (i.e. their first year of high school study) every year, and they were randomly assigned into 8 classes. In general, they were the top 40% to top 15% students, in comparison to all same-aged female student population in Taiwan. As this study was conducted about one month after the class assignment above, the students in these two classes could be viewed as being randomly assigned. In addition to randomized assignment, a SEV survey administered immediately before this study also indicated that there was no significant difference in student SEV between these two classes (note: $p \gg 0.05$, please refer to table 2 listed in `findings' section later). Then, one class was assigned to a traditional group (a total of 49 students) and the other to a STS group (52 students). This study was conducted within their `fundamental physical science' course regularly taught at the school. This school used Taiwan's nation-wide curriculum and textbook for this course. Due to the contextual limitations of the study site, these two classes were taught by two different science teachers for this course. (During the process of conducting this study, in the study site, no single science teacher taught two female science classes at the same time). However, both teachers are female and had the same years of high school teaching experiences (3 years at the beginning of the study). Both of them majored in physics and graduated from the same teacher-training university and they had similar SEV orientations, as assessed in the beginning of this study.[3] The teacher of STS group had related STS training from some workshops and educational seminars held in Taiwan.

Treatment (STS versus traditional instruction)

This study employed an experimental research design to examine how may STS play a role on student SEV. In this study, as that proposed by Aikenhead (1994), STS oriented instruction included two dimensions; one was at the content level while the other was at the methodological level. At the content level, STS instruction emphasized major concepts in science, exploring the depth, not the breadth of

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scientific knowledge. By using a variety of instructional resources (e.g. newspaper, World Wide Web, lessons from the history of science or other community resources), the instruction explored the relationships between science, technology and society, presented scientific concepts in the context of human experiences, and discussed contemporary science-related issues and problems in society or in the local context (e.g. energy source depletion, pollution explosion). At the methodological level, STS instruction provided learner centred learning environments, and conducted inquiry-based exploration. It also encouraged divergent thinking, cooperative learning, problem solving, everyday decision making, issue-based debating and discussion (Heath 1992, Yager 1993). On the other hand, the traditional group students, at the content level, mostly followed the fact-based content provided by the nationwide textbook. At the methodological level, they were subject to conventional teaching strategies, such as textbook reading, largely one-way lecturing, and extensive tutorial problem solving exercises, as is commonly used in Taiwanese science classrooms. The students in the STS group as expected may have spent more time in some after class peer discussion; however, the in class instructional time was the same for both groups (four 50-minute periods per week).

The way of implementing STS instruction in this study, proposed by Heath (1992) as the most promising approach, was that of infusing STS materials and activities into an existing course, in this case the `fundamental physical science' course. With the recognition that STS instructional materials developed in the USA or Europe are not directly applicable in other countries, while these materials should be locally developed (Rubba 1987), the author, STS teacher and some STS researchers cooperatively developed STS instructional materials for this study (based on Taiwan's nation-wide curriculum). Many STS projects directed by the National Science Council, Taiwan, ROC and by the Ministry of Education, Taiwan, ROC, also provided numerous practical modules for this study. For example, when instructing the concepts of nuclear energy, the STS group conducted a role playing activity and debate about whether Taiwan should build a fourth nuclear electrical power generating plant. Students were asked to collect relevant social, scientific and technological information and then to discuss this issue from various perspectives. The STS group students were also asked to regularly present some science related issues that appeared in newspaper or relevant magazines. However, the teachers in both groups followed the same teaching sequence in presenting major science concepts because there were cross-class achievement tests that all students had to take almost every month within the school. The treatment (STS instruction) and control (traditional teaching) classes each lasted about eight months, a very long period of research treatment not frequently found in science education research.

Assessing scientific epistemological views

There are numerous instruments which have been developed by educators to assess students' views about science. Those recently developed include Views on Science Technology Society (VOSTS) by Aikenhead and Ryan (1992), Edmondson's (1989) questionnaire and Pomeroy's (1993) questionnaire. Aikenhead and Ryan's VOSTS instrument has a total of one hundred and fourteen items; thus, it is too demanding for 10th graders to complete. Edmondson's questionnaire lacks a high consistency in assessing students' SEV. Pomeroy's questionnaire has a relatively high consistency in assessing people's SEV and includes relatively few questions (i.e. 16 items used in this study). Consequently, this study used a Chinese version of Pomeroy's questionnaire to assess students' SEV. Another important rationale of using this questionnaire comes from the fact that the Chinese version of Pomeroy's questionnaire has been used in some other studies with Taiwanese secondary school learners (e.g. Tsai 1996, 1997, 1998a, 1998b, 1999a, 1999b, 1999c) and these studies have concluded that it showed adequate reliability and construct validity of assessing student SEV.

The questionnaire consists of bipolar agree-disagree statements on a 5-1 Likert scale. The scores of the questionnaire could be viewed as representing a one dimensional assessment of student SEV; namely, a continuum from empiricist to constructivist perspectives. The empiricist position assumes that scientific knowledge is a discovery of an objective reality external to ourselves and discovered by observing, experimenting or application of a universal scientific method. It also claims that evidence in science accumulated carefully will result in sure knowledge. Currently, the broad trend prevailing in the philosophy of science is constructivism, which has replaced the trend of empiricism (Nussbaum 1997). The constructivist views of science emphasize the theory-laden quality of scientific exploration and the role of conceptual change in progressive evolution of scientific understanding. These views also support an idea that scientific knowledge should be viewed as an invented reality, which is also constructed through the use of agreed upon paradigms, acceptable forms of evidence, social negotiations in reaching conclusions, as well as cultural and contextual impacts as recognized by participating scientists (Tsai 1998c). This study used Pomeroy's items that represent a range of viewpoints including at one pole of `traditional views of science' (empiricist views), to the other pole of `non-traditional views of science' (constructivist views of science). The following two items were sample questions representing empiricist views and constructivist views of science respectively:

- Science is the ideal knowledge in that it is a set of statements which are objective; i.e. their substance is determined entirely from observations (empiricist view); and
- Different cultural groups have different processes of gaining valid knowledge of natural laws (constructivist view).

