Lasting Effects of Instruction Guided by the Conflict Map: Experimental Study of Learning About the Causes of the Seasons

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Received 2 March 2004; Accepted 25 January 2005

Abstract: This study was based on the framework of the "conflict map" to facilitate student conceptual learning about causes of the seasons. Instruction guided by the conflict map emphasizes not only the use of discrepant events, but also the resolution of conflict between students' alternative conceptions and scientific conceptions, using critical events or explanations and relevant perceptions and conceptions that explicate the scientific conceptions. Two ninth grade science classes in Taiwan participated in this quasi-experimental study in which one class was assigned to a traditional teaching group and the other class was assigned to a conflict map instruction treatment. Students' ideas were gathered through three interviews: the first was conducted 1 week after the instruction; the second 2 months afterward; and the third at 8 months after the treatment. Through an analysis of students' interview responses, it was revealed that many students, even after instruction, had a common alternative conception that seasons were determined by the earth's distance to the sun. However, the instruction guided by the framework of the conflict map was shown to be a potential way of changing the alternative conception and acquiring scientific understandings, especially in light of long-term observations. A detailed analysis of students' ideas across the interviews also strongly suggests that researchers as well as practicing teachers need to pay particular attention to those students who can simply recall the scientific fact without deep thinking, as these students may learn science through rote memorization and soon regress to alternative conceptions after science instruction. © 2005 Wiley Periodicals, Inc. J Res Sci Teach 42: 1089–1111, 2005

Research evidence and findings on the learning of science have supported that students usually use alternative conceptions constructed before or even after formal science instruction to interpret natural phenomena (Wandersee, Mintzes, & Novak, 1994). Therefore, students often use

Contract grant sponsor: National Science Council, Taiwan; Contract grant number: NSC 88-2511-S-009-001, NSC 91-2511-S-009-008.
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DOI 10.1002/tea.20089
Published online 3 November 2005 in Wiley InterScience (www.interscience.wiley.com).

their alternative conceptions to assimilate new perceptions and conceptions. The alternative conceptions, which are different from those accepted by scientists, are persistent and resistant to alteration by traditional teaching strategies (Clement, 1982; Tsai, 1999a). Accordingly, it is essential for students to transform their existing conceptions into more scientifically accepted ones, generally aligning with science educators' perspectives or interpretations of ''conceptual change'' (Dole & Sinatra, 1998; Posner, Strike, Hewson, & Gertzog, 1982; Tsai, 1998a).

Although numerous perspectives about conceptual change have been proposed, the one initiated by Posner et al. (1982) is clearly among the most influential models, and has gained some support from research literature and teaching practice (e.g., Hewson & Thorley, 1989; Stofflett, 1994; Stofflett & Stoddart, 1994; Wandersee et al., 1994). Posner et al. (1982) proposed a model of conceptual change, which involves a series of conditions, including: (1) students become dissatisfied with existing (alternative) conceptions because the conceptions appear useless to solve a problem; (2) a new conception must be intelligible; (3) a new conception must appear initially plausible; and (4) a new conception should be fruitful, and has more explanatory power and is useful to solve future problems. Educators (e.g., Hewson & Thorley, 1989) have also suggested that the students are those who should judge whether these conditions are met. Other researchers have also highlighted the importance of contextual, social, affective, and cultural factors in the process of conceptual change. For example, Pintrich, Marx, and Boyle (1993) urged educators to consider the ways in which students' motivational views about themselves as learners and their roles in classroom learning contexts can promote or hinder conceptual change. Vosniadou (1999) and Vosniadou and Ioannides (1998) have also pointed out the value of relating conceptual change to social, cultural, and situational factors. For instance, Diakidoy, Vosniadou, and Hawks (1997) presented evidence that students' conceptual change in astronomy is influenced by cultural contexts. The researchers tend to believe that the process of conceptual change involves complicated social, affective, and situational factors. The framework of the conflict map examined later in this study basically follows the Posner et al. model; however, some contextual and social issues about conceptual change are addressed.

Role of Anomalous Data and Cognitive Conflict

Taking into account Posner et al.'s (1982) model, science educators are cognizant that anomalous data play an important role in knowledge acquisition in science. Limon and Carretero (1997) and Mason (2000) found that presenting anomalous data, at least, facilitated the achievement of the first steps of the conceptual change process. Research by Chinn and Brewer (1993, 1998) may represent one of the most comprehensive analyses about the role of anomalous data. They revealed the following eight possible responses when individuals encounter anomalous data: (1) ignore the data; (2) reject the data; (3) admit uncertainty about the validity of the data; (4) eliminate the data from the domain of the current theory; (5) hold the data in abeyance; (6) reinterpret the data; (7) accept the data and make tangential changes to the current theory; and (8) accept the data and change the theories. Among the aforementioned responses, seven of them involve suspecting the anomalous data to ''defend'' the original theory. Consequently, simply presenting a cognitive conflict or anomalous data in learning environments does not seem to warrant conceptual change. Chinn and Brewer (1993) have also pointed out that the characteristics of prior knowledge and the new theory, the nature of the anomalous data, and processing strategies may influence how people respond to anomalous data and then relate to the possibility of fostering conceptual change. It should be noted that, although the idea of cognitive conflict or anomalous data may be more aligned with the Posner et al. (1982) model, its use is also related to contextual and social aspects of conceptual change. For example, the anomalous data should be presented in the context of students' cultural experiences to possibly trigger their cognitive conflict. Chinn and Brewer (1993) also claimed that prior knowledge (or alternative conception) may be entrenched because it satisfies strong personal and social purposes; it is then carefully retained even after encountering anomalous data.

The above discussion may suggest a general sequence to facilitate students' conceptual change: (1) learners encounter phenomena, ideas, or anomalous data that conflict with their existing conceptions and such events are rudimentary in leading them to question their notions of natural phenomena; (2) students must see the new ideas or conceptions as initially plausible and easily understood and internalize these ideas into their knowledge schemata; and (3) students are able to reinforce and validate the newly learned concepts by applying them to a novel situation or other problems. The use of the conflict map proposed later concurs with this perspective, and involves some contextual and social issues.

