

# Reinterpreting and reconstructing science: Teachers' view changes toward the nature of science by courses of science education

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## Abstract

The purpose of this study was to examine the effects of science education courses on a group of Taiwanese inservice and preservice teachers' views toward the nature of science. There were two science education courses in the study; one was for 36 inservice teachers, while the other one was for 32 preservice teachers. Both of the courses included the philosophy of science, the instruction about student alternative conceptions and theories of conceptual change, and some classroom activities for science education. The data sources were based upon these teachers' questionnaires, written responses to open-ended questions and interviews. The findings derived from this study revealed that both inservice and preservice teachers, to a certain extent, changed their views toward the nature of science when completing the courses. Many of them might reinterpret and reconstruct their views about science during the courses, and their views had progressed toward more constructivist-oriented. This study also suggested that the instruction about student alternative conceptions and conceptual change theories was more helpful than direct instruction about the philosophy of science in changing teachers' views about science.

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## 1. Introduction

One of the major goals of science education is to help students develop an adequate understanding about the nature of science. McComas and Olson (1998) have conducted a qualitative analysis of science education standards documents from many countries, revealing that there is a high degree of agreement about the views toward the nature of science to be shared with students. These views,

often perceived as *constructivist* views of science, emphasize the tentative nature of science knowledge, the theory-laden quality of scientific exploration and the role of conceptual change in progressive development of scientific understanding. They also support that scientific knowledge should be regarded as an invented reality, which is also constructed through the use of agreed-upon paradigms, acceptable forms of evidence, social negotiations in reaching conclusions, and technological, contextual and cultural impacts are recognized by participating scientists. These views are very different from traditionally *empiricist* perspectives. The

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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 asserts that evidence in science accumulated carefully will produce infallible knowledge (Tsai, 1998a, 2000a). The empiricist view may also regard science as a simply algorithmic process or a value-free activity (Bencze et al., 2003). Although recent science education standards stress the need of communicating the constructivist views with students, ironically, relevant studies have often found that science teachers may not have these views, and many of them hold empiricist-oriented views toward the nature of science (Lederman, 1992).

Anderson, Harty, and Samuel (1986) compared the results between the preservice secondary science teachers' views about the nature of science in 1969 and those in 1984. They found that the preservice teachers in 1984 showed significantly more agreement with the constructivist philosophy of science than their counterparts in 1969. They, however, asserted that teachers' understanding about the nature of science in 1984 was still lower than one might desire. Strikingly, all of the 25 science teachers in Gallagher's research (1991) viewed scientific knowledge in an objectivist and empiricist perspective, even though two of them had strong academic background in the history and philosophy of science. The study conducted by King (1991) showed similar results for beginning science teachers and he concluded that "science teachers are predominantly scientific and positivistic in their views of science" (p. 139). The study completed by Donnelly (1999) also showed that many science teachers held a belief that scientists placed a stronger emphasis on established knowledge and they perceived uncertainty as threatening. This belief is more aligned with the empiricist perspective about science. Moreover, Tsai (2002a) interviewed 37 science teachers about their views toward the nature of science, and found that more than a half of the teachers expressed empiricist views. A more recent study conducted by Tsai (2003) investigated more than one thousand science students' and their teachers' perceptions toward the laboratory learning environments, and found there was a gap between these students' perceptions and those of teachers. The teachers sampled showed higher preferences for better equipment and material environments for laboratory work than did their students. Data from follow-up interviews suggested

that the empiricist epistemological views about science held by teachers might be one of the important factors causing differences in perceptions between students and teachers regarding laboratory learning environments. In conclusion, research literature has generally suggested that many teachers hold empiricist-aligned views about the nature of science.

Teachers' views toward the nature of science are often considered as an important factor that frames their teaching beliefs, and these views may be related to instructional practice (Hammrich, 1997; Lederman, 1992). The studies by Brickhouse (1989), Hashweh (1996) and Tsai (2002a) showed that teachers' views about the nature of science, to a certain extent, were consistent with their teaching. For example, Hashweh (1996), through the use of questionnaire and survey data obtained from 35 science teachers, revealed that teachers having constructivist views about the nature of science were more likely to consider students' alternative conceptions, had a richer repertoire of instructional strategies, used more effective ways for promoting student conceptual change, and reported more frequent use of effective teaching strategies than teachers holding empiricist views did. Similarly, Tsai (2002a) found that the interviewed science teachers' views toward the nature of science and their beliefs about teaching science were closely correlated. The teachers holding more constructivist views toward the nature of science tended to show more agreement with constructivist-oriented ideas about teaching science. However, recent studies conducted by Abd-El-Khalick, Bell, and Lederman (1998), Mellado (1997), Lederman (1999), and Southerland, Gess-Newsome, and Johnston (2003) have revealed that the correspondences between teachers' epistemological position toward the nature of science and actual teaching practice are more complicated than originally assumed. For instance, Lederman (1999) found that teachers' level of experience, intentions and perceptions of students were more critical factors related to classroom practice.