Pomeroy's (1993) questionnaire included a total of 17 items on `traditional views of science' and `non-traditional views of science.' However, a prior study (Tsai 1996) revealed that one item in the Chinese version of Pomeroy's (1993) questionnaire did not show adequate consistency in assessing students' SEV. The question item is `The best way to prepare to become a scientist is to master the scientific body available in the finest texts.' This study excluded this item when surveying students' SEV. Hence, the final questionnaire used in this study included only 16 items. Pomeroy (1993) reported that the reliability for these two parts (or poles) was moderately high (Cronbach's $\alpha = 0.651$, and 0.591, respectively). The same coefficients calculated from this study were 0.703 and 0.662 respectively for these two parts of questions. As this study assumed that students' SEV could be represented by a continuum from empiricist to constructivist perspectives, it investigated such a one dimensional assessment of students' SEV. Therefore, students' questionnaire responses were scored as follows to represent their SEV. For the

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constructivist perspective items, a `strongly agree' response was assigned a score of 5 and a `strongly disagree' response was assigned a score of 1, while items representing an empiricist view were scored in a reverse manner. A prior study that compared student questionnaire results and interview details with twenty 14 year old students (Tsai 1998b) supported that such a scoring method, in general, could differentiate student SEV orientation. This scoring manner was also employed in some other studies about student SEV (e.g. Tsai 1999a, 1999b, 1999c). By this way, students having strong beliefs about the constructivist views would have higher average scores on the questionnaire. On the other hand, students with empiricist aligned SEV would have lower average scores. Prior interview details also suggested that, by and large, students scored middle in the questionnaire tended to have both constructivist and empiricist-oriented epistemological views of science (Tsai 1998b). In this study, three SEV surveys (i.e. Pomeroy's questionnaire) were administered to all subjects. They were administered before, at the midterm and at the final month of conducting the study.

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Student interview

Science educators have highlighted the importance of integrating qualitative and quantitative research methodologies in science education (e.g. Niaz 1997). In addition to administering SEV questionnaires for quantitative analyses, this study selected twelve STS group students for in-depth interview to acquire qualitative description about student SEV change.[4] These students were selected from the following strategy: four were randomly selected from the students who scored in the top one-third of Pomeroy's (1993) questionnaire; four were randomly chosen from the average group (those scoring most close to the mean of the subjects, by and large, those holding both empiricist and constructivist views of science); and four were randomly selected from the bottom one-third group. Such a selection strategy, similar to that used in Tsai's (1998b) study, corresponds to a `maximum variation sampling' method for qualitative research (Patton 1990: 172). The interview framework, based on the assertions summarized in Tsai's (1998c) paper about the constructivist epistemology, included the following five dimensions:

- 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?);
- 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 science? How and why?);
- The invented reality of science (e.g. Is scientific knowledge discovered or invented? Why?);
- 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?); and
- The cultural (or contextual) impacts on science (e.g. Do different cultural groups of people have different types of `science'? How?)

These interview dimensions and corresponding assertions are shown in figure 1. It should be noted that the major purpose of interviewing these selected subjects in the present study was to acquire a richer and more complete understanding about

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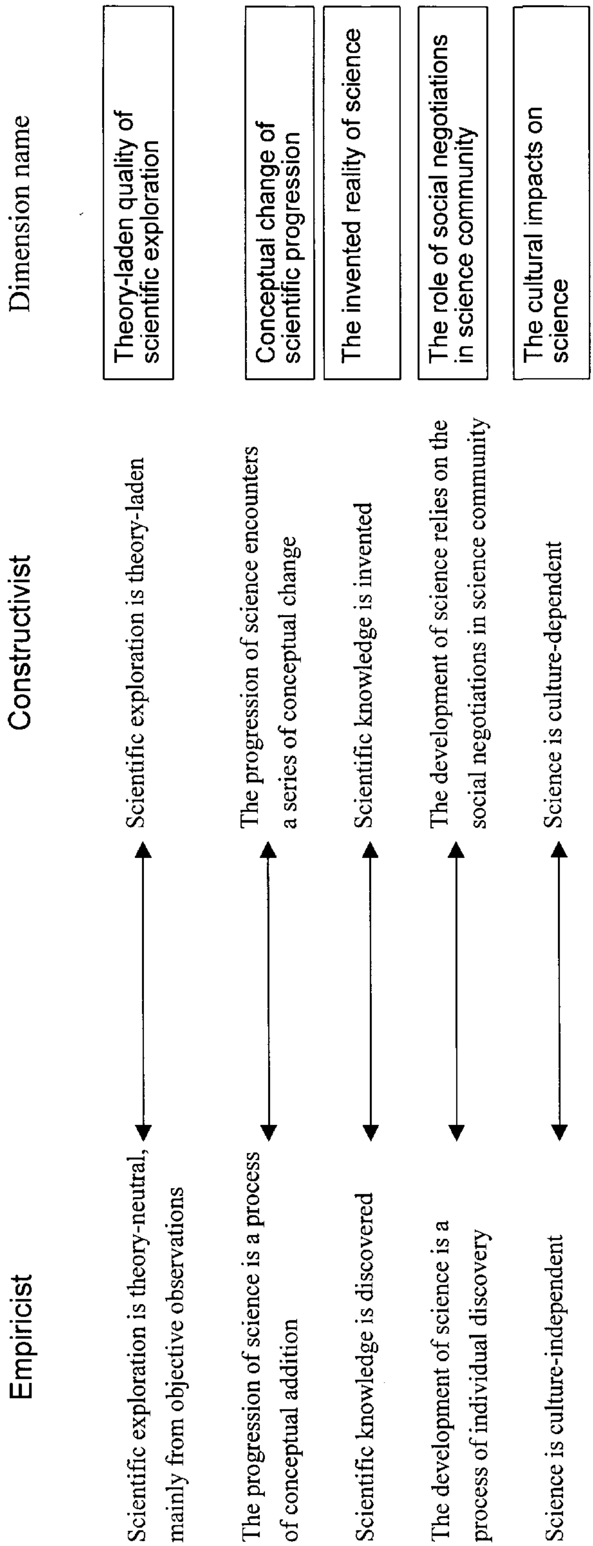

Figure 1. The dimensions of interview framework of exploring student SEV.

student SEV and SEV change, though the interview details could partially be used as an indicator of strengthening the construct validity of the questionnaire used (i.e. Pomeroy's (1993) questionnaire). Hence, the interview questions in this study were not the same as those used in Tsai's (1998b) study. As a result, these interview dimensions did not fully nor equally correspond to the question items of Pomeroy's questionnaire. In fact, a further examination between the question items (a total of 16 items used in this study finally) and interview dimensions revealed the following:

- Four items in Pomeroy's questionnaire assessed student SEV about the theory-laden quality of scientific exploration. (e.g. scientists rigorously attempt to eliminate human perspective from observation, stated in an empiricist view);
- Three question items explored student SEV about the conceptual change of scientific progress (e.g. non-sequential thinking, i.e. taking conceptual leaps, is characteristics of many scientists, stated in a constructivist position);
- Three question items assessed student SEV concerning the invented reality of science (e.g. intuition plays an important role in scientific discovery, stated in a constructivist view);
- Two items assessed student SEV about the cultural impacts on science (e.g. different cultural groups have different processes of gaining valid knowledge of natural laws, stated in a constructivist position);
- No items explored student SEV concerning the role of social negotiations in science community; and
- Four items can not be certainly categorized into any interview dimension above (e.g. scientists integrate many processes concurrently).