Instruction Guided by the Conflict Map

In the last decade there has been increased research interest in investigating the use of teaching strategies to promote conceptual change among science students. Some of the instructional methodologies have been developed, revised, and tested and proven to be effective (to name a few), such as bridging analogies (Clement, 1988), computer-assisted simulations (Windschitl & Andre, 1998), and inquiry-oriented activities (Trundle, Atwood, & Christopher, 2002).

Unlike the aforementioned instructional approaches, the conflict map proposed herein specifically asserts that students should resolve two conflicts during the process of conceptual change: one exists between new perception and students' alternative conception (conflict 1), and the other one exists between student alternative conception and the scientific one (conflict 2) (Hashweh, 1986). The resolution of conflict 1 does not necessarily clarify conflict 2. Conflict 1 may be resolved through discrepant events, and resolution of conflict 2 could be achieved using "critical events or explanations" and relevant perceptions and conceptions that explicate the scientific conception. Both the discrepant and critical events regard anomalous data in which theoretical predications are in conflict with empirical data. Often, in the case of a discrepant event, students are confronted with an unfamiliar, new finding, whereas, in the case of a critical event, the students are invited to make an inference that contradicts a fact that is already well known to the learners or in the context of their cultural experiences. The discrepant and critical events are usually presented in the format of small-group discussion to encourage students to freely explore their ideas, concerns, and alternatives regarding these events. In addition to the discrepant and critical events, the conflict map uses other relevant conceptions and perceptions to support the target scientific conception. Figure 1 shows the framework of a conflict map, and a full description of the rationale behind using a conflict map was presented in Tsai (2000). The origin of using the conflict map is based on the research work of Tsai (2000), which was extended from the theoretical framework of Hashweh (1986).

Clearly, use of the discrepant event and critical event in the conflict map could fulfill Posner et al.'s (1982) first condition of conceptual change—the dissatisfaction with existing ideas. The instruction of a target scientific conception could fulfill Posner et al.'s second condition. Educators can use linguistic expressions, images, examples, or analogies to make the target conception intelligible. The third condition, the plausibility of the target conception, could potentially be achieved when the discrepant and critical events, relevant scientific concepts, and possibly other supporting perceptions are introduced and well integrated in the instruction. Other perceptions (and perhaps other scientific concepts) related to the target scientific concept could foster the

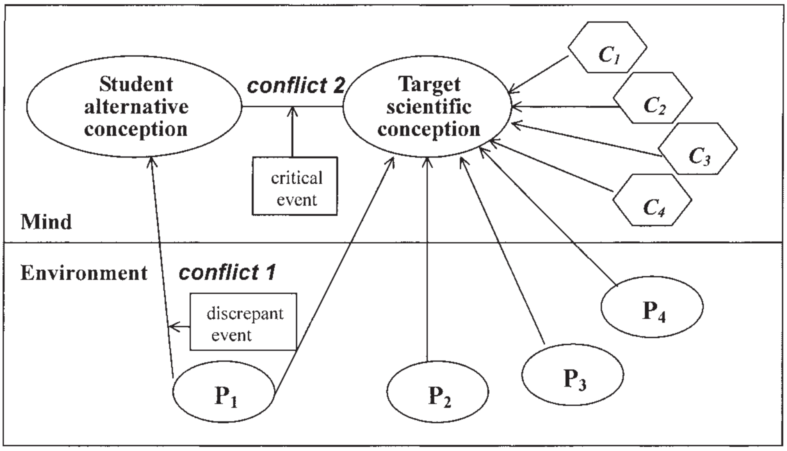


Figure 1. The framework of the conflict map (modified from Tsai, 2000, p. 291). P1, the perception inducing a discrepant event; P2, P3, P4, other supporting perceptions; C1, C2, C3, C4, relevant scientific conceptions.

fourth condition, showing the fruitfulness of the target conception. In other words, the rationale of the conflict map is consistent with the theoretical frameworks of the Posner et al.'s (1982) model of conceptual change (Fig. 2). Hence, the suggested instructional sequence in Figures 1 and 2 positions the discrepant event (or P1) and critical event first; then target scientific conceptions, C1,

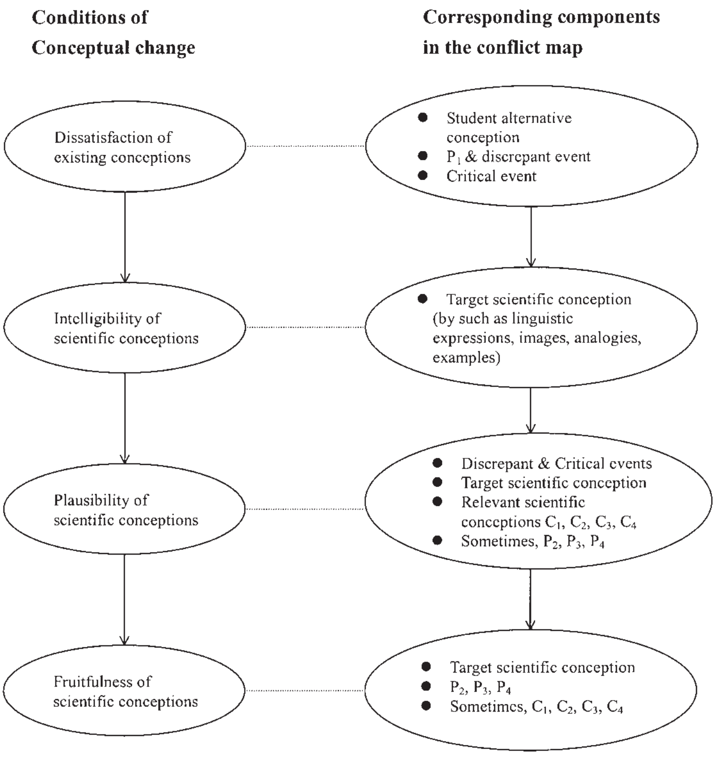


Figure 2. The rationale of using the conflict map and its instructional sequence.