The relationship between teachers' views toward the nature of science and their teaching orientations received some challenges in light of recent research findings. The uncertainty of this relationship in an actual classroom setting may arise from the complex contexts of school environments. However, researchers and educators cannot dispute the importance of this relationship in providing more insights

to improve science education, as Brickhouse (1989) has suggested that “[the] central role of teachers’ epistemological commitments must be addressed...if we are to encourage more advantageous classroom practices” (p. 482). As well, Aikenhead (1987) and Tsai (2002b) have proposed that teachers do not have adequate knowledge to implement Science, Technology and Society (STS) instruction if they lack the instruction regarding the epistemological and sociological nature of science in their former science education, especially in teacher education programs. As stated previously, science teachers may widely share the empiricist traditions toward science (Duschl, 1990; Lederman, 1992). It is not proposed that the empiricist views about science are totally wrong; however, in the perspectives of science education, these views may cause some problems for the practice of science teaching. For example, Millar (1989) has suggested that science educators will encounter two obvious dangers if the nature of science is perceived as empiricist oriented. One is a pedagogical danger that teaching science becomes a business of rote memorization of standard facts, laws, theories, methods and problem-solving procedures, and the other is an epistemological danger that science is viewed as infallible and a body of absolute facts or received knowledge.

As a result, another area of relevant interest is how to change teachers’ views toward the nature of science. Abd-El-Khalick and Lederman (2000a) proposed that there were two major approaches of changing teachers’ views about the nature of science: one was implicit, using science-based inquiry strategies and activities, and the other one was explicit, utilizing elements from the history and philosophy of science in the instructional process. The studies by Abd-El-Khalick and Lederman (2000b) and Lin and Chen (2002), which assessed the influences of history of science courses on preservice science teachers’ views toward the nature of science, clearly, employed the explicit approach. Palmquist and Finley’s (1997) research, which showed that some preservice teachers could progress toward constructivist views of science when conceptual change, and inquiry-oriented activities were taught, could be viewed as using an implicit approach. This study examined the effects of two science education courses on changing teachers’ views about the nature of science. These two courses were designed for inservice teachers and preservice teachers separately. However, both courses integrating some elements of the philosophy

of science and instructional models for conceptual change and inquiry activities. Hence, in Abd-El-Khalick and Lederman’s (2000a) perspectives, the courses were perceived as using both explicit and implicit approaches of changing teachers’ views about the nature of science. In sum, the purposes of this study were:

1. What were inservice and preservice teachers’ views about the nature of science in the beginning and at the end of each course?
2. How did inservice and preservice teachers change (if any) their views about the nature of science derived from each course?
3. What were the possible sources for their view changes?

## 2. Method

### 2.1. *Intervention: the courses*

This study mainly examined the effects of two science education courses on inservice and preservice teachers’ understandings about the nature of science. The first course (Course I) was offered by a specialized master program in a national university of Taiwan to enhance inservice science teachers’ knowledge and ability of applying e-learning theories to science teaching. As requested by these teachers, the course allocated much of the instructional time to the theories relevant to science education. The second science education course (Course II) was offered by a teacher preparation program at the same university for students. The students enrolled in Course II were preservice science teachers for secondary education. The instructional content of both courses mainly addressed the following four parts: (1) philosophy of science, (2) student alternative conceptions and conceptual change, (3) classroom activities for STS (Science-Technology-Society) instructional design, concept map and Gowin’s Vee, and (4) e-learning theories.

To state more specifically, the instruction about the philosophy of science mainly included the following ideas:

- Observations are theory-laden.
- The occurrence of contradictory fact does not necessarily lead to the change of existing theories.

- Science requires human creativity.
- Science knowledge is created and validated by the use of agreed-upon paradigms, acceptable forms of evidence, social negotiations in scientific community.
- Scientific work is influenced by social and cultural factors.
- There is no certain codified scientific method or rule of conducting scientific research.