The categorization above was conducted by the author and a researcher having research background in science education. It seems that the questionnaire items did not fully nor evenly correspond to the interview dimensions; therefore, in the `findings' section (presented later), it happened that some students' questionnaire results (about four among the twelve students) did not show a high consistency with their interview details. Another possibility for this may come from the fact that some students may not have learned to present their views about science well during the interview.

Moreover, this study viewed STS instruction as both an implicit and an explicit way of changing student SEV. It is further hypothesized that the methodology used in STS instruction, such as open-ended inquiry activities and group cooperative learning, categorized as an implicit way of improving people's SEV by Abd-El-Khalick and Lederman (1998), could help students have more constructivist oriented SEV on the dimensions of the theory-laden quality of scientific exploration, the invented reality of science and the role of social negotiations in science community. For example, the group work may help students acquire the view that the development scientific knowledge is socially mediated among a group of individuals, and the open-ended inquiry could help students understand the importance of background theories and creativity in scientific exploration. On the other hand, the content of STS instruction, which may integrate historical cases or arguments in the classroom discussion, viewed as an explicit mode of improving people's SEV by Abd-El-Khalick and Lederman, may help students well contem-

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Table 1. Possible linkages between elements of STS instruction and relevant SEV dimensions.

Elements of STS instruction	*Relevant SEV dimensions*	*Way of changing SEV categorized by Abd-El-Khalick and Lederman 1998*
Instructional methodology (e.g., open-ended inquiry, role-playing activities, group learning, debates and discussion).	• Theory-laden quality of scientific exploration • The invented reality of science • The role of social negotiations in science community	Implicit
Instructional content (e.g., historical cases and arguments in the development of science, discussion about the interaction among science, technology and society)	• Conceptual change of scientific progression • The cultural impacts on science	Explicit

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plate the conceptual change of scientific progression and the cultural impacts on science. Table 1 presents the possible linkages between the elements of STS instruction and corresponding dimensions of scientific epistemological views.

The interview was conducted independently for each selected subject. To document the possible SEV change, the interview was conducted both in the first month and the final month of the research treatment for all selected subjects. All of the interviews were tape recorded. In the second interview (conducted in the final month of this study), if a subject stated quite different views of science from what she expressed in the first interview, the researcher replayed the tape recorded in the first interview and then asked the subject to explain why she had such a SEV change. That is, this study used the student's SEV prior elicited to stimulate her to contemplate the process of SEV change. In this way, not only was the interview was conducted in a more neutral way, but it could also possibly provide the sources of student SEV change. All of student interview data were transcribed by a research assistant (in Chinese) and a second independent research assistant, who actually listened to the whole set of interview audio tapes, validated the interview data elicited in this study. Then, the author translated the interview details from Chinese into English. The translated data were also examined by another educational researcher who was proficient in English.

Findings

The results in table 2 show that these two groups of students did not have significant SEV score difference in the first survey (administered before the conducting of this study), indicating that these two groups of students, on average, had similar SEV orientations in the beginning of this study. This result also somewhat supports the validity of randomized assignment used in this study. In the second survey, administered in the mid-term of this study, there were also no significant differences of SEV scores between traditional group and STS group students.

However, in the final survey, completed in the final stage of the eight month treatment, the SEV scores of STS group students were significantly higher than those of traditional group. Such a score difference indicated that, after a long period of STS treatment, STS group students tended have SEV more oriented to constructivist views of science than traditional group subjects. This further suggests that student SEV could be viewed as a set of higher-order thoughts requiring more time to show possible change.

The ANCOVA result in table 3 was calculated by viewing student SEV scores on the first SEV survey as a covariate predicting student scores on the final SEV survey. In other words, the first survey could be viewed as student SEV pretest; therefore, in order to confirm student SEV progression, student SEV scores obtained from the first survey may be controlled. Another reason for working this statistical analysis is that in the first SEV survey, the scores of STS group students (an average of 2.92, shown in table 2) seemed to be slightly (but not significantly) higher than those of traditional group subjects (an average of 2.86). The ANCOVA result in table 3 further confirms the SEV difference between traditional group and STS group in the final SEV survey, as that shown in table 2. It is concluded that STS instruction facilitated the development of constructivist oriented SEV for these female students.

This study further approaches another research question; that is, among STS students, which group of students changed their SEV most? Similar to the way of classifying student SEV that was employed in the `methodology-student interview' section, this study used STS students' SEV scores elicited in the first SEV survey to categorize them into a constructivist group (i.e. students who scored in the top one-third of Pomeroy's (1993) questionnaire), a mixed group (i.e. those scoring most close to the mean of the subjects) and an empiricist group (i.e. students who scored in the bottom one-third of the questionnaire). These three group included 17, 18 and 17 subjects respectively. Table 4 compared student SEV scores between the first survey and final survey, sorted by these three groups.

The results in table 4 reveal that STS students in the constructivist group did not have a significant SEV score change between the first and final surveys. However, the students classified as the mixed and empiricist groups progressed significantly in SEV scores after the STS treatment ($p < 0.05$ and $p < 0.01$, respectively). Figure 2 clearly displays these findings. Students in the constructivist group have almost the same SEV scores in the first and final surveys (but a slightly decreasing average score in the final); however, students in the empiricist group had an apparent SEV score increase from the first survey to the final survey. That is, among STS group students, those originally having empiricist-aligned views of science tended to progress most toward the constructivist-oriented epistemology (from 2.66 to 2.94). A further examination of the results of the empiricist group students showed that students had the most score increase on the following two items:

- The process of scientific discovery often involves an ability to look at things in ways which are not commonly accepted. (increasing from an average score of 2.53 to 3.24); and
- Different cultural groups have different processes of gaining valid knowledge of natural laws. (increasing from an average score of 2.82 to 3.41).

