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Chin-Chung Tsai
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Chin-Chung Tsai, Centre for Teacher Education, National Chiao Tung University, 1001 Ta Hsueh Road, Hsinchu 300, Taiwan

Summary

This study was conducted to explore the interplay between students' scientific epistemological beliefs and their perceptions of constructivist learning environments. Through analysing 1,176 Taiwanese tenth-graders' (16-year-olds) questionnaire responses, this study found that students tended to perceive that actual learning environments were less constructivist orientated than what they preferred. Students having epistemological beliefs more orientated to constructivist views of science (as opposed to empiricist views about science) tended to have a view that actual learning environments did not provide sufficient opportunities for social negotiations ($p < 0.01$) and prior knowledge integration ($p < 0.01$); and moreover, they show significantly stronger preferences to learn in the constructivist learning environments where they could (1) interact and negotiate meanings with others ($p < 0.001$), (2) integrate their prior knowledge and experiences with newly constructed knowledge ($p < 0.001$) and (3) meaningfully control their learning activities ($p < 0.001$). The main thrust of the findings drawn from this study indicates that teachers need to be very aware of students' epistemological orientation towards scientific knowledge, and to complement these preferences when designing learning experiences, especially to provide constructivist-based lessons to enhance science learning for students who are epistemologically constructivist orientated.

Keywords: constructivism, scientific epistemological beliefs, science education, learning environments

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Address for correspondence: Dr Chin-Chung Tsai, Centre for Teacher Education, National Chiao Tung University, 1001 Ta Hsueh Road, Hsinchu 300, Taiwan. Tel: 886 3 5931691. Fax: 886 3 5938083. E-mail: cctsai@cc.nctu.edu.tw

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Introduction

In the past two decades, science educators have contributed substantially to a better understanding of students' scientific 'misconceptions' or 'alternative conceptions' (Wandersee, Mintzes and Novak, 1994). This research is particularly significant since most of us agree that the learners' prior knowledge highly influences how new knowledge is constructed. However, to fully account for the organizing role of prior knowledge in gaining new knowledge and skills, educators should not limit their attention to students' alternative conceptions. Other aspects of their knowledge structures and patterns of reasoning are worth investigating, including philosophical and attitudinal variables. For example, there is research evidence that students' Scientific Epistemological Beliefs (SEB) play an essential role in determining their learning orientations towards science and the ways of organizing cognitive structures of scientific knowledge (Edmondson, 1989; Tsai, 1998a, 1998b, 1999a, 1999b). Science educators are aware of the importance of SEB on the process of conceptual change (Posner *et al.*, 1982; Tyson *et al.*, 1997). These beliefs also very likely guide students' meta-learning assumptions (Roth and Roychoudhury, 1994; Tsai, 1998b).

Moreover, educators should note that in science classrooms how the teacher explains scientific ideas and organizes information could be important as a model in determining students' SEB and their learning perceptions. That is, the learning environment created by the science teacher also plays a role in shaping students' perceptions of the way science is practised and how new knowledge is created. Eric, a subject in a study by Tobias (1990), wrote the following essay reflecting on his experiences when he was enrolled in a college physics course:

> 'The class consisted basically of problem-solving and not of any interesting or inspiring exchange of ideas. The professor spent the first 15 minutes defining terms and apparently that was all the new information we were going to get on kinematics . . . I still get the feeling that unlike a humanities course, here the professor is the keeper of the information, the one who knows all the answers. This does little to propagate discussion or dissent. The professor does examples the 'right way' and we are to mimic this as accurately as possible. Our opinions are not valued, especially since there is only one right answer, and at this level, usually only one [right] way to get it' (pp. 20–1).

Eric's reflections could be interpreted as follows. First, the learning environment directed by the professor may misguide how Eric will view scientific knowledge by leading him to think that scientific knowledge is a collection of absolute truths. Secondly, perhaps, Eric's beliefs are close to those of a constructivist view of science (asserting that scientific knowledge is constructed on the basis of scientists' agreed paradigms, evidence and negotiation, as opposed to empiricist views of science), so he is not comfortable in such a science classroom emphasizing didactic methods, a learning environment opposite to his preferences.