The instruction about student alternative conceptions and conceptual change mainly covered the following: Piaget's cognitive theory, students' alternative conceptions in various science domains and their possible origins, conditions and models of conceptual change, and teaching strategies facilitating conceptual change. In addition, most teachers completed a piece of homework by actually interviewing some (high school) students' alternative conceptions. They were also asked to design some inquiry activities to challenge or change student alternative conceptions.

In addition, each course involved some classroom (practical) activities. For example, these teachers were asked to work as small groups to design lesson plans for STS instruction, construct concept maps and Gowin's Vee (Novak & Gowin, 1984). Then, they had opportunities to share their work in class.

Both of the courses also emphasized the importance of e-learning theories for science instruction. However, since Course I was offered by a program for inservice science teachers to enhance their ability of applying e-learning to science education, it included relatively more amount of time (9 h) for communicating e-learning theories. The course for preservice teachers (Course II) had put relatively less time on this topic. Other instructional content for both courses included: the goals of science education, gender issues, international comparisons

for science achievement, informal science education, and group presentation for final project. The major instructional content for these two courses is listed in Table 1. The course content was quite similar between these two courses. These courses were taught by a male professor, with a doctoral degree in science education. Both courses were implemented in a semester (about 4 months), about 2 h each week.

## 2.2. Participants

The participants in this study were the teachers enrolled in the courses mentioned above. Course I included 36 inservice teachers (12 female), while Course II included 32 preservice teachers (13 female). All of them had a major in a related science field in the baccalaureate degree program. The inservice teachers ranged in age from 28 to 56 years old, and their teaching experiences ranged from 3 to 27 years with an average of about 9 years. The preservice teachers had an age range from 21 to 28 years. As this study involved both inservice and preservice teachers but with different courses, it could provide some comparative results for these two groups of teachers. Not many previous studies about science teacher education were conducted by this way of research design and data gathering.

## 2.3. Instruments

A Chinese-version of Pomeroy's (1993) questionnaire was administered to assess teachers' views toward the nature of science. The questionnaire consists of bipolar agree–disagree statements on a 5–1 Likert scale. To explore teachers' views toward the empiricist position of science, this study used Pomeroy's scale items that represented the "traditional" viewpoints (empiricist views, e.g., Scientists

Table 1  
Main course content by science education courses in the study

	Inservice teachers (Course I)	Preservice teachers (Course II)
Philosophy of science	4.5 h	4h
Student alternative conceptions and conceptual change	6 h	6h
Classroom activities for STS instructional design, concept map and Gowin's Vee	4.5 h	5h
Theories about e-learning	9 h	3h

Other instructional content includes: the goals of science education, gender issues, international comparisons for science achievement, informal science education, and group presentation for final project.

rigorously attempt to eliminate human perspective from observation, a total of 8 items). On the other hand, those representing a “nontraditional views of science” scale (constructivist views of science, e.g., Different cultural groups have different processes of gaining valid knowledge of natural laws, a total of 9 items) were selected for assessing teachers’ views toward the constructivist position. Pomeroy (1993) reported that the reliability for these two scales was moderate (Cronbach’s  $\alpha = 0.651$ , and  $0.591$ , respectively). The same coefficients calculated from this study were  $0.71$  and  $0.70$ , respectively, for these two scales (when combining the data of inservice and preservice teachers) for the pre-course survey, and the coefficients were  $0.74$  and  $0.72$  for the post-course survey. (The details about pre-course and post-course surveys will be provided later). These coefficients indicated satisfactory level of reliability. The Chinese version has been tested and adopted in a series of research about students’ and teachers’ views toward the nature of science in Taiwan (Tsai, 1998b, c, 1999a, b, 2000b, 2002b).

Teachers’ questionnaire responses were scored as follows to represent their views about the nature of science. For the constructivist perspective items, a “strongly agree” response was assigned a score of 5 and a “strongly disagree” response was assigned a score of 1, and items representing an empiricist view were scored in the same manner. As previous studies often suggested that many teachers had mixed views between the constructivist and empiricist perspectives (Palmquist & Finley, 1997; Tsai, 2002b), teachers’ responses in the two scales were scored separately. Teachers attaining higher scores in a scale showed more agreement with the responding position.