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Table 2. The effect of STS instruction on scientific epistemological views.

	First Survey			*Second Survey*			*Final Survey*		
	Traditional	*STS*	*t*	*Traditional*	*STS*	*t*	*Traditional*	*STS*	*t*
Scientific epistemological views (mean)[a]	2.86 [0.27][b]	2.92 [0.24]	−1.18	2.90 [0.23]	2.95 [0.20]	−1.10	2.91 [0.24]	3.03 [0.20]	−2.74**

Notes: ** $p < 0.01$ by t-test
[a]. n= 49 for traditional group and n= 52 for STS group
[b]. Value in parentheses is standard deviation

Table 4. Scientific epistemological view change of STS group students.

	Constructivist			*Mixed*			*Empiricist*[a]		
	First survey	*Final survey*	*t*	*First survey*	*Final survey*	*t*	*First survey*	*Final survey*	*t*
Scientific epistemological views (mean)	3.15 [0.18][b]	3.11 [0.16]	1.00	2.94 [0.05]	3.04 [0.16]	−2.70*	2.66 [0.17]	2.94 [0.24]	−3.81**

Notes: * $p < 0.05$, ** $p < 0.01$ by t-test
[a]. n= 17 for constructivist group, n= 18 for mixed group and $n = 17$ for empiricist group; the categorization of student group is based on student responses obtained from the first SEV survey
[b]. Value in parentheses is standard deviation

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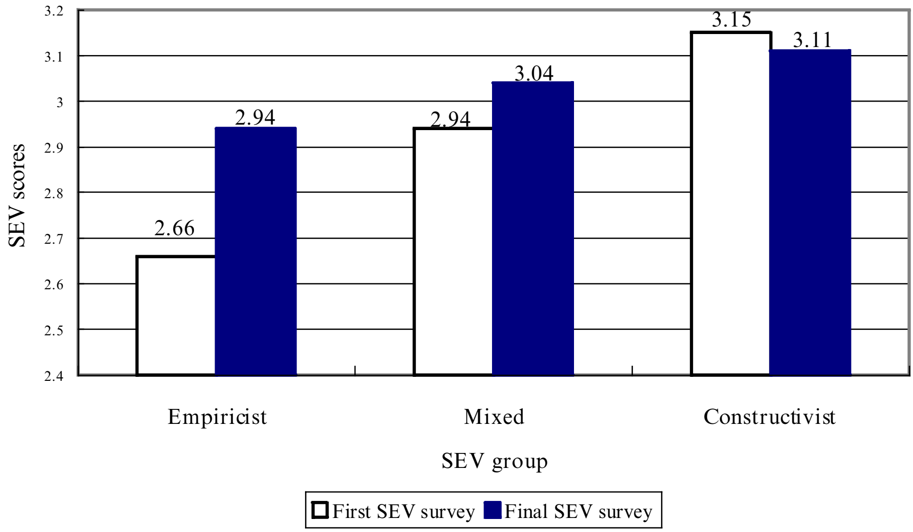

Figure 2. Students' average SEV scores obtained from the first and final surveys, sorted by different SEV groups.

Table 3. ANCOVA Result of the SEV score between groups (for final SEV survey).

Sources	*df*	*Sum of Squares*	*Mean Square*	*F*	*p*
Between groups	1	0.328	0.328	6.888	*
First SEV survey	1	0.026	0.026	0.557	
Residual	98	4.665	0.048		

*: $p < 0.05$

Table 5. The SEV scores of STS group subjects interviewed.

Constructivist subjects	*Mixed subjects*	*Empiricist subjects*[a]
C1 (3.13, 2.94, 3.19)[b]	M1 (2.94, 3.19, 3.06)	E1 (2.75, 3.06, 3.13)
C2 (3.19, 3.13, 3.00)	M2 (2.94, 2.88, 3.06)	E2 (2.44, 3.06, 3.00)
C3 (3.38, 3.19, 3.19)	M3 (2.94, 3.00, 3.19)	E3 (2.50, 2.63, 2.56)
C4 (3.13, 3.00, 2.94)	M4 (2.94, 2.75, 3.00)	E4 (2.63, 2.75, 2.88)

[a] The categorization of student group is based on student responses obtained from the first SEV survey.
[b] The sequence of the numbers represent student's SEV scores on the first, second and final surveys respectively.

Based on these quantitative results, these empiricist group students, after a long period of STS instruction, seemed to adhere more to the beliefs that science was developed in some creative manner and it was also shaped by cultural influences. In sum, in light of developing students' understanding about the constructivist epistemology, STS instruction was beneficial to students originally having empiricist aligned SEV.

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This study further conducted a series of interviews on STS group students, exploring their SEV and related change. As described earlier, students' SEV scores elicited in the first survey were used to categorize their SEV groups as constructivist, mixed and empiricist groups and four students in each group were randomly chosen. The STS students chosen from the constructivist group were labelled as C1, C2, C3 and C4. And, when applying the same rule, this study had M1, M2, M3 and M4 subjects for the mixed group, and E1, E2, E3 and E4 for the empiricist group. Consequently, a total of the twelve students in STS group were interviewed and their SEV scores, as assessed by Pomeroy's (1993) questionnaire, were listed in table 5. The results presented in table 5 show that some constructivist subjects seemed to have a little score regression across three SEV surveys (e.g. C3, C4), but many mixed and empiricist subjects increased their scores gradually (e.g. M2, M3, E1, E4). This situation somehow corresponds to the results displayed in table 4 and figure 2.

All of these selected STS group students were interviewed in the beginning and final stages of this study (i.e. the first and the second interviews). The interval between the first interview and the second was about seven months. The interview framework included five aforementioned dimensions of representing their SEV, that is, the theory-laden quality of scientific exploration, conceptual change of scientific progression, the invented reality of science, the role of social negotiations in science community and the cultural impacts on science. These dimensions and corresponding assertions have been shown in figure 1. After examining students' interview details, it was found that some students' SEV, in all dimensions, did not change very much (i.e. C3, C4, M3, M4, E3 and E4).[5] However, as a result of STS instruction, some students clearly displayed a SEV change from empiricist-aligned SEV toward more constructivist-oriented SEV in the following dimensions: the theory laden of scientific exploration, the role of social negotiations in science community, and the cultural impacts on science (interview details will be provided later). Only one student (C1 student) emphasized the role of social negotiations in the first interview, but she finally expressed science as a process of individual discovery in the second interview. In the following, some qualitative evidence about some subjects' SEV change, progressing from empiricist SEV toward more constructivist-oriented SEV, is presented. It also should be noted that even constructivist group subjects (defined on the basis of the *relative* questionnaire scores), in some cases, may have expressed their SEV in empiricist philosophical tradition. In the second interview, students were asked to listen to a replay of their prior interview narrative (i.e. that expressed in the first interview) to explain their SEV change.