Students' learning environment perceptions, to a certain extent, also represent their beliefs about what constitutes learning and how knowledge is created. As an example, a high school student in Gunstone's (1991) study who strongly asserted that science was a collection of proven facts and formulae did not see any advantage in the 'conceptual change' teaching strategy (i.e. an example of so-called constructivist teaching strategy) even after he had really experienced it. The preceding discussion gives us some clues for the relationships between students' SEB and their perceptions or preferences for certain learning environments.

Relevant literature: the constructivist epistemology

The possible interaction between student SEB and learning environment perceptions could also be illustrated through exploring the constructivist epistemology. Constructivism is a relatively new paradigm for education, philosophy and psychology. The constructivist epistemology could be applied to both the merits of contemporary philosophy of science and those of learning psychology. The epistemology reveals an analogy that the developmental mechanism of scientific theories is similar to an individual's knowledge construction since one's childhood (Cleminson, 1990; Duschl, 1990; Nussbaum, 1983; Wandersee, 1992). This analogy does not assert that the content of students' conceptual development recapitulates those ideas presented in the history of science (though, in some cases, this really happens: see e.g. Eckstein and Kozhevnikov, 1997); rather, it asserts that the conditions, the justifications and the processes of conceptual growth for both scientists and learners are quite similar. This concurs with what Duschl (1990) has stated, that 'learning as it occurs within individuals is guided by the same basic sets of principles that guide the growth of knowledge in science' (p. 12). Tsai (1998c) summarizes eight assertions of the constructivist epistemology by drawing many cases from the history of science and philosophy of science, and from educational studies regarding students' science learning. These assertions are listed in Table 1, providing a potential interplay between the philosophy of science and students' learning psychology in science.

These assertions discuss the theory-laden and conceptual change qualities of scientific knowledge acquisition, and further illustrate how our knowledge in science should be viewed as an invented reality, which is also constructed through social negotiations and through contextual and cultural impacts. The interplay (of the constructivist epistemology) between the philosophy of science and students' science learning implies that there may be a similar interaction between students' philosophical views of science (i.e. SEB) and their learning assumptions or orientations.

In this study, students' views of science were represented by their scores gathered from a SEB survey. Student perceptions of constructivist learning environments, which were assessed through exploring students' views about what ideal and actual instructional environments look like, were used as an indicator to reveal their learning assumptions or orientations. Currently, the practice of constructivism is highly advocated by science educators (Tobin and Tippins, 1993; Tsai, 1998c; Yager, 1995), and it is also widely applied to various disciplines (Brooks and Brooks, 1993; Fosnot, 1996). Particularly, numerous science educators emphasize the creation of constructivist learning environments for students. Students' scientific epistemological beliefs have been recognized as an essential component of science learning environments (Roth and Lucas, 1997). The practice of constructivism in science education may not be fully successful without considering student SEB variations. Through analysing more than 1,000 Taiwanese tenth-graders' (16-year-olds) questionnaire responses, this study is an attempt to examine the possible relationships between student SEB and perceptions of constructivist learning environments, with applications of the improvement of science teaching and learning.

TABLE 1 The constructivist epistemology: the interplay between the philosophy of science and students' learning psychology in science