C2, C3, and C4; and finally P2, P3, and P4. The conclusions derived from the discrepant and critical events may be incorporated again into the latter part of the sequence to show the plausibility of the target scientific conception. The teacher can follow the instructional sequence presented in the conflict map, which introduces a series of events, conceptions, and related perceptions to overcome students' certain alternative conceptions or to help them develop scientific conceptions.[1]

Thus, use of the conflict map does not assert that the cognitive conflict *per se* can promote conceptual change; rather, it provides more opportunities for students to explore existing as well as new experiences and conceptions. Use of the conflict map not only presents the cognitive conflict or anomalous data, but also assists students in exploring the connections between anomalous data, alternative conceptions, scientific conceptions, other knowledge, and experiences, thus helping students to engage in deep processing about the target scientific concepts. Because the use of the conflict map is developed on the basis of students' existing knowledge and related experiences, it is also consistent with the perspective proposed by Hewson and Thorley (1989) that the conceptual change requirements of intelligible, plausible, and fruitful must be in the students' conceptions. However, instruction guided by the conflict map does not completely ignore the contextual/social aspects of conceptual change. For example, instruction guided by the conflict map highlights the importance of presenting anomalous data in the context of students' cultural experiences (e.g., the use of critical event). It also encourages students' participation in the social development of science knowledge, such as group discussion of discrepant and critical events. In this way, the contextual and social issues of conceptual change may be addressed.

Figure 3 displays a conflict map of overcoming students' common alternative conception that seasons are determined by the earth's distance from the sun. A discrepant event describes that, in June and July, the earth is slightly further away from the sun, whereas the earth is closer to the sun in December and January. A critical event explains that if seasons were caused by the earth's distance to the sun, both the Southern and Northern Hemispheres would have the same seasons at the same time. This clearly contradicts the well-known fact (cultural knowledge or existing experiences) that, when it is winter in the Northern Hemisphere, it is summer in the Southern Hemisphere. Therefore, the discrepant event may provide new empirical data to challenge students' alternative conceptions, and, to a certain extent, may cause some surface dissatisfaction with these ideas. The critical event is intended to critically address the inadequacy of alternative conceptions through students' other well-known knowledge or cultural experiences.

The target scientific conception in Figure 3 demonstrates that seasons are caused mainly by the earth's 23.5° tilt of axis, whereas the earth's positional orbit is a relatively negligible effect. Hence, the ideas of rotation, revolution, Tropic of Cancer, and Tropic of Capricorn are relevant concepts for the target scientific concept. The length of day and night and the warm Christmas in Australia and New Zealand are supporting perceptions of the scientific concept.[2] The instruction guided by the conflict map is expected to offer opportunities for students to clarify and articulate scientifically acceptable understandings of the causes of seasons and possibly to modify their ideas through the instruction.

Interventions for Changing Alternative Conceptions or Articulating Scientific Understandings

In recent years, science educators have conducted a variety of instructional interventions to change students' alternative conceptions and to help them construct scientific understandings for different science domains, such as physics (Lubben, Netshisaulu, & Campbell, 1999; Ravanis &

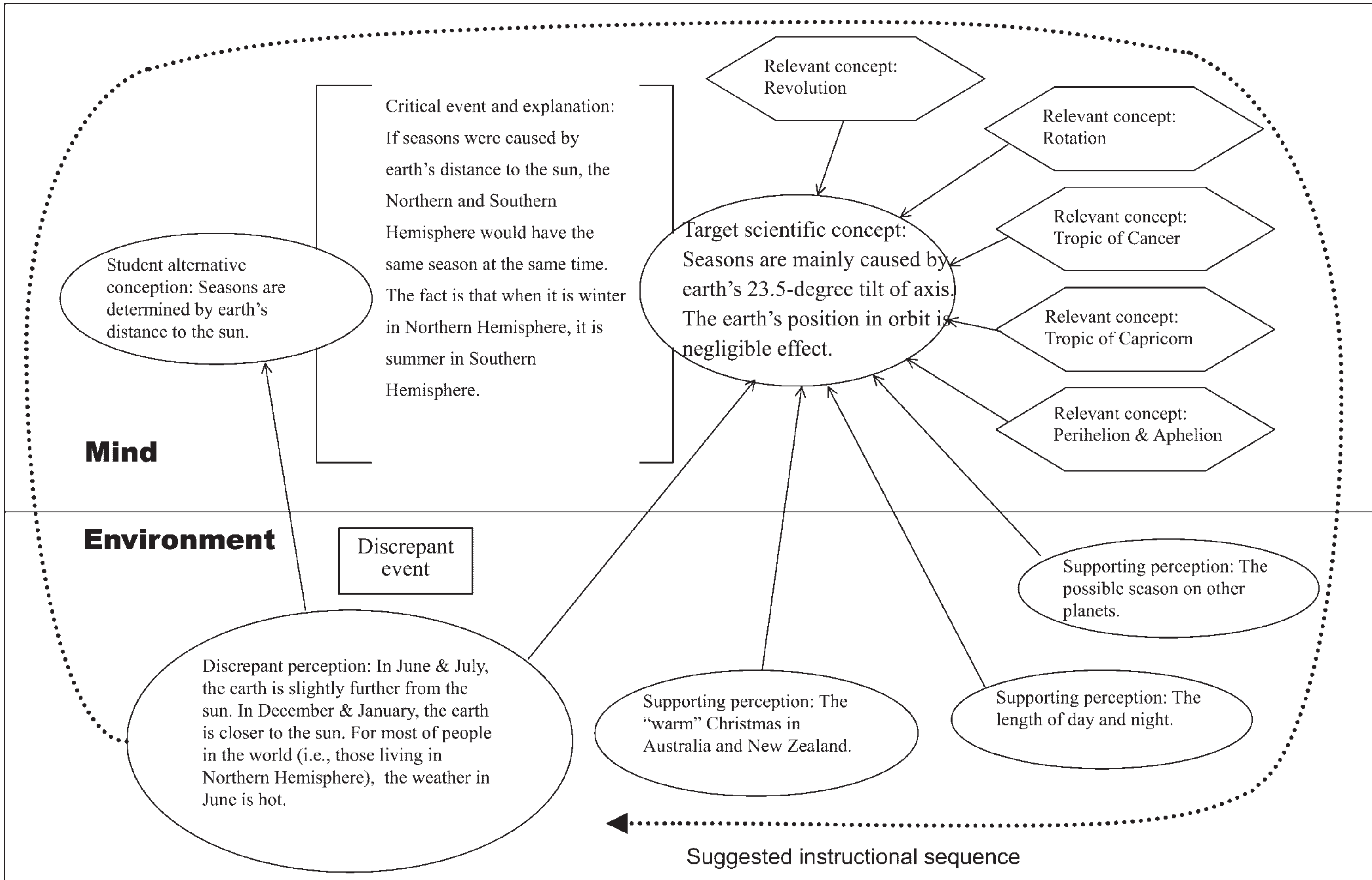


Figure 3. A conflict map about the cause of seasons.