When responding to the question like `does theory play a role on scientists' observations?', M1 and E1 students had the following responses:

M1 (first interview): It is important that scientists need to be objective. Any theoretical point of views should not influence their observations. If every scientist has his (or her) own theory, how could we have `science'? Science is accurate, and it is independent from one's theory.

M1 (second interview): Scientists may rely on some existing theories when doing experiments and recording observations. However, they should reply on the `right' or `well-confirmed' theories. Otherwise, they can not have good experimental results.

M1 (after listening to a replay of her first interview data):

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I don't know why my ideas change a little. But my current views make more sense to me. For example, when scientists do an experiment, what kinds of variables to be controlled may need some existing theories.

E1 (first interview): Scientists should have a `blank mind' when making observations. Otherwise, they will have some bias, then influencing the accuracy of observations.

E1 (second interview): Their observations are influenced by the theories they believe in. Everyone has his (or her) opinions that affect the way he (or she) perceives something. It is the same for scientists.

E1 (after listening to a replay of her first interview data): I think scientists are common people, and it is impossible for them to have a `blank mind' when recording observations. They would try to report some observations that favour their own theory.

Researcher: Why do your views have such a change?:

E1: Umm . . . I am not clear why.

The interview details listed above suggested a possibility that some open ended inquiry and role playing activities in STS instruction may have helped them understand the constructivist SEV. For instance, M1 mentioned the control of variables (an important process of conducting inquiry exploration in science) and E1 expressed that everyone had his (or her) opinions of perceiving something (a basic assumption of role-playing activity). These responses somewhat confirm an aforementioned hypothesis that the instructional methodology used in STS activities could help students understand the theory-laden quality of scientific exploration, perhaps, through an implicit way. Moreover, STS instruction may shape a more humane image of scientists for students (e.g. scientists are common people). The passage illustrated by E1 also suggested a possibility that she believed that scientists should `ideally' be empiricists, but they `actually' practiced science as constructivist. This interpretation needs further exploration in the future.

As regards to the interview dimension of `the role of social negotiations in science community,' many students (eight among the twelve) in the first interview agreed the importance of social mediation among scientists (the view close to constructivist SEV position). As a result, only one interviewed subject (M1) clearly changed her SEV from more empiricist SEV to constructivist-oriented SEV:

Researcher: Do other scientists influence one scientist's research work? Or science is a process of individual exploration, mainly depending on personal efforts?

M1 (first interview): Science is a process of personal discovery. For example, when Einstein proposed the theory of relativity, no contemporary scientists could understand. The development of the theory relied on his individual efforts.

M1 (second interview): I think the discussion, communication, and critics among scientists are important. By these, they can modify or refine their ideas.

M1 (after listening to a replay of her first interview data): Right now, I think Einstein is a special case.

Researcher: Why do your views have such a change?

M1: Umm . . . I cannot clearly state why. But my current views seem commonsense to me.

Besides, E2 student had a little justification about her SEV in this interview dimension:

Researcher: Do other scientists influence one scientist's research work? Or science is a process of individual exploration, mainly depending on personal efforts?
E2 (first interview): It seems that both views are convincing to me.
E2 (second interview): Although some science is discovered by the means of a scientist's personal exploration, the discussion with other scientists may be more important to the scientist. By this, he (or she) could make sure whether he (or she) is on the right track.
E2 (after listening to a replay of her first interview data): I think, science, in the beginning, may be an individual exploration, but it is very important to check if the scientist's work is supported by others' experimental results, and then his (or her) work could convince others.
Researcher: Your views seem to have a little change, could you explain why?
E2: Why? . . . It (i.e. the view she stated in the second interview) is just more realistic to me.

M1's SEV change (or perhaps, E2's) may have come from the practice of group work or cooperative learning, frequently used in STS instruction. In such learning activities, she required to negotiate with their peers, and then reached a consensus or shared understanding among her learning partners. That is, the instructional methodology used in STS activities may help students realize the importance of social negotiations in science community. Also, E2 seemed to construct a more realistic image about science. In the interview dimension of `the cultural impacts on science,' C2, E2 and M2 students exhibited some SEV progression:

Researcher: Do different cultural groups of people have different types of `science'? How?
C2 (first interview): I think only American, English, German and some other western people have `science' . . . What we call science is referred to the facts listed in the science texts. It contains formula, some English symbols and strange graphs.
C2 (second interview): I think we (i.e. Chinese or Taiwanese) may have our own science, but it is different from that listed in science textbooks.
C2 (after listening to a replay of her first interview data): Again, I think we may have our own science. But it is different from that listed in science textbooks.
Researcher: Why do your views have such a change?
C2: I don't know why.
E2 (first interview): All of science is discovered by western people. They have modern technology to discover the facts.
E2 (second interview): I think every cultural group may have their own science. For example, we have a different system of `science'. But not all of every cultural group's science is correct.
E2 (after listening to a replay of her first interview data): Perhaps, because Chinese did not have good instruments and relevant technology, we develop our science in a much different way. Researcher: Why do your views have such a change?
E2: Umm . . . (after waiting for a long time) I think it may come from a chance in this semester that I was looking for some information to be presented at the class. At the time, I accidentally read an article about science in ancient Chinese.
M2 (first interview): All of the scientific knowledge is discovered by foreigners. Someone once told me that Chinese did not have `science.'
M2 (second interview): It is possible that every cultural group has their own science.

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M2 (after listening to a replay of her first interview data):

	Oh! I think my definition of `science' changed. If what we call science is the formula and laws listed in science textbooks, Chinese do not have science. However, if science is way of describing natural phenomena, of course, we have our own science.
Researcher:	Why do your views have such a change?
M2:	I don't think it is a `change'. I just give a broad definition of science.

Students' responses elicited in the first interview implied that many Taiwanese students had a stereotype image that science was a product of western society, and science did (or does) not exist in Chinese or Taiwanese society or culture. This finding may be applied to many learners in eastern countries. The lack of Chinese history of science in Taiwan's science textbooks may reinforce such an impression. The inclusion of corresponding history of science in one country's science curricula may facilitate students' understanding about the cultural impacts on science. E2 student's second interview data also provided clearer evidence that STS instruction in this study, that may have offered opportunities for students to contact the history of science, could help students perceive the cultural impacts on science.