Constructivist philosophy of science	*Students' learning psychology in science*
1 Observations are theory-laden	Students' existing conceptions play an important role for new knowledge acquisition
2 Theories will be retained even when encountering apparent anomalies	Students' alternative conceptions are resistant to change by conventional teaching strategies
3 Science grows through a series of revolutions	Students should experience a series of conceptual changes when learning science
4 The scientific theories between two (or more) paradigms are incommensurable	Students' ideas and those of teachers may be incommensurable; teachers should understand students' learning/thinking from their perspectives
5 Science does not represent the reality while scientists are producers of the reality, not the reproducers of the reality; scientific knowledge comes from human imagination	Students are knowledge producers, not knowledge reproducers; learning is an active process of knowledge construction, not a passive process of knowledge reproduction; learning science requires students' creativity
6 Scientific knowledge comes from a series of criticism, validation, consensus and social negotiation in the scientific community	Students learn effectively and meaningfully in a favourable environment where their ideas are explored, compared, criticized and reinforced through talking and listening to others
7 There is no certain 'scientific method' and there is not only one way to interpret the same natural phenomena	Students learn by various methods; teachers should encourage students' multiple ways of researching, questioning and problem-solving
8 Scientific knowledge is the product of a complex social, historical, cultural and psychological activity	Students' knowledge acquisition occurs in a complex social, historical, cultural and psychological context

Methodology

Subjects

The initial sample of this study included 1,283 Taiwanese tenth-graders (16-year-olds). The population was stratified into three demographic areas, Northern, Central and Southern Taiwan. Six high schools from Northern Taiwan, four schools from Central Taiwan and four schools from Southern Taiwan were selected. The school number ratio selected roughly corresponds to the actual high school number ratio across these three areas. For each selected school, two classes were chosen. Although this sample could not be viewed as a national sample, the selected Taiwanese tenth-graders had various academic backgrounds, demographic areas and socio-economic levels, and may, to a certain extent, be said to represent Taiwanese tenth-graders. Because some students failed to complete all of the questionnaires used in this study (described later) or had missing data in the questionnaire(s), their results were excluded from final analyses of this study. Consequently, the final sample for this study included 1,176 students and 47 per cent of them are females.

Instrument assessing student scientific epistemological beliefs

Researchers have developed various instruments to assess students' views about science. Those recently developed include *Views on Science–Technology–Society* (VOSTS: Aikenhead and Ryan, 1992), and Edmondson's (1989) and Pomeroy's (1993) questionnaires. Aikenhead and Ryan's VOSTS instrument includes a total of 114 items; thus, it is too demanding for tenth-graders to complete well. Edmondson's questionnaire, however, lacks a high consistency in assessing students' SEB. Pomeroy's questionnaire, however, has a relatively high consistency in assessing students' SEB and it includes relatively few questions (i.e. 16 items used in this study). Therefore, this study used a Chinese version of Pomeroy's questionnaire to assess students' SEB. The Chinese version of Pomeroy's questionnaire has been used in some other studies with Taiwanese secondary school students (e.g. Tsai, 1996a, 1996b, 1997, 1998a, 1998b, 1999a, 1999b, 1999c), and these studies have suggested that it shows satisfactory reliability and construct validity in assessing student SEB. Also, when compared to other like instruments, Pomeroy's question content more closely parallels the assertions presented in Table 1 regarding the constructivist philosophy of science.

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 SEB; namely, a continuum from empiricist to constructivist perspectives. The empiricist view describes that scientific knowledge is a discovery of an objective reality external to ourselves and it is discovered by observing, experimenting or application of a universal scientific method. The empiricist position may also claim that evidence in science accumulated carefully will produce infallible knowledge. On the other hand, the constructivist views of science, shown as the assertions listed in Table 1, highlight the theory-laden quality of scientific exploration and the role of conceptual change in the progression 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 and social negotiations in reaching conclusions, as well as cultural and contextual impacts as recognized by practising scientists (Tsai, 1998c). This study used Pomeroy's items that represent 'traditional views of science' (empiricist views) and 'non-traditional views of science' (constructivist views). The following four items were sample questions cited from the questionnaire:

1 Scientists rigorously attempt to eliminate the human perspective from observations (empiricist view, assessing student SEB regarding the first assertion listed in Table 1, which will be scored in a reverse manner, described later).
2 Non-sequential thinking, i.e. taking conceptual leaps, is characteristic of many scientists (constructivist view, assessing student SEB regarding the third assertion listed in Table 1).
3 Legitimate scientific ideas sometimes come from dreams and hunches (constructivist view, assessing student SEB regarding the fifth assertion listed in Table 1).
4 Different cultural groups have different processes of gaining valid knowledge of natural laws (constructivist view, assessing student SEB regarding the eighth assertion listed in Table 1).