This study was conducted to explore teachers’ possible view changes by the courses; therefore, Pomeroy’s (1993) Likert-type questionnaire was administered in the first session of each course to assess their initial views about science. One additional open-ended question was also attached to explore the teachers’ views about science in the beginning of each course. The open-ended question was as simple as “What is your view about science?” The same questionnaire (i.e., Pomeroy, 1993) was administered in the final session of each course. In addition, the end-of-course questionnaire also included an open-ended survey, asking the teachers to reflect their contemporary views about science, possible view changes and the sources of changes (please refer to Appendix A). For instance, each

teacher was asked to retrospect whether his or her views about science had changed, deciding an option among “no change,” “somewhat change” and “change,” and then giving reasons for the selected option. If the teachers did not express clear ideas in the survey, the researcher conducted individual interviews with these teachers for further clarification. As a result, a total of three preservice and two inservice teachers were interviewed. The written responses and possibly some interview data were used for content analysis to reveal teachers’ possible view changes and the sources of changes.

#### *2.4. In-depth interviews with some selected teachers*

In order to acquire a more complete picture about how teachers in the courses developed their views about the nature of science, this study conducted some individual interviews with these teachers. Five preservice and five inservice teachers were randomly selected for the interview. (Consequently, these selected teachers here were not the same as those in the previous section who did not express their ideas clearly in the open-ended survey.) However, as two inservice teachers did not have time for the interview, five preservice teachers, but only three inservice teachers, were finally interviewed. These teachers were asked to reflect on their views about the nature of science derived from the courses during interviews. The teachers were interviewed individually by a trained researcher. The interviews were audiotaped and were transcribed. The author analyzed the interview data by finding some representative ideas as expressed by the teachers. The author translated the interview data cited in this paper. The translated data were further examined by a second independent Chinese speaker, who actually listened to the interview tapes.

### **3. Results**

#### *3.1. Questionnaire responses*

Since one of the major purposes in the study was to investigate teacher view changes resulting from the courses, an analysis of teachers’ questionnaire (developed by Pomeroy, 1993) responses would provide more direct information for their view changes. Table 2 shows that both the inservice teachers (i.e., teachers in Course I) and preservice teachers (i.e., teachers in Course II) tended to more support the constructivist views after completing the

Table 2  
Teachers' view changes about science as assessed by questionnaires

	Inservice teachers (Course I, $n = 36$ )			Preservice teachers (Course II, $n = 32$ )		
	Pre-test <sup>a</sup> (mean, SD)	Post-test <sup>b</sup> (mean, SD)	$t^c$	Pre-test <sup>a</sup> (mean, SD)	Post-test <sup>b</sup> (mean, SD)	$t^c$
Constructivist items	3.05 (0.33)	3.21 (0.35)	-3.40**	3.12 (0.53)	3.29 (0.51)	-3.97***
Empiricist items	3.26 (0.38)	3.20 (0.38)	1.42 (n.s.)	3.17 (0.43)	3.01 (0.37)	3.39**

\*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$ .

<sup>a</sup>Pomeroy (1993) questionnaire administered in the beginning of the course.

<sup>b</sup>Pomeroy (1993) questionnaire administered at the final session of the course.

<sup>c</sup>Paired  $t$ -test used.

Table 3  
Teachers' views about science when comparing to neutral views (value = 3)

	Inservice teachers (Course I, $n = 36$ )		Preservice teachers (Course II, $n = 36$ )	
	Pre-test <sup>a</sup> ( $t$ , significance)	Post-test <sup>b</sup> ( $t$ , significance)	Pre-test <sup>a</sup> ( $t$ , significance)	Post-test <sup>b</sup> ( $t$ , significance)
Constructivist items	0.85 (n.s.)	3.67**	1.31 (n.s.)	3.24**
Empiricist items	4.13***	3.17**	2.18*	0.10 (n.s.)

\*  $p < 0.05$ ; \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$ .

<sup>a</sup>Pomeroy (1993) questionnaire administered in the beginning of the course.

<sup>b</sup>Pomeroy (1993) questionnaire administered at the final session of the course.

courses (when comparing to their views in the beginning of each course). However, a comparison between inservice teachers' questionnaire responses in the beginning and those at the end of Course I did not reveal statistical view differences in the empiricist items in both questionnaires ( $t = 1.42$ , n.s.). On the other hand, preservice teachers tended to show less agreement with empiricist views when finishing Course II ( $t = 3.39$ ,  $p < 0.01$ ). This part of analysis revealed some statistical significance on teachers' view changes about science; nevertheless, it should be noted that the score changes as assessed by Pomeroy's (1993) questionnaire were not very considerable in terms of the absolute values. For example, the inservice teachers in Course I had the average questionnaire score of 3.05 in the beginning of the course and slightly progressed to the score of 3.21 at its end. Therefore, in order to fully document the teachers' view changes about science, this study gathered other information (such as written responses to open-ended questions and interview data) for exploration.