Moreover, M2 student's responses implied that STS instruction may have induced a broad view about science, not limiting science simply as the formula, facts, and laws presented in traditional science classes. In sum, the aforementioned interview results suggest that STS instruction, to a certain extent, could allow students to understand better the role of scientists and how they work, and construct a more realistic and socially contextualized image of science for students. The same findings were revealed in Solbes and Vilches' study (1997) on 16 to 18 year-old learners in Spain.

However, students' SEV in the dimensions of `the invented reality of science' and `the conceptual change of scientific progression' did not show obvious progression. All of the interviewed students still believed that science was discovered and many of them (ten among them) still adhered to a view that the development of scientific knowledge is simply a process of conceptual addition. Science educators are encouraged to find more effective ways to challenge students' epistemological views on these two dimensions.

By and large, the interview data showed some qualitative evidence that students seemed to progress toward constructivist-oriented SEV as a result of STS instruction, consistent with the quantitative findings reported in table 2 and table 3. The interview results also supported that empiricist and mixed subjects' SEV may have more progression, because the students who changed from empiricist-aligned to constructivist oriented SEV in the interview (i.e. E1, E2, M1, M2 and C2 students, please refer to the interview transcripts reported above) were likely came from mixed or empiricist groups. This also somewhat concurs with the finding revealed in table 4.

Finally, the interview indicated that student SEV change, in many cases, may have occurred in an implicit way, as most of these subjects could not clearly state why they had SEV change (e.g. E1, M1). One plausible interpretation is that students may not have enough confidence to generalize what and how they learned in STS instructional activities to (what they believed about) how scientists actually practiced science. For example, they had many inquiry-based scientific explora-

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tion and group learning activities in STS instruction, but they did not surely know whether the way they did (i.e. the instructional methodology) was similar to that of scientists. This interpretation could be further supported by the fact that the only one student who clearly stated why her SEV changed (i.e. E2) had a SEV progression on understanding the cultural impacts on science, whereas all students with SEV change on the theory-laden quality of science and the role of social negotiations in science community could not clearly explain their SEV change. The hypothesis of this study presented earlier described that the methodology used in STS instruction, categorized as an implicit way of improving people's SEV, could help students acquire more constructivist oriented SEV on the dimensions of the theory-laden quality of scientific exploration and the role of social negotiations in science community. On the other hand, the content of STS instruction, which may include historical cases or arguments in the classroom discussion, viewed as an explicit manner of improving people's SEV, may help students perceive the cultural impacts on science. Consequently, students with SEV change that possibly came from the methodology of STS instruction (e.g. E1, M1) may not clearly expressed the reasons of their change (because the way of changing SEV is implicit), while students with SEV change (e.g. E2) that probably stemmed from the STS content may help students document their view change in a more explicit way. Although this interpretation requires more research, it may suggest that to change students' SEV, science educators may need more explicit ways of discussing the epistemology of science with students, especially at the content level. Meyling's (1997) paper, providing a programme for explicitly discussing epistemology of science for physics students (grade 11-13), could be viewed as an attempt to address this. This also concurs with the suggestion by some contemporary science educators that a constructivist-oriented epistemological view of science should be made more explicit in curricula (Stein and McRobbie 1997).

Discussion

Through analysing a group of Taiwanese female 10th graders' questionnaire and interview results, this study concluded that STS instruction, to a certain extent, could help female students acquire a better understanding about the constructivist-oriented epistemological views of science. Palmquist and Finley's (1997) research showed that some pre-service teachers in a teaching programme could acquire contemporary (constructivist-oriented) SEV when conceptual change and cooperative learning (i.e. constructivist-based instructional approaches) were taught, even though there was little direct instruction about the nature of science. Similarly, the high school female students in this study may not have had direct instruction about the philosophy of science;[6] they seemed to progress toward more constructivist oriented SEV after a long period of STS instruction treatment. Clearly, STS instruction could also be viewed as an example of explicating constructivist-based teaching strategies (Yager 1995). Moreover, the results of this study also support that the use of STS instruction as a means of changing student SEV could be considered as both implicit and explicit, since the STS instruction in this study, at the methodological level, conducted science-based inquiry activities, while, at the content level, it sometimes included historical cases and discussed some epistemological issues (but, in this study, *not directly teaching* the philosophy of science) for students.

The interview results gathered from STS group students showed that their SEV change, in many cases, was most likely implicit. A possible reason is that students did not have confidence to generalize the way they learned or the way they did about science to the way scientists actually practiced about science. Such a possibility recommends the need for educators to be concerned about the experience of science being portrayed to students. Recently, science educators become more critical about the practical work in the practice of science education (Hodson 1996, or the mini-special issue of *International Journal of Science Education*, Volume 20(6) 1998). However, the practical work provided by typical cookbook-like laboratory activities may misguide students' SEV. Hodson (1998) warns that excessive use of the algorithm recipes of laboratory work leads students to believe in a single method of science. Fisher *et al*. (1998) argue that a significant proportion of laboratory activities currently conducted by school science remain highly prescriptive and most practical tasks in science laboratory manuals provide students with little or no opportunity for open-ended or inquiry learning. This may also lead to a situation that students gain little conceptual understanding from the practical work (e.g. Watson *et al*. 1995).

Moreover, the high success of school science experiments strengthens the illusion of certain knowledge in science (Hodson 1998). Rigano and Ritchie (1995) have observed the student practice of `fudging' which involves faking, fabricating or stealing data (e.g. making results fit the textbook, making up results from other students) in school laboratory activities. Changing the way in which scientific knowledge is practiced in school laboratory activities may be another potential way of helping learners acquire constructivist-oriented SEV. This way of improving student SEV is likely an implicit approach, as categorized by Abd-El-Khalick and Lederman (1998). Furthermore, some educators proposes an integrated curriculum that well combines the history and philosophy of science with the features of STS instruction (e.g. Eichinger *et al*. 1997, Monk and Osborne 1997), offering a more explicit manner of improving student SEV. When educators have lamented that the practice of science education and curriculum is always conducted in the context of the empiricist tradition (Duschl 1985, Tobin and McRobbie 1997), such an integrated curriculum may illuminate a potential way of providing a more appropriate image of science and learning science for students.