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, 1996a) revealed that one item in the Chinese version of Pomeroy's questionnaire did not show adequate consistency in assessing students' SEB. The present study excludes this item when investigating students' SEB. Hence, the final questionnaire used in this study included only 16 items. Pomeroy reported that the reliability for these two parts was moderately high (Cronbach's $\alpha = 0.65$, and 0.59, respectively). The same coefficients calculated from this study were 0.68 and 0.65 respectively for the two parts of the questionnaire.

Because this study viewed that students' SEB could be represented by a continuum from empiricist to constructivist perspectives, students' questionnaire responses were scored as follows to represent their SEB. For the constructivist perspective items, a 'strongly agree' response was assigned a score of 5 and a 'strongly disagree' response assigned a score of 1, while items representing an empiricist view were scored in a reverse manner. A previous study that compared student questionnaire results with interview details of 20 14-year-olds (Tsai, 1998b) supported the conclusion that such a scoring method, in general, could differentiate student SEB variations; this scoring method was also employed in some other studies on student SEB (e.g. Tsai, 1999a, 1999b, 1999c). Students having strong beliefs regarding the constructivist position thus have higher scores on the questionnaire; on the other hand, students with empiricist-aligned SEB have lower scores. Prior interview details also suggested that students who scored in the middle in the questionnaire tended to have both constructivist- and empiricist-oriented epistemological views of science (Tsai, 1998b).

Instrument assessing student perceptions of constructivist learning environments

To assess students' perceptions of constructivist learning environments, a Chinese version of the *Constructivist Learning Environment Survey* (CLES), originally developed by Taylor and Fraser (1991), was administered. The CLES contains the following four scales (seven items for each scale):

1 *Negotiation scale*: measuring perceptions of the extent to which there are opportunities for students to interact, negotiate meaning and build consensus with others.
2 *Prior knowledge scale*: measuring perceptions of the extent to which there are opportunities for students to meaningfully integrate prior knowledge and experiences with newly acquired knowledge, and to have enough time to construct ideas.
3 *Autonomy scale*: measuring perceptions of the extent to which there are opportunities for students to practise deliberate and meaningful control over learning activities, and to think independently of the teacher and others.
4 *Student-centredness scale*: measuring perceptions of the extent to which there are opportunities for students to experience learning as a process of creating and resolving personally problematic experiences.

Also, the CLES includes two forms, one the actual (or perceived) form, assessing the extent of the agreement between actual learning environments and constructivist learning environments, and the other the preferred form, assessing the match between students' views about ideal learning environments and constructivist ones. Both forms were administered in this study. Taylor and Fraser (*ibid.*)

reported the α-reliability to be 0.79, 0.74, 0.72 and 0.61 for each scale of the actual form, and 0.85, 0.69, 0.73 and 0.73 for each scale of the preferred form of CLES. The same coefficients calculated from the results of this study were 0.84, 0.78, 0.78 and 0.72 for actual form, and 0.81, 0.77, 0.79 and 0.70 for preferred form. Taylor and Fraser also conclude that these scales display both discriminant and predictive validity. The following cites four sample items from the CLES instrument:

1 In this class, I ask other students about their ideas. (negotiation scale, actual form)
2 In this class, I prefer to see if what I learned in the past still makes sense to me. (prior knowledge scale, preferred form)
3 In this class, I do investigations in my own way. (autonomy scale, actual form)
4 In this class, I prefer the teacher to show the correct method for solving problems. (student-centredness scale, preferred form, stated in a reverse manner)

Table 2 illustrates how the four scales are related to the eight assertions listed in Table 1 regarding the constructivist views of student science learning. For example, the first three assertions (about the concept-laden quality of learning science) are related to the CLES prior knowledge scale. The fifth assertion (about the invented nature of students' ideas), clearly, is related to the autonomy scale. Each CLES item has a five-point Likert scale, with categories ranging from 'very often' (5) to 'never' (1).