Moreover, Table 3 shows an analysis for these teachers' views when statistically comparing to the neutral position (value of 3). Table 3 reveals that, on

average, the inservice teachers in the beginning of Course I tended to support empiricist views about science ( $t = 4.13$ ,  $p < 0.001$ ), while showed statistically neutral views toward the constructivist views ( $t = 0.85$ , n.s.). However, at the end of Course I, they supported both views ( $p < 0.01$ ), implying a mixed position between constructivist and empiricist ideas. The preservice teachers in the beginning of Course II, similar to those inservice teachers in Course I, expressed positive agreement with empiricist views ( $t = 2.18$ ,  $p < 0.05$ ), but neutral toward the constructivist position ( $t = 1.31$ , n.s.). They, however, likely displayed an opposite view to this when completing the course. At the end of the Course II, the views toward the nature of science held by preservice teachers, on average, tended to be statistically positive toward the constructivist position ( $t = 3.24$ ,  $p < 0.01$ ) and neutral toward the empiricist position ( $t = 0.10$ , n.s.). One may argue that the choice of 3 as neutral position and the consequent comparisons may not be very meaningful. These significance tests, however, provided a statistically straightforward way to display the orientations of the teachers' views about the nature of science. Since this study also conducted some

content analyses of the teachers' written replies to open-ended questions, it is believed that more detailed explorations both from the quantitative-type questionnaires and from the written documents could complement each other to show the teachers' view changes toward the nature of science.

### 3.2. *Written responses to open-ended questions*

As just stated, this study also gathered teachers' written responses to some open-ended questions. For example, at the end of each course, the teachers were asked to contemplate their possible view changes (see Appendix A). Table 4 presents an analysis for the teachers' self-selected options indicating their view changes. The sub-categories of "change to more constructivist-oriented" and "change to more empiricist-oriented" were classified by the author and further validated by an independent researcher. The categorization was based on their written responses for explaining their possible view changes. As mentioned previously, two inservice science teachers and three preservice science teachers did not show clear direction of change in the open-ended survey. Therefore, a follow-up interview with each of these teachers was conducted. Their data were integrated with the analysis of the open-ended survey, and then all of the teachers' view changes are presented in Table 4. The sub-category of "change to more constructivist-oriented" may have included those showing view changes from empiricist views to mixed or from mixed to constructivist. In the same manner, the sub-category of "change to more empiricist-oriented" included those initially having constructivist-oriented views but finally showing mixed views.

In this paper, the empiricist and constructivist views of science are independently different, but not necessarily opposite. For instance, the empiricist views support that scientific work is objective because of its neutral observations. The constructivist views also assert that scientific exploration is relatively objective (than the research in other domains), but the objectivity mainly comes from the careful validation and criticism among the practicing scientists in the science community.

According to Table 4, a half of inservice teachers reported with "somewhat change", and 28% of them stated that they "changed" their views about the nature of science. In the preservice teacher sample, 38% of them indicated "somewhat change" and 44% of them reported "change." The results in Table 4 also displays that almost all of the inservice and preservice teachers stating "somewhat change" and "change" were further categorized as "change to more constructivist-oriented." For instance, one inservice teacher wrote that:

In the beginning of this course, I believed that science is totally objective. All observations are independent from any theoretical background and human's ideas. At the end of this course, I gradually believe that science is a human activity and it may be influenced by cultures.

The following written responses presented by a preservice teacher could be viewed as another example.

In the past, I viewed science as purely objective, and it provided a correct description of the nature. Now, I think science only offers a way for us to interpret the world.