Koliopoulos, 2004), chemistry (Ardac & Akaygun, 2004; Case & Fraser, 1999), biology (Pearsall, Skipper, & Mintzes, 1997; Windschitl & Andre, 1998), and earth sciences (Sneider & Ohadi, 1998; Trundle et al., 2002). The interventions were implemented by different features of instruction, including cognitive conflict (Limon, 2001; Limon & Carretero, 1997; She, 2004; Tsai, 2003), inquiry-based activities (Sneider & Ohadi, 1998; Trundle et al., 2002), computer simulations (Sanger & Greenbowe, 2000; Windschitl & Andre, 1998), analogy (Tsai, 1999a), and concrete manipulations (Case & Fraser, 1999).

Based on research data, there are at least three major implications regarding how the present study was conducted. First, many studies have investigated students' or teachers' alternative conceptions about the causes of seasons (Atwood & Atwood, 1996; Trumper, 2001, 2003; Sharp, 1996), but very few have implemented interventions to help students modify conceptions and acquire scientific understandings. Second, most of the intervention studies reviewed previously assessed students' ideas only a short time after the treatment, such as immediately posttest or a few days posttest (e.g., Case & Fraser, 1999; Sneider & Ohadi, 1998). Only a few studies monitored students' ideas for a relatively longer time by delay test, such as 1 month (Sanger & Greenbowe, 2000), 3 months (Tsai, 2003), or 13 weeks (Pearsall et al., 1997) after the intervention. To examine the lasting effects of the research treatment, a longer, more careful exploration of students' ideas may be necessary. Also, students' ideas should be better assessed over different periods of time to determine their possible ideational changes. Third, some studies have evaluated students' concepts by intervals after the intervention, but they did not track each individual's ideas across different assessments administered at different times. Rather, they mainly analyzed their ideas by group performance, on average (e.g., Pearsall et al., 1997; Tsai, 2003). If research can be conducted to review individual students' ideas across different assessments by time, educators may better understand the process of conceptual learning.

Research Purposes

Studies (e.g., Atwood & Atwood, 1996; Schneps, 1988; Trumper, 2001) have revealed that students, even graduates from prestigious universities and preservice teachers, usually have a common alternative conception about the causes of seasons—that seasons are determined by the earth's distance to the sun. How to help students understand the scientific conception about the causes of seasons may be an important issue for science educators. Therefore, the purpose of this study was to implement an intervention guided by the framework of the conflict map (see Fig. 3),[3] and then investigate the possible instructional effects in helping students to articulate scientific understandings about the causes of seasons. Through a quasi-experimental educational research design, two groups of ninth graders' conceptual understandings were investigated, as they received either traditional teaching or conflict map–based instruction. In addition, as described earlier, exploring the lasting effects is quite important for instructional intervention. Through comparing these two groups of students' concepts about the causes of seasons as elicited in a postinstruction interview, a 2-month delay interview, and an 8-month retention interview, this study sought to determine how the instruction informed by the ideas of the conflict map could help students acquire and retain scientific conceptions about the causes of seasons for a longer time. Moreover, our investigation attempted to track each individual's ideas across different interviews, thus trying to gain a better picture for the process of student knowledge acquisition. In sum, this study, through a quasi-experimental research design, was conducted to explore the lasting effects of instruction guided by the conflict map on students' conceptual learning about the causes of seasons.

Methods

Participants

The participants in this study came from two classes in a junior high school in Taipei, Taiwan. Both classes (ninth graders, 15-year-olds) were taught by a male science teacher with 8 years of teaching experiences.[4] The teacher held a bachelor degree of science in physics and a master degree of science in astronomy physics. He also frequently attended workshops about constructivist-oriented instruction and showed some intention to implement relevant ideas for teaching. Therefore, he had adequate background knowledge about students' alternative conceptions, conceptual change, and constructivism.

One class was assigned to a traditional instruction group (42 students), whereas the other class was assigned to conflict map instruction treatment (40 students). Twenty-five students were randomly selected from each group for interviews about their ideas regarding the causes of the seasons (described later). Table 1 shows that there was no significant difference in science scores between these two groups as revealed in the previous semester and by the midterm examination (about earth sciences) administered immediately before conducting the research treatment ($p > 0.05$). The selected students in both groups (25 in each group) also did not differ significantly in these science scores ($p > 0.05$). This implies that the two groups had similar prior knowledge in science or earth science before the start of the study. They subsequently participated in this quasi-experimental educational research.

Research Treatment

According to the teacher's experience, for students having prior conceptions of rotation and revolution, he estimated that it took about two periods (50 minutes per period) to teach the target concept (shown in the conflict map) with a traditional approach (as what he usually did). Consequently, the teacher, after consulting with the present investigators, proposed a two-period instructional plan for teaching the target concept in a traditional way. To control the time effects, this study created a treatment lesson plan of the same length of time. The treatment basically followed the instructional sequence provided by the conflict map shown in Figure 3. The instruction guided by the conflict map was also collaboratively developed by the teacher and the investigators on the basis of the teacher's rich experiences with students and some local research reports or projects on Taiwanese students' learning about the causes of seasons (e.g., Chiu & Wong, 1995).

Table 1
Students' prior science scores between both groups

	Traditional Instruction Group (Mean, SD)	Conflict Map Group (Mean, SD)	*t*-Value
All students	N = 42	N = 40	
Previous semester[a]	73.38 (12.2)	74.25 (13.8)	−0.30 (NS)
Midterm exam[b]	70.88 (15.4)	69.85 (16.7)	0.29 (NS)
Selected students	N = 25	N = 25	
Previous semester	74.36 (12.2)	72.9 (13.7)	0.39 (NS)
Midterm exam	71.96 (16.0)	69.1 (16.6)	0.62 (NS)

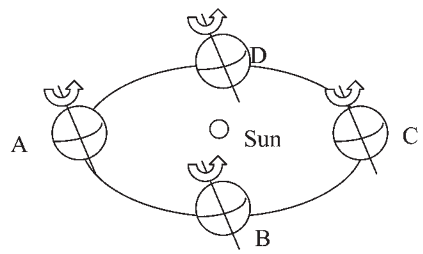
NS, not significant.
[a]Scores for science subject, ranging from 0 to 100.
[b]Scores for earth science subject, ranging from 0 to 100.