Although the change in students' epistemological views from questionnaire and interview may mainly be attributed to the STS instruction, some other factors may also contribute to student SEV change during the process of conducting this study. For example, based on some in-depth interview results, when compared to the views expressed in the beginning of this study, the STS group science teacher seemed to hold more constructivist oriented SEV at the final stage of this study (Tsai 1998d). This implies that the science teacher may have played an important role in facilitating student SEV progression.

Finally, some prior studies revealed that female students tended to not only exhibit lower participation in inquiry oriented science activities, but also have more inappropriate views about science and learning science (e.g. Jovanovic and King 1998, Kenway and Gough 1998). Nevertheless, the research evidence of this study suggested that female high school students, through STS instruction, could acquire more proper (constructivist oriented) epistemological views toward science. According to some earlier research results (e.g. Edmondson 1989, Songer and Linn 1991, Tsai 1998a, 1998b), it is convincing that these female

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students, after acquiring constructivist-oriented SEV, could employ more meaningful learning strategies and possess better attitudes when constructing scientific knowledge.

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Notes

1. Although some researchers recommend avoidance of using the term `constructivist' to describe one's philiosphical position of science (e.g. Loving 1997: 448), this paper still uses the term because science educators in general mat be more familiar with it. The constructivist philosophy of science is oriented to instumentalism, contextualism, realtivism and anti-realism.
2. Even though philosophers may have quite different views about the epistemology of science (e.g. Alters 1997), the present study, as suggested by some science educators (e.g. Nussbaum 1997), views the constructivist epistemology as a more mature view toward the nature of science (compared to the empiricist one). Therefore this study uses the word `progress' or `progression' to describe such a process of SEV change.
3. It is realized that the different teachers in both groups may be an important variable influencing the research results. The high similarity between these two teachers (e.g. academic background, sex, teaching experiences, SEV orientation) could be viewed as an alternative of controlling this variable. In the beginning of this study, these two science teachers had close SEV scores, as assessed by Pomeroy's (1993) questionnaire (scoring method described in `methodology-assessing scientific epistemological views' section). Their scores, in the beginning of this study, near to the mean of the questionnaire, were 3.06 and 3.00 for the traditional and STS group teacher, respectively.
4. In fact, 12 students in the traditional group were also selected for in-depth intervew. Because their interview data showed that their SEV, in most cases, did not show much change, this paper decided to report only the interview details of STS group subjects.
5. M3 and E4 students' questionnaire results showed that their scores increased as a result of STS instruction, however, they did not verbally express their SEV change in the interview. As described in the Methodology-student interview section, this discrepancy may have come from the following ideas that: (1) the questionnaire items did not fully nor equally correspond to the interview dimensions; and (2) they may not have learned to present their views about science during the interview well. The first justification could possibly be applied to the cases of C1 and C2 students (details will be presented later). Although C2 students had a score decrease resulting from STS instruction, her SEV about the cultural impacts of science, gathered from in-depth intervew, seemd to progress toward more constructivist views of science. There were only two questions exploring student SEV on this interview dimension. C1 student's SEV score remained almost unchanged between the first and final surveys, but her SEV that were expressed in the interview likely changed in the dimension about the role of social negotiations in the science community. Such a discrepancy in C1 student could well be explained, because no one question item in the SEV survey assessed student views on the interview dimension.

6. However, sometime there was some informal discussion about the epistemology of science when conducting STS instruction (e.g. discussing the interplay between the development of scientific knowledge and social impacts).

References

ABD-EL-KHALICK, F. and LEDERMAN, N. G. (1998) *Improving science teachers' conceptions of the nature of science: a critical review of the literature*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, San Diego, CA, April.

AIKENHEAD, G. (1994) Consequences to learning science through STS: a research perspective. In J. Solomon and G. Aikenhead (eds) *TS education: International erspectives on reform* (New York: Teachers College Press), 169-186.

AIKENHEAD, G. and Ryan, A. G. (1992) The development of a new instrument: `views in Science Technology Society'. *Science Education,* 71, 145-161.

ALTERS, B. J. (1997) Whose nature of science? *Journal of Research in Science Teaching,* 34, 39-55.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (1989) *Science for All Americans* (Washington, DC: American Association for the Advancement of Science).

DEPARTMENT OF EDUCATION AND SCIENCE (1989) *Science in the National Curriculum* (London: HMSO).

DRIVER, R., LEACH, J., MILLAR, R. and SCOTT, P. (eds) (1996) *Young People's Images of Science* (Philadelphia, PA: Open University Press).

DUSCHL, R. A. (1985) Science education and philosophy of science twenty-five years of mutually exclusively development. *School Science and Mathematics,* 85, 541-555.

DUSCHL, R. A. and HAMILTON, R. J. (1998) Conceptual change in science and in the learning of science. In B. J. Fraser and K. G. Tobin (eds) *International Handbook of Science Education* (Dordrecht, Netherlands: Kluwer), 1047-1065.

EDMONDSON, K. M. (1989) The influence of students' conceptions of scientific knowledge and their orientations to learning on their choices of learning strategy in a college introductory level biology course. Unpublished doctoral dissertation, Cornell University, Ithaca, NY, USA.

EICHINGER, D. C., ABELL, S. K. and DAGHER, Z. R. (1997) Developing a graduate level science education course on the nature of science. *Science and Education,* 6, 417-429.

FISHER, D., HARRISON, A., HENDERSON, D. and HOFSTEIN, A. (1998). Laboratory learning environments and practical tasks in senior secondary science classes. *Research in Science Education,* 28, 353-363.

HAMMRICH, P. L. (1998) Cooperative controversy challenges elementary teacher candidates' conceptions of the `nature of science'. *Journal of Elementary Science Education,* 10, 50-65.

HEATH, P. A. (1992) Organizing for STS teaching and learning. *Theory into Practice,* 31, 53-58.

HODSON, D. (1996) Practical work in school science: exploring some directions for change. *International Journal of Science Education,* 18, 755-760.

HODSON, D. (1998) Becoming critical about practical work: changing views and changing practice through action research. *International Journal of Science Education,* 20, 683-694.

HOFER, B. K. and PINTRICH, P. R. (1997) The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research,* 67, 88-140.

JOVANOVIC, J. and KING, S. S. (1998) Boys and girls in the performance-based science classroom: who's doing the performing. *American Educational Research Journal,* 35, 477-496.