Table 4  
Content analysis of teachers' written responses for view changes

	Inservice teachers (Course I, $n = 36$ )		Preservice teachers (Course II, $n = 32$ )	
	<i>N</i>	%	<i>N</i>	%
No change	8	(22)	6	(19)
Consistently constructivist	1	(3)	2	(6)
Consistently empiricist	7	(19)	4	(13)
Somewhat change	18	(50)	12	(38)
Change to more constructivist-oriented	17	(47)	11	(34)
Change to more empiricist-oriented	1	(3)	1	(3)
Change	10	(28)	14	(44)
Change to more constructivist-oriented	10	(28)	14	(44)
Change to more empiricist-oriented	0	(0)	0	(0)

Table 5

The views toward science shown in written responses in the beginning of each course

View about science	Inservice teachers ( <i>n</i> )	Preservice teachers ( <i>n</i> )
Science is objective, neutral and independent from human's perspectives	22	20
Science has certain rules and methods	12	14
Science is searching for an accurate description about the world	11	7
Science is helpful to human life	7	16
Science is a collection of facts, laws and principles	3	4
Science come from a steady accumulation of correct information	3	2

*Note:* An individual teacher might show more than one of the views about science listed in the table. The table indicates the number of teachers who wrote the corresponding view when replying to the open-ended question "What is your view about science?"

Table 6

The views toward science shown in written responses at the end of each course

View about science	Inservice teachers ( <i>n</i> )	Preservice teachers ( <i>n</i> )
The development of science experienced conceptual change	25	22
The growth of science knowledge may be influenced by social and cultural factors	10	17
Science does not necessarily involve certain rules and methods	6	12
Science is objective, neutral and independent from human's perspectives	9	5
Science is helpful to human life	5	8
Science providing a way of interpreting the world	3	7

*Note:* An individual teacher might show more than one of the views about science listed in the table.

This part of results were consistent with those revealed by Tables 2 and 3, showing that these teachers in general progressed toward more constructivist-oriented views about science.

In Table 5, a content analysis is provided to summarize teachers' written responses (to an open-ended question) about their views about science in the beginning of each course. Those listed in Table 5 were major views shared by the teachers when conducting content analyses of their written responses. It is clear that in the beginning of each course, many teachers adhered to the belief that "science is objective, neutral, and independent from human's perspective" (22 inservice teachers and 20 preservice teachers). Moreover, many of them perceived the feature of science as its certain rules and methods (12 inservice and 14 preservice teachers). Preservice teachers might hold more pragmatic views toward science, as sixteen of them mentioned the idea that "science is helpful to human life." A similar content analysis is presented in Table 6 for these teachers' views of science at the end of each course. In the written responses, many of them emphasized the conceptual change feature of science knowledge (25 inservice and 22 preservice

teachers). In addition, the social and cultural influences on science were recognized by many teachers (10 inservice teachers and 17 preservice teachers). The number of teachers who expressed the idea that "science is objective, neutral, and independent from human's perspective" (the most popular view in the beginning of the courses) decreased to only 9 in the inservice and 5 in the preservice sample.

The teachers in the study were asked to reflect their possible sources of view changes. Table 7 shows an analysis of this. It was interesting to find that many teachers (17 inservice and 15 preservice) contributed their view changes to the instruction about student alternative conceptions and conceptual change. However, not many teachers (7 inservice and 7 preservice) perceived their view changes as deriving from direct instruction about the philosophy of science. Some teachers also thought that the classroom activities about STS, concept map, and Gowin's Vee and interview homework were helpful for them to change their (generally empiricist) views about science. The instruction about the philosophy of science may help teachers simply acquire some thoughts as a



Table 7  
Teachers' self-reflected sources of view changes on the open-ended survey

Source of change	Inservice teachers ( <i>n</i> )	Preservice teachers ( <i>n</i> )
Philosophy of science	7	7
Theories of student alternative conceptions and conceptual change	17	15
Classroom activities for STS instructional design, concept map and Gowin's Vee	6	7
Homework (interview with students)	5	6
Personal reading	2	3
Intuition or no clear sources	3	2

*Note:* Only teachers indicating "somewhat change" and "change" responded to this question ( $n = 28$  for inservice and  $n = 26$  for preservice). An individual teacher might have more than one of the view change sources listed in the table.

series of viewpoints; however, these ideas were likely remote and isolated from their experiences. On the other hand, the theories of conceptual change and alternative conceptions may help these teachers deeply contemplate their (or their students') ideas. The variation as well as the viability of student alternative conceptions were explored, which might guide these teachers to elaborate some epistemological issues, such as the status of science knowledge and its changing feature. In addition, through the theoretical perspectives of conceptual change, they might make some implicit connections between theoretical perspectives of learning and teaching science and those toward the nature of science. In other words, they were probably able to apply their thoughts about science learning and teaching (such as instructional strategies of conceptual change) to some features of the nature of science (such as the conceptual change characteristic for the development of scientific knowledge).