(1) The tutorial problem:

Please explain why the summer occurs on the hemisphere of Earth that is tilted toward the Sun.

(2) Two sample items on the quiz (note: Correct answers are designated by *):

The diagram below shows the revolution of Earth around the Sun. Try to choose the answer that best fits each of the questions below:



1. When Earth moves to position C, what season will it be in Taiwan? (1) spring (2) summer* (3) autumn (4) winter.
2. When Earth moves from C to D, what will happen in terms of alterations of daylight and nighttime periods (hours) in a day? (1) daylight and nighttime hours are always equal (2) increasing daylight hours (3) decreasing daylight hours* (4) nighttime hours are always longer than daylight hours.

Figure 4. Sample tutorial problem and quiz questions used in the traditional instruction group.

In the first period of the conflict map group study, the teacher first reviewed the concepts of rotation and revolution. He then asked students to explain the possible causes of seasons. The students then worked in small groups to discuss possible explanations. Students presented their ideas to the whole class, and the teacher finally introduced the discrepant event in Figure 3 (i.e., in June and July, the earth is slightly further from the sun, whereas in December and January the earth is closer to the sun). The teacher further used the critical event to challenge students' alternative conception (i.e., if seasons were caused by the earth's distance to the sun, the Northern and Southern Hemispheres would have the same season at the same time). The teacher ended the instruction at this point for students to think more about other contradictions and alternatives.

In the second period, the teacher first reviewed the discrepant and critical events presented in the first period. After listening to more students' ideas, the teacher gave a scientific explanation that seasons are caused mainly by the earth's 23.5° tilt of axis. This part of the instruction used some balls of different sizes and role-playing activities to explain the possible relationships between the sun and the earth. The teacher then related the target scientific concept to other scientific concepts, such as revolution, rotation, Tropic of Cancer, and Tropic of Capricorn, coupled with the conclusions drawn from the discrepant and critical events. Finally, the teacher used other perceptions to support the target scientific concept, such as the length of day and night, the ‘‘warm’’ Christmas in Australia and New Zealand, and the possible seasons on other planets. Hence, the instructional sequence is consistent with the illustrations presented in Figures 2 and 3.

The traditional approach employed in the study, however, emphasized direct guidance and lectures, occasional demonstrations, and clear explanations of the causes of seasons to the students given by the teacher in the classroom. Class discussions between the teacher and students and among the students were also embedded in the traditional teaching format. The key feature of this instruction was to provide students with clear and detailed lectures and explanations concerning the causes of seasons. Therefore, the following instructional activities were presented for the traditional instruction group. In the first period of the traditional group study, the teacher gave a review about rotation and revolution. He then directly gave a scientific model to explain the causes of seasons. Similar to that in the conflict map group, this part of the instruction used different sizes of balls, role-playing activities, and group discussions to explain the possible relationships between the sun and the earth. In the second period, the ideas of Tropic of Cancer and Tropic of Capricorn were introduced and emphasized. The teacher then guided the students to finish some tutorial problems and a quiz in the textbooks. The questions shown in Figure 4 exemplify one of the tutorial problems and two sample items from the quiz used in the traditional instruction group. Students applied their knowledge about the causes of seasons to solving these problems and the quiz.

In the study, care was taken to ensure that an appropriate comparison was attained between the traditional and conflict map teaching approaches. During the treatment period, each group received an equivalent amount of instructional time and was provided with similar role-playing small-group activities. In addition, both groups also had the same learning objectives (i.e., topics on the causes of seasons), and had equal opportunities to practice their learning objectives. Therefore, the scope of the content covered by the two treatments was found to be equivalent relative to the posttreatment interviews. Students’ invested time during the instruction was controlled between these two groups in this quasi-experimental study.

Data Collection

The selected participants (i.e., 25 students in each group) were interviewed individually at 1 week after the treatment to explore their ideas about the causes of seasons (the immediate interview). The interview was conducted by a trained researcher. The same students were interviewed again 2 months and also 8 months after the treatment to investigate their ideas about the causes of seasons in light of long-term observations (the delay and retention interviews). Therefore, there were three interviews undertaken by this study, including the one at 1 week after (immediate interview), the other one 2 months after (delay interview), and final one at 8 months after (retention interview) the research treatment. Not many previous studies examining the effects of conceptual change instructional strategies explored students’ ideas for such a long time. Due to the unexpected absence of some participants in the second interview, the sample numbers for the second interview were 22 for the traditional instruction group and 23 for the conflict map group, whereas 22 students in each group finished the final interview. The interview questions mainly probed students’ ideas about the causes of seasons (e.g., Could you tell me what the causes of seasons are? Do you have any other evidence or phenomena that can support the causes of seasons you just mentioned?). All interview data were tape-recorded and transcribed. To categorize students’ conceptions about the causes of seasons, the verbatim transcripts were analyzed in a way similar to the phenomenographic method (Marton, 1981, 1986). That is, researchers found content-specific similarities and differences between students' ideas about the phenomena (i.e., the causes of seasons in this study), and constructed categories that characterized the qualitatively different ways expressed by the students.

Categories of Classifying Students' Ideas

Through phenomenographic analyses, students' interview responses were mainly characterized into three categories: scientific, alternative conception, and no conception; each category may include some subcategories. The categories of description were developed by the researchers and were based on verbal descriptions of students' interview responses.

1. *Scientific*: Students who stated that the cause of seasons came from the earth's 23.5° tilt of axis.

   Among the students recalling the scientific conception, four exclusive subcategories were identified after examining student interview transcripts.

   Fact: Students who could state the scientific fact, but could not provide any further explanations.

   N & S Hemispheres: Students who could not only provide the scientific fact, but also mention the different seasons between the Northern and Southern Hemispheres.

   Distance negligible: Students who could not only state the scientific fact, but could also justify that the earth's position in orbit is a relatively negligible effect about the causes of the seasons.[5]

   NS & DN: Students who could not only provide the scientific fact, but also state the ideas of both "N & S Hemispheres" and "Distance Negligible" described earlier.