Students' responses on the CLES instrument were scored as follows to represent their perceptions of constructivist learning environments. For their responses on the items presented in a constructivist view, the five-point Likert scale was scored, with 5, 'very often', down to 1, 'never', responses, whereas students' responses on those statements presented in a traditional or non-constructivist way were scored in the reverse manner. The total scores for each student's responses on each scale in both forms of the CLES were used as indicators to display their perceptions of constructivist learning environments, hence every student had eight different scores to show their perceptions towards such environments. Since each scale of the CLES includes seven items, students' scores on each scale could range from 7 to 35. Students who showed closer perceptions or stronger preferences for certain types of constructivist learning environment would gain higher scores on a related scale of the CLES, while students who favoured traditional ways of teaching were expected to have lower scores for the same scale. For instance, students showing a greater preference to learn by interacting with others' ideas would have higher total scores on the

TABLE 2 The relationships between the CLES instrument and the constructivist views for students' science learning

CLES scale	*Relevant constructivist assertions for student science learning, as listed in Table 1*							
	1	2	3	4	5	6	7	8
Negotiation						√√		√
Prior knowledge	√√	√√	√					
Autonomy					√√		√√	
Student centredness				√√			√	√√

√√ highly related; √ possibly related.

negotiation scale of the CLES preferred form than those showing a lower preference.

The CLES instrument has been used in other educational studies (see e.g. Roth and Roychoudhury, 1994) and its Chinese version (preferred form) was used in Tsai's (1996a, 1997) study. The Chinese-version CLES (preferred form) was also validated by interviewing a group of Taiwanese 14-year-olds after actually receiving constructivist-oriented or traditional-oriented teaching strategies.

Administration of the instruments

The order of administering the instruments was the CLES actual form first, then the SEB survey and finally CLES preferred form. The period between the administration of two subsequent instruments was one to two weeks for all subjects.

Results

Perceptions of constructivist learning environments

Before examining the relationships between student SEB and learning environment perceptions, it may be interesting to explore students' responses on each CLES scale. Table 3 presents students' average scores on each scale of the CLES actual form and preferred form.

First, students had comparable scores on each scale of the CLES actual form; however, their responses diverged on each scale of the CLES preferred form. For example, students show much stronger preferences for learning environments emphasizing their prior knowledge and experiences. On the other hand, student-centred learning environments, relatively, were not well-favoured by students; Figure 1 clearly illustrates these. These findings may indicate that students tended to enjoy a learning process that strongly involved their prior knowledge or everyday applications; however, they may still believe in the teacher's authority in facilitating their learning. Moreover, students' scores on the preferred form were much higher than those on the actual form. When using (paired) t-tests to examine the differences between student actual form scores and preferred form scores, it was found that students' scores on the preferred form were significantly higher than those of the actual form on each scale, as shown in Table 3. This implied that many students tended to complain that actual learning environments did not adapt their preferences well and they tended to prefer learning environments

TABLE 3 Student perceptions of constructivist learning environments as assessed by CLES actual and preferred forms (n = 1,176)

	Actual		*Preferred*		*t-test between actual and preferred scores*
Scale	*Mean*	*S.D.*	*Mean*	*S.D.*	*t*
Negotiation	20.37	3.54	24.40	4.46	–30.2***
Prior knowledge	19.86	3.62	26.23	4.22	–45.0***
Autonomy	19.43	3.97	23.34	4.16	–22.9***
Student centredness	18.26	4.34	18.74	4.40	–2.54*