### 3.3. Interview results

This study conducted individual interviews with eight teachers (3 inservice and 5 preservice). Among these teachers, one inservice teacher and one preservice teacher did not think their views about science had changed over the course. Both of them still showed empiricist-aligned views about science. For instance, they stated that:

Teacher A (preservice): I think the most important feature of science is its objectivity and accuracy. Scientists are finding the truths.... I am a physics major. My academic experiences clearly tell me about this.

Teacher F (inservice): There is no doubt that scientific knowledge gains its unique status, as it is neutral, objective and value free. Every cultural

group uses the same correct science knowledge to conduct research, and make technological products.

Nevertheless, the other six teachers believed that their views about science, to a certain extent, had changed. These teachers, for example, had the following responses:

Teacher C (preservice): I gradually find that I might have "misconceptions" about science in the past. Now, for me, science is developed by human's thoughts and creativity. Scientific knowledge provides us with a way of interpreting the world.

Teacher G (inservice): This course is very challenging for me. Many ideas contradict to my original views. For example, in the past, I thought science was very straightforward, simple and independent from human's perspectives. Now, I realize that people ourselves are, more or less, participating in the scientific inquiry.

Teacher D (preservice): I think this course help me reinterpret and reconstruct "what is science?" Science is a product collaboratively constructed by scientists. It does not necessarily represent the truth. In addition, social and cultural factors may also impose some impacts on the development of science.

When asked to think about their possible view change sources, among these six teachers, one teacher contributed the change to the course instruction about the philosophy of science, but as many as four teachers mentioned about student alternative conceptions and/or the theories of conceptual change. For example, these teachers stated that:

Teacher G (inservice): The theoretical models of conceptual change help me to think that the

development of science also experiences conceptual change. All of knowledge is tentative and changing all the times, no matter students' ideas or scientists' ideas.

Teacher E (preservice): When learning about student alternative conceptions, I find that many of their ideas are developed in a reasonable way. These ideas are well founded. Many of them are quite similar to those proposed by earlier scientists... I think I gradually realize the conceptual change feature about science. And, all of us are "constructing" science.

Teacher H (inservice): In the past, I could not figure out why my students always had certain erroneous conceptions, even after several times of instruction. When I learned some theoretical frameworks about student alternative conceptions, plus the homework of interviewing students, I think students, to a certain extent, like scientists, try to construct some ideas to describe the world around us. Then, I begin to understand what the teacher (course instructor) said about the constructivist nature of science.

In sum, the interview results above were fairly consistent with those revealed by questionnaires and open-ended question responses. Many teachers changed their views toward science into a more constructivist perspective. The instruction about student alternative conception and conceptual change might play an important role, helping them to make the connection between learning science and the nature of science. Many teachers in the courses seemed to reinterpret and reconstruct their views about science.

#### 4. Discussion and conclusions

This study has shown that science education courses integrating some ideas about the philosophy of science and contemporary learning theories and activities (e.g., student alternative conception and conceptual change) are helpful in changing both preservice and inservice teachers' views toward the nature of science. The preservice teachers in this study, initially having empiricist-aligned views about science, tended to possess more constructivist-oriented views about science after the course. The inservice teachers showed more agreement with constructivist views about science in the conclusion of the course, but their position toward the empiricist views about science remained statistically

unchanged. This implied that the inservice teachers might have shaped more established beliefs about science, which could not be easily altered. Because this study involved both inservice and preservice teachers but for separate (with similar content) courses, such a more direct comparison between the views shown by inservice teachers and those by preservice teachers may be informative. Perhaps, due to their prior academic experiences in science and rich practice in teaching science, the inservice teachers might have strongly developed some certain (possibly empiricist-oriented) views about science, while these views were resistant to change. These views are similar to student alternative conceptions in science (Trumper, 2003; Wandersee, Mintzes, & Novak, 1994). Without proper instruction and guidance, the teachers will likely remain their original ideas. Therefore, some educators (e.g., Akerson, Abd-El-Khalick, & Lederman, 2000) also suggested that the instruction for changing teachers' views about the nature of science might be rendered more successfully when integrated within a conceptual change approach such as that proposed by Posner, Strike, Hewson, and Gertzog (1982). That is, the instruction should, first, assess teachers' preconceptions about the nature of science, and then provide cognitive dissonance regarding their views toward the nature of science. In addition, the plausibility as well as the fruitfulness of contemporary (constructivist-oriented) views about science should be presented.