   Based on the content of interview responses, each student categorized as having a "scientific" conception was further classified into one (and only one) subcategory listed.
2. *Alternative Conception*: Students who had alternative conceptions about the causes of seasons. There were four exclusive subcategories for this group of students.

   Distance: Students who believed that the cause of seasons was the varying distance of the earth from the sun. However, students in this subcategory did not mention the orbit of the earth's revolution or the ideas of Perihelion and Aphelion to reinforce their alternative conception.

   Orbit: Students who stated that the cause of seasons came from some idiosyncratic models about the orbit of earth's revolution.

   Distance & Orbit & Perihelion (D & O & P): Students who not only believed that the distance of the earth from the sun caused the seasons, but also mentioned the orbit of the earth's revolution and the ideas of Perihelion and/or Aphelion to reinforce their alternative conception.

   Tilt Change: Students who asserted that the tilt of the earth's axis changed as the earth revolved around the sun, or that the pole of the hemisphere having summer was pointed almost directly toward the sun (by changing the tilt of the axis). That is, these students believed that seasons were caused by a changing tilt of the earth's axis.

   Based on the content of the interview responses, each student categorized as holding an "alternative conception" was classified into one (and only one) subcategory listed.
3. *No Conception*: Students who could not provide any idea.

Data Analysis

Every individual student's interview data were classified into either one of the aforementioned categories (i.e., "Scientific," "Alternative," or "No Conception"), and one subcategory

Table 2
The responses gathered from three interviews

	Traditional Instruction Group	Conflict Map Group
First interview	N = 25	N = 25
Scientific conception	17 (68%)	19 (76%)
Alternative conception	7 (28%)	6 (24%)
No Conception	1 (4%)	0 (0%)
Second interview	N = 22	N = 23
Scientific conception	9 (40.9%)	15 (65.2%)
Alternative conception	11 (50%)	7 (30.4%)
No Conception	2 (9.1%)	1 (4.3%)
Final interview	N = 22	N = 22
Scientific conception	5 (22.7%)	12 (54.5%)
Alternative conception	13 (59.1%)	8 (36.4%)
No Conception	4 (18.2%)	2 (9.1%)

(except the category of ‘‘No Conception’’). The categorization processes were conducted by a university science education professor and a secondary school science teacher. They read the whole set of interview transcripts independently and then decided on a conceptual category and possibly a subcategory for each participant's ideas in each round of the interview. The categorization agreement was 0.92 (Cohen's kappa) between these two researchers. For the interview data that did not reach the researchers' agreed-upon categorization, the researchers reviewed the transcripts again and discussed them case by case, and then determined a final categorization.

Results

Students' Responses in the First Interview

Students' interview results are presented in Table 2 for the first (immediate) interview. In the first interview, conducted 1 week after the research treatment, 68% of the students in the traditional group and 76% of the students in the conflict map group expressed scientific conceptions about the causes of seasons. From this perspective, both traditional instruction and conflict map–guided instruction probably had similar effects on students' ideas about the causes of seasons, probed 1 week after the treatment.

Moreover, a detailed analysis of students' responses as elicited in the first interview, presented in Table 3, provided some noteworthy findings. More than a half of the students in the traditional instruction group who recalled scientific knowledge were categorized as ‘‘Fact’’ conception (a total of 9 of 17 students). That is, most of students in the traditional instruction group, viewed as correct respondents, could merely recall the scientific fact without providing any further explanation. On the other hand, among the 19 students who could state scientific conceptions in the conflict map group, only 5 were classified into the ‘‘Fact’’ subcategory. Many could further explain the different seasons between Northern and Southern Hemispheres (8 students). Still others could explain not only the different seasons between Northern and Southern Hemispheres, but also clarify the relatively negligible effects caused by the earth's position in orbit (6 students); however, only two students in the traditional group expressed the same views. Table 3 also shows that those students, in both groups, had alternative conceptions, which were mainly related to the view that the cause of seasons was the varying distance of the earth from the sun (shared by the

Table 3
A detailed analysis of responses gathered from three interviews

	First Interview		Second Interview		Final Interview	
	Traditional Instruction Group (n = 25)	Conflict Map Group (n = 25)	Traditional Instruction Group (n = 22)	Conflict Map Group (n = 23)	Traditional Instruction Group (n = 22)	Conflict Map Group (n = 22)
Scientific						
Fact	9 (36%)	5 (20%)	5 (22.7%)	5 (21.7%)	4 (18.2%)	3 (13.6%)
N & S Hemispheres	5 (20%)	8 (32%)	3 (13.6%)	7 (30.4%)	1 (4.5%)	6 (27.3%)
Distance Negligible	1 (4%)	0 (0%)	0 (0%)	1 (4.3%)	0 (0%)	2 (9.1%)
NS & DN[a]	2 (8%)	6 (24%)	1 (4.5%)	2 (8.7%)	0 (0%)	1 (4.5%)
Alternative						
Distance	3 (12%)	1 (4%)	2 (9.1%)	2 (8.7%)	4 (18.2%)	3 (13.6%)
Orbit	0 (0%)	1 (4%)	1 (4.5%)	0 (0%)	1 (4.5%)	0 (0%)
D & O & P[b]	3 (12%)	2 (8%)	4 (18.2%)	2 (8.7%)	4 (18.2%)	3 (13.6%)
Tilt Change	1 (4%)	2 (8%)	4 (18.2%)	3 (13.0%)	4 (18.2%)	2 (9.1%)
No Conception	1 (4%)	0 (0%)	2 (9.1%)	1 (4.3%)	4 (18.2%)	2 (9.1%)

[a]Students stated both ‘‘N & S Hemispheres’’ and ‘‘Distance Negligible.’’
[b]Students stated the ideas including all of ‘‘Distance,’’ ‘‘Orbit,’’ and ‘‘Perihelion & Aphelion.’’

subcategories of ‘‘Distance’’ and ‘‘D & O & P’’). Some students, even after instruction, showed such prevailing alternative conceptions, which have been documented extensively in the research literature (e.g., Atwood & Atwood, 1996; Schneps, 1988; Trumper, 2001).