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

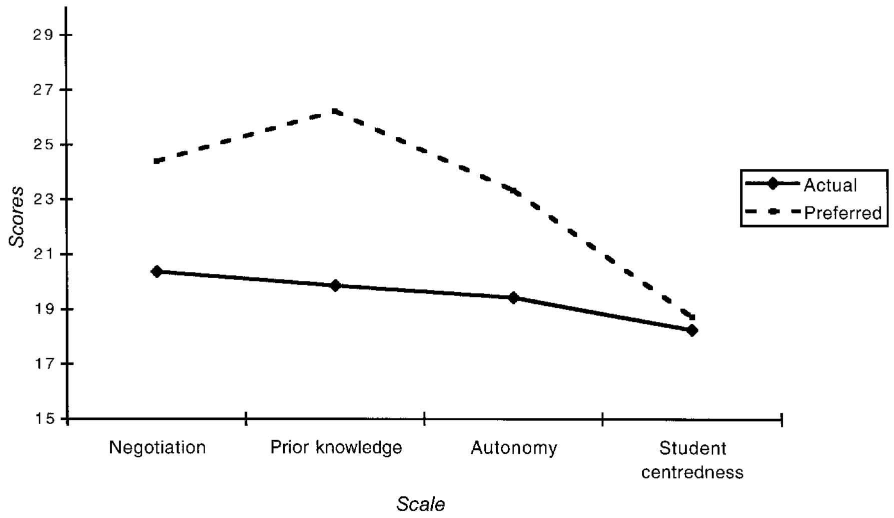

FIGURE 1 Student perceptions of constructivist learning environments on each CLES scale (n = 1,176)

where they could have more opportunities to interact with others, integrate their prior knowledge, think independently and to resolve personally problematic experiences.

Relationships between student SEB and learning environment perceptions

In order to acquire quantitative results about the interplay between students' SEB and their learning environment perceptions, the relationships between students' responses on Pomeroy's (1993) questionnaire and their scores on the CLES instrument were explored; the correlation coefficients are presented in Table 4.

Students' responses on the SEB instrument were significantly correlated with their scores on two of the four scales of the CLES actual form and on three of the four scales of the preferred form. Students having SEB more orientated to constructivist views of science tended to perceive that actual learning environments did not offer adequate opportunities for them to negotiate their ideas ($r = -0.09$, $p < 0.01$), nor integrate with their prior knowledge ($r = -0.08$, $p < 0.01$).

Moreover, students holding epistemological beliefs more close to constructivist views about science tended to show significantly stronger preferences to learn in the constructivist environments, where they could: (1) interact, negotiate meanings and build consensus with others ($r = 0.22$, $p < 0.001$); (2) have enough time to integrate their prior knowledge and experiences with newly constructed knowledge ($r = 0.20$, $p < 0.001$); and (3) have opportunities to exercise deliberate and meaningful control over their learning activities and to think independently ($r = 0.17$, $p < 0.001$). That is, there is a positive relationship between 'knowledge constructivist' and 'learning constructivist' orientations, in Hashweh's terminology (1996, p. 49). These findings are exactly the same as those in Tsai's (1997) study with a small sample of Taiwanese 14-year-olds.

However, there was no significant correlation between students' epistemological beliefs about science and the extent of their preferences to experience learning as a process of creating and resolving personally problematic experiences (i.e.

TABLE 4 The relationships between students' epistemological views about science and their perceptions for constructivist learning environments (n = 1,176)

	Negotiation (actual)	*Prior knowledge (actual)*	*Autonomy (actual)*	*Student centredness (actual)*
SEB	–0.09**	–0.08**	0.04	0.02
	Negotiation (preferred)	*Prior knowledge (preferred)*	*Autonomy (preferred)*	*Student centredness (preferred)*
SEB	0.22***	0.20***	0.17***	0.01

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

student-centredness scale). That is, constructivist-oriented SEB students did not tend to prefer student-centred learning activities more than did those who held empiricist views of science; and many of them, whether they were categorized as constructivist- or empiricist-oriented SEB learners, still tended to rely on teachers' authority for lesson planning. By and large, the results in Table 4 revealed that there were some relationships between students' scientific epistemological beliefs and their perceptions of constructivist learning environments.