In addition, one interesting finding revealed in this study was the result that many teachers tended to reflect their sources of view changes from the instructional theories (e.g., alternative conceptions, conceptual change) and related activities. In the perspective of Abd-El-Khalick and Lederman (2000a), this may be an implicit way of changing teachers' views about the nature of science. In Tsai's (2002a) study, science teachers' beliefs about learning science, teaching science and the nature of science are closely correlated. Therefore, it is plausible to assume that the teachers in this study may have made some connections between learning science and the nature of science. Their actual experiences of interviewing students for probing their alternative conceptions (as course homework) may have helped them further elaborate the theories of alternative conceptions and conceptual change. Then, they were more able to effectively apply the ideas of learning science to some tenets about the nature of science. The

parallelism for the construction of science students' ideas and scientists' knowledge has been found and discussed in research literature (Duschl, 1990; Eckstein & Kozhevnikov, 1997; Tsai, 1998a, 2000a). Therefore, their beliefs about students' science learning and those about the nature of science were probably mutually supportive and developed in a complementary way. However, as the theories of learning science or conceptual change were more directly related to their teaching practice, they might tend to explore these more deeply and then regard them as one of the main sources of view changes.

The research findings also concur with those reported by Palmquist and Finley (1997). Palmquist and Finley showed that some preservice teachers could progress toward the constructivist views of science when conceptual change, and inquiry-oriented theories and activities were taught while in their course little direct instruction about the philosophy of science was presented. They hypothesized that their teachers were able to contemplate the implicit relationships between the nature of science and learning science due to their overall background studying and working in the science fields. In this study, both the philosophy of science and theories of science learning were explicitly taught, but many teachers contributed their view changes to the instruction of learning theories. Since all of the inservice and preservice teachers in this study had a major in a science-related field (e.g., physics, chemistry, biology), they may, as those in Palmquist and Finley's (1997) study, more readily elaborate the implicit connections between the nature of science and theoretical perspectives of learning and teaching science. It is suggested that both of these two sides of beliefs (nature of science, and learning [or teaching] science) are closely related, and thus constructing the teachers' epistemologies toward science (Tsai, 2002a).

One may still argue that the favorable results revealed in this study may stem from the influence of social desirability on responses. For example, it is perhaps not surprising if after experiencing a course in which these teachers were taught an "appropriate" view of what science is about, they were then more likely to reproduce this view in their questionnaire responses. In particular, due to the time constraints, the pre and post questionnaires were administered only 4 months apart; hence, the close proximity of the questionnaires might not suggest a

profoundly held change in their views about science. In other words, the results revealed in this study might not necessarily reflect a deeply long-term view change by the teachers. It is proposed that a study exploring these teachers' views about science for quite a long time after the courses should be done. One follow-up study that can also be conducted is to explore whether the teachers in this study integrate some constructivist views about the nature of science or teaching science in their actual teaching practice after the courses. The views acquired in the courses may shape some pedagogical beliefs, which subsequently guide teaching practice. Research on teachers' beliefs for teaching has become one of the major concerns for studies of teaching and teacher education (e.g., Freire, Choraio, & Sanches, 1992; Holt-Reynolds, 2000; Nettle, 1998; Stipek, Givvin, Salmon, & MacGyvers, 2001). Some participant classroom observations with the teachers involved may be potentially helpful to explore the long-term effects of the courses. Moreover, this follow-up study can also examine the relationship between teachers' beliefs about science (or teaching science) and their real instructional practice.

In conclusion, both inservice and preservice teachers in this study, to a certain extent, changed their views toward the nature of science when enrolled in the courses of science education. Many of them may have reconstructed and reinterpreted their views about science, which were, in general, more constructivist-oriented. Furthermore, the instruction about student alternative conceptions and conceptual change theories was more helpful than direct instruction about the philosophy of science in changing the teachers' views about science. Researchers are encouraged to explore more ways to facilitate teachers' development of appropriate views about science. In addition, teachers' views about science and their impacts on teaching strategies and behaviors clearly also need further research work.

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## Appendix A. The open-ended questions assessed at the end of each course

After the instruction of this course, do you think you have changed your views about science? (Check one, and answer the following question)

( ) No change. Please describe your views about science?

( ) Somewhat change, or ( ) Change

1. Please describe your view change. For example, you have changed your views about science from certain views to what kinds of views?

2. Please explain the possible sources of your view change (such as: certain parts of course content, or your personal reading or others).

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