Students’ Responses in the Second (Delay) Interview

In the second interview, which was conducted 2 months after the research treatment, more students in the conflict group could recall scientific knowledge (n = 15, 65.2%) than those in the traditional instruction group (n = 9, 40.9%), also shown in Table 2. On the other hand, about 60% of the students in the traditional group expressed alternative conceptions or no conceptions, but only about 35% of the students in the conflict map group held alternative conceptions or expressed no conceptions. When exploring students’ ideas 2 months after the treatment, the conflict map instruction displayed more favorable outcomes than traditional instruction.

Table 3 further presents a detailed analysis of students’ responses gathered from the second interview. Again, similar to the finding revealed in the first interview, more than a half of the students in the traditional instruction group who recalled scientific knowledge were classified in the ‘‘Fact’’ subcategory (5 of the 9 students). More students in the conflict map group could further explain the different seasons between Northern and Southern Hemispheres and/or clarify the relatively negligible effects caused by the earth’s position in orbit (43.4%)[6] than those in the traditional group (18.1%). The second interview also revealed that approximately 27.3% of the traditional instruction group students held the ‘‘distance’’ alternative conception (combining the percentage of ‘‘Distance’’ and ‘‘D & O & P’’), whereas about 17.4% of the conflict map group students showed the same view.

Students’ Responses in the Final (Retention) Interview

Students’ final (retention) interview results are also presented in Table 2. In the final interview, undertaken 8 months after the research treatment, merely 22.7% of the students (n = 5) in the traditional group expressed scientific conceptions about the causes of seasons. In contrast, still half of the students in the conflict map group (54.5%, n = 12) held the same conceptions. These results likely suggest meritorious improvement with research treatment on long-term evaluation, such as 8 months in the current study.

Again, a detailed analysis of students' responses, as elicited in the final interview, is presented in Table 3. Among the five students who recalled scientific knowledge in the traditional instruction group, four were categorized in the ''Fact'' conception category. In other words, almost all students in the traditional instruction group who were viewed as correct respondents in the final interview could simply state the scientific fact with no further explanation. On the other hand, among the 12 students expressing scientific conceptions in the conflict map group, only 3 were classified in the ''Fact'' subcategory, and many could further explain the different seasons between the Northern and Southern Hemispheres. Table 3 also shows that many students in both groups categorized as having alternative conceptions held an idea that seasons were determined by the earth's distance to the sun.

Students' Concepts Across Interviews

This study involved three interviews to elicit students' ideas about the causes of seasons, and attempted to explore the short- and long-term effects of the research treatment. Consequently, an analysis of individual students' concepts across these interviews may be useful to illustrate the actual effects of the study. Table 4 presents an analysis for students' responses across the first interview and the second interview. It was found that only eight students in the traditional group having scientific conceptions as elicited in the first interview expressed scientific conceptions in the second interview. In contrast, however, as many as 14 students in the conflict map group had scientific conceptions in both interviews. More students in the conflict map group could firmly keep the scientific conceptions compared with those in the traditional instruction group. Moreover, in the traditional group, six students originally held scientific conceptions, but had alternative conceptions (i.e., the path of scientific to alternative) 2 months later, and two students expressed scientific conceptions in the first interview but could not state any conceptions in the second interview (i.e., the path of scientific to no conception). On the other hand, in the conflict map group, only four students were tracked on the path of ''Scientific'' to ''Alternative,'' and no students were on the path of ''Scientific'' to ''No Conception.'' Finally, five students in the

Table 4
Students' concepts across the first and second interviews

Path	Traditional Instruction Group (n = 22)[a]	Conflict Map Group (n = 23)[b]
Scientific → Scientific	8[c]	14
Scientific → Alternative	6	4
Scientific → No Conception	2	0
Alternative → Scientific	1	1
Alternative → Alternative	5	3
Alternative → No Conception	0	1

[a]One student originally categorized as ''Scientific,'' one student categorized as ''Alternative,'' and one categorized as ''No Conception'' in the first interview, failed to participate in the second interview.
[b]One student originally categorized as ''Scientific'' and one student categorized as ''Alternative'' in the first interview failed to participate in the second interview.
[c]This indicates that eight students had ''scientific'' conceptions in the immediate (first) interview, and still had a ''Scientific'' conception in the delay (second) interview.

Table 5
Students' concepts across the second and final interviews

Path	Traditional Instruction Group (n = 22)	Conflict Map Group (n = 22)[a]
Scientific → Scientific	5[b]	12
Scientific → Alternative	3	2
Scientific → No conception	1	1
Alternative → Scientific	0	0
Alternative → Alternative	10	6
Alternative → No conception	1	0
No conception → No conception	2	1

[a]One student categorized as ''alternative'' in the second interview failed to participate in the final interview.
[b]This indicates that five students had ''scientific'' conceptions in the delay (second) interview, and still had a ''scientific'' conception in the retention (final) interview.

traditional instruction group and three in the conflict map group offered alternative conceptions in both the first and second interviews.

A similar analysis was undertaken for students' interview responses across the second and final interviews, as shown in Table 5. Table 5 shows that 5 students in the traditional instructional group and 12 students in the conflict map group expressed scientific knowledge in both the second and final interviews. However, three students in the traditional instructional group and two students in the conflict map group, having recalled scientific conceptions in the second interview, stated alternative conceptions in the final interview.

Concepts Expressed by Students Originally Categorized as "Scientific"

On the basis of the findings just presented, the students originally having scientific conceptions (in the first or second interview) may represent a group of students required for careful investigation. Table 6 shows that 50% of traditional instruction group students who were categorized as ''Scientific'' in the first interview stated alternative conceptions or no conceptions in the second interview (n = 8), whereas only 22.2% of conflict map group students originally classified as ''Scientific'' experienced the same path (n = 4). Similarly, Table 7 shows students' concepts across the second and final interviews for those who were viewed as ''Scientific'' in the second interview. It was revealed that four traditional instruction group students who were categorized as ''Scientific'' in the second interview expressed alternative conceptions or no conceptions in the final interview (44.4% among those classified as ''Scientific'' in the second

Table 6
Concepts across the first and second interviews for students categorized as "Scientific" in the first interview

Path	Traditional Instruction Group[a] n, %)	Conflict Map Group[b] (n, %)
Scientific → Scientific	8 (50%)	14 (77.8%)
Scientific → Nonscientific[c]	8 (50%)	4 (22.2%)

[a]One student in the traditional instruction group originally categorized as ''Scientific'' in the first interview failed to participate in the second interview.
[b]One student in the conflict map group originally categorized as ''Scientific'' in the first interview failed to participate in the second interview.
[c]This path totals the paths of ''Scientific to Alternative'' and ''Scientific to No Conception.''