KAHLE, J. B. and MEECE, J. (1994) Research on gender issues in the classroom. In D. L. Gabel (ed.) *Handbook of research on science teaching and learning* (New York: Macmillan), 542-557.

KENWAY, J. and GOUGH, A. (1998) Gender and science education in schools: a review `with attitude.' *Studies in Science Education,* 31, 1-30.

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LEDERMAN, N. G. (1992) Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching,* 29, 331-359.

LOVING, C. C. (1997) From the summit of truth to its slippery slopes: science education's journey through positivist-postmodern territory. *American Educational Research Journal,* 34, 421-452.

MELLADO, V. (1998) Preservice teachers' classroom practice and their conceptions of the nature of science. In B. J. Fraser and K. G. Tobin (eds) *International Handbook of Science Education* (Dordrecht, Netherlands: Kluwer), 1093-1110.

MEYLING, H. (1997) How to change students' conceptions of the epistemology of science. *Science and Education,* 6, 397-410.

MONK, M. and OSBORNE, J. (1997) Placing the history and philosophy of science on the curriculum: A model for the development of pedagogy. *Science Education,* 81, 405-424.

NATIONAL RESEARCH COUNCIL (1996) *National Science Education Standards* (Washington, DC: National Academy Press).

NIAZ, M. (1997) Can we integrate qualitative and quantitative research in science education? *Science and Education,* 6, 291-300.

NICHOLS, S. E., GILMER, P. J., THOMPSON, A. D. and DAVIS, N. (1998) Women in science: expanding the vision. In B. J. Fraser and K. G. Tobin (eds) *International Handbook of Science Education* (Dordrecht, Netherlands: Kluwer), 967-978.

NUSSBAUM, J. (1997) History and philosophy of science and the preparation for constructivist teaching: the case of particle theory. In J. J. Mintzes, J. H. Wandersee and J. D. Novak (eds) *Teaching science for understanding* (New York: Academic Press), 165-194.

PALMQUIST, B. C. and FINLEY, F. N. (1997) Preservice teachers' views of the nature of science during a postbaccalaureate science teaching program. *Journal of Research in Science Teaching,* 34, 595-615.

PATTON, M. Q. (1990) *Qualitative Evaluation and Research Methods* (Newbury Park, CA: Sage).

PINTRICH, P. R., MARX, R. W. and BOYLE, R. A. (1993) Beyond cold conceptual change: the role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research,* 63, 167-199.

POMEROY, D. (1993) Implications of teachers' beliefs about the nature of science: Comparison of the beliefs of scientists, secondary science teachers, and elementary science teachers. *Science Education,* 77, 261-278.

RIGANO, D. L. and RITCHIE, S. M. (1995). Student disclosures of fraudulent practice in school laboratories *Research in Science Education,* 25, 353-363.

RUBBA, P. A. (1987) Perspectives on science-technology-society instruction. *School Science and Mathematics,* 87, 181-186.

SOLBES, J. and VILCHES, A. (1997) STS interactions and the teaching of physics and chemistry. *Science Education,* 81, 377-386.

SONGER, N. B. and LINN, M. C. (1991) How do students' views of science influence knowledge integration? *Journal of Research in Science Teaching,* 28, 761-784.

SPEERING, W. and RENNIE, L. (1996) Students' perceptions about science: The impact of transition from primary to secondary school. *Research in Science Education,* 26, 283-298.

STEIN, S. J. and MCROBBIE, C. J. (1997) Students' conceptions of science across the years of schooling. *Research in Science Education,* 27, 611-628.

TOBIN, K. and MCROBBIE, C. J. (1997) Beliefs about the nature of science and enacted science curriculum. *Research in Science Education,* 6, 355-371.

TSAI, C.-C. (1996, May) The interrelationships between junior high school students' scientific epistemological beliefs, learning environment preferences and cognitive structure outcomes. Unpublished doctoral dissertation, Teachers College, Columbia University.

TSAI, C.-C. (1997, June) *The interplay between scientific epistemological beliefs and preferences for constructivist learning environments of Taiwanese eighth graders.* Paper presented at the Fourth International Seminar `From Misconceptions to Constructed Understanding', Cornell University, Ithaca, New York. [on-line] Available at http://www2.ucsc.edu/mlrg/proc4abstracts.html

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TSAI, C.-C. (1998a) An analysis of Taiwanese eighth graders' science achievement, scientific epistemological beliefs and cognitive structure outcomes after learning basic atomic theory. *International Journal of Science Education,* 20, 413-425.

TSAI, C.-C. (1998b) An analysis of scientific epistemological beliefs and learning orientations of Taiwanese eighth graders. *Science Education,* 82, 473-489.

TSAI, C.-C. (1998c) Science learning and constructivism. *Curriculum and Teaching,* 13, 31-52.

TSAI, C.-C. (1998d). *Changing scientific epistemological beliefs: a case of STS instruction*. Paper presented at annual meeting of Chinese Association for Research in Science Education, Kaoshiung, Taiwan, ROC (presented in Chinese).

TSAI, C.-C. (1999a). *Female 10th graders' cognitive structure outcomes: the effects of STS instruction and scientific epistemological beliefs*. Paper will be presented at the annual meeting of National Association for Research in Science Teaching, Boston, MA.

TSAI, C.-C. (1999b) Laboratory exercises help me memorize the scientific truths: a study of eighth graders' scientific epistemological views and learning in laboratory activities. *Science Education* 83(6).

TSAI, C.-C. (1999c) Content analysis of Taiwanese 14 year olds' information processing operations shown in cognitive structures following physics instruction, with relations to science attainment and scientific epistemological beliefs. *Research in Science and Technological Education*, 17.

TYSON, L. M., VENVILLE, G. J. and HARRISON, A.G. (1997) A multidimensional framework for interpreting conceptual change events in the classroom. *Science Education,* 81, 387-404.

WATSON, R., PRIETO, T. and DILLON, J. (1995). The effect of practical work on students' understanding of combustion. *Journal of Research in Science Teaching,* 32, 487-502.

YAGER, R. E. (1993) Science-technology-society as reform. *School Science and Mathematics,* 93, 145-151.

YAGER, R. E. (1995) Constructivism and the learning of science. In S. M. Glynn and R. Duit (eds) *Learning Science in the Schools: Research Reforming Practice* (Mahwah, NJ: Lawrence Erlbaum Associates), 35-58.

YAGER, R. E. and LUTZ, M. V. (1995) STS to enhance total curriculum. *School Science and Mathematics,* 95, 28-35.

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