Furthermore, Table 3 shows that students, on average, had significantly higher scores on the CLES preferred form than those on the actual form; and Table 4 reveals that, in many cases, there were negative relationships between student SEB orientations and perceptions of actual learning environments (i.e. empiricist-aligned SEB students had *higher* scores on the *actual* form than constructivist SEB students), but positive relationships between student SEB and preferences for constructivist learning environments (i.e. empiricist-aligned SEB students had *lower* scores on the *preferred* form than constructivist SEB students). These findings may suggest that empiricist-aligned SEB students may have relatively closer perceptions towards actual and preferred learning environments; however, constructivist-oriented SEB students may express a remarkable discrepancy towards these two sets of learning environments. The actual learning environments (in general, conducted in traditional modes – e.g. almost one-way lecturing and textbook reading) may favour students with empiricist-oriented SEB, as the actual learning environments better accommodate their preferences (though some studies found that there was no significant relationship between student SEB orientations and science achievement as measured by traditional standard tests: see e.g. Tsai, 1998a, 1999a). However, the obvious discrepancy of perceptions expressed by constructivist SEB students may cause difficulties for their science learning in common science classrooms. Educators and science teachers should recognize this discrepancy when implementing science instruction.

Implications

There were significant differences of student perceptions towards actual and preferred learning environments. Students tended to perceive that actual learning environments did not provide enough opportunities for social negotiations of scientific ideas, a sound coherence of prior experiences, deliberate control of learning activities or for personalized instruction. This suggests that teachers, in general, need to conduct science lessons with a more constructivist-oriented mode of instruction for students than currently practised.

This study further reveals that there were some relationships between student scientific epistemological beliefs and their perceptions of constructivist learning environments. By and large, students with epistemological beliefs tending towards a more constructivist view of science tended also to prefer constructivist-oriented learning environments. The interaction between student SEB and learning environment perceptions indicates that students who express a philosophical perspective closer to a constructivist view of science may benefit most from constructivist science teaching. It further implies that an appropriate view about a constructivist epistemology of science may be an essential prerequisite for implementing constructivist-based instructional strategies. Recent research asserts that students' epistemological beliefs (either in general or about science) may come mainly from their formal schooling (Tsai, 1996a, 1996b). As a result, if formal schooling does not carefully address a constructivist epistemology for students, it is expected that the practice of constructivism in science education could not then be successful.

It is encouraging that recent practice of STS instruction (Science–Technology–Society instruction – integrated or interdisciplinary science curricula emphasizing the interplay between science, technology and society) has shown that it is a potential way of explicating the constructivist epistemology of science for students. The instructional content (e.g. historical cases and arguments in the development of science, discussion about the interaction of science, technology and society) and methodology (e.g. open-ended inquiry, role-playing activities, group learning, debates and discussion) of STS instruction could help students acquire constructivist views of science (Tsai, 1999d).

Furthermore, as found by previous studies (e.g. Edmondson, 1989; Tsai, 1998b), constructivist-oriented SEB students tended to employ more meaningful learning strategies, while empiricist-aligned SEB learners tended to use rote memorization when acquiring scientific knowledge. Earlier research also revealed that student epistemological orientations towards science were not significantly correlated with their science achievement as measured by traditional tests (Tsai, 1998a, 1999a). That is, students having more constructivist-oriented SEB were not necessarily higher achievers, whereas students holding empiricist SEB were not necessarily lower achievers. This, as proposed by Novak (1985), implies that the traditional way of testing or evaluation cannot effectively differentiate the meaningfulness of students' science learning.

This study was not conducted with an experimental research design in place; hence, it is limited to correlation analyses between students' scientific epistemological beliefs and learning perceptions. However, this research strongly suggests that student scientific epistemological beliefs were an essential component in determining students' learning perceptions or orientations. The main thrust of the findings derived from this study indicates that teachers need to be highly aware of students' epistemological orientation towards science, and to complement these preferences when designing learning experiences, especially to provide constructivist-based lessons to enhance science learning for students who are epistemologically constructivist-oriented.

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