Table 7
Concepts across the second and final interviews for students categorized as "Scientific" in the second interview

Path	Traditional Instruction Group (n, %)	Conflict Map Group
Scientific → Scientific	5 (55.6%)	12 (80%)
Scientific → Nonscientific[a]	4 (44.4%)	3 (20%)

[a]This path totals the paths of "Scientific to Alternative" and "Scientific to No Conception."

interview), whereas only 20% of conflict map group students labeled as "Scientific" in the second interview had the same path of ideational change ($n = 3$). The results in Tables 6 and 7 indicate that conflict map group students were more likely to keep the scientific conceptions once they had been acquired. As stated previously, instruction guided by the conflict map can provide more integrated frameworks about scientific conceptions, thus facilitating the development of more robust knowledge structures; therefore, students may not easily return to some alternative conceptions.

Among the students who expressed scientific conceptions in the interviews, those classified in the "Fact" subcategory may be particularly worthy for further exploration, as many students in school science tend to merely recall or memorize the scientific information without deep thinking (Chin & Brown, 2000; Tsai, 1998b). Therefore, it may be of interest to track how students placed in the "Fact" conception category in the interview may develop or change their ideas in a later interview. Table 8 presents an analysis across the first and second interviews. Two students in the traditional instruction group initially had a "Fact" conception in the first interview, but held a "Distance" alternative conception in the second interview; still, two in the group shifted from the "Fact" to the "Distance & Orbit & Perihelion" subcategory, two from "Fact" to "Tilt Change," and two from "Fact" to "No Conception." In sum, among the nine students in the traditional group who were classified into the "Fact" subcategory in the first interview, eight expressed alternative conceptions or no conceptions in the second interview, and only one was still in the "Fact" subcategory in the second interview. It is also of interest to associate these findings with those from Table 6. Table 6 shows that eight students in the traditional group had the path from "Scientific" to "Alternative or No Conceptions," and Table 8 indicates that eight students who were originally viewed as "Fact," a subcategory of "Scientific," changed to "Alternative" or "No Conceptions" in the second interview. That is, in the traditional instruction group, *all* of the students who had the scientific conceptions immediately after the instruction but expressed alternative or no conceptions (a total of eight students) in the second interview came from the group of students who merely stated the scientific fact without providing any further justifications in the first interview (i.e., students in the "Fact" subcategory of the first interview).

Table 8
Concepts across the first and second interviews for students categorized as "Fact" in the first interview

Path	Traditional Instruction Group (n)	Conflict Map Group (n)
Fact → Distance	2[a]	1
Fact → D & O & P[b]	2	1
Fact → Tilt Change	2	2
Fact → No Conception	2	0
Fact → Fact	1	1

[a]This indicates that two students had a "Fact" conception in the immediate (first) interview, but had a "Distance" conception in the delay (second) interview.
[b]Students stated the ideas including all of "Distance," "Orbit," and "Perihelion & Aphelion."

Similarly, among the conflict map group students who were viewed as ''Fact'' in the first interview, one student changed to ''Distance,'' one changed to ''Distance & Orbit & Perihelion,'' and two changed to ''Tilt Change'' in the second interview, whereas only one student remained in the ''Fact'' subcategory. In other words, a total of four students initially in the ''Fact'' subcategory expressed alternative conceptions in the second interview (Table 8). Based on the results in Table 6, only four students in the conflict map group were on the path from ''Scientific'' to ''Alternative and No Conceptions'' across the first and second interviews. Similar to the finding revealed by the traditional instruction group, in the conflict map instruction group, again, *all* of the students who had scientific conceptions immediately after the instruction but expressed alternative conceptions in the second interview originated from the group of students who could simply utter the scientific fact without offering any further explanations in the first interview.

A similar analysis was undertaken across the second and final interviews (Table 9). Two students in the traditional instruction group categorized as ''Fact'' in the second interview held the ''Distance'' alternative conception in the final interview, and one student in the conflict map group had the same ideational path. One student in the traditional instruction group and one student in the conflict map changed from ''Fact'' to ''Distance & Orbit & Perihelion'' across the two interviews. Also, one student in the traditional instruction group and one student in the conflict map group changed from ''Fact'' to ''No Conception.'' Finally, the number of students who remained in the ''Fact'' category across two interviews was one and two for the traditional instruction group and conflict map group, respectively. Again, it may be of interest to compare the results in Table 9 those in Table 7. Table 7 reveals that four students in the traditional instruction group labeled as ''Scientific'' in the second interview changed to ''Nonscientific'' in the final interview. However, Table 9 shows that four ''Fact'' students in the traditional instruction group ultimately expressed nonscientific ideas (two ''Distance,'' one ''Distance & Orbit & Perihelion,'' and one ''No Conception''). That is, in the traditional instruction group, *all* students who could recall scientific knowledge in the second interview but ultimately stated nonscientific conceptions came from those classified as the ''Fact'' subcategory in the second interview. Precisely the same finding was observed for the conflict map group. Table 7 shows that three students in the conflict map group categorized as ''Scientific'' in the second interview changed to ''Nonscientific'' in the final interview. Similarly, Table 9 also revealed that three ''Fact'' students in the conflict map group finally expressed nonscientific ideas (one ''Distance,'' one ''Distance & Orbit & Perihelion,'' and one ''No Conception''). Again, it could be concluded that *all* of the students who had scientific conceptions in the second interview but finally stated alternative or no conceptions originated from the group of students who could only supply the scientific fact with no further explanation in the second interview.

The findings summarized in Tables 6–9 strongly suggest that students, who can merely recall the scientific fact once after the instruction, will very likely regress to some alternative conceptions

Table 9
Concepts across the second and final interviews for students categorized as "Fact" in the second interview

Path	Traditional Instruction Group (n)	Conflict Map Group (n)
Fact → Distance	2[a]	1
Fact → D & O & P[b]	1	1
Fact → No Conception	1	1
Fact → Fact	1	2

[a]This indicates that two students had a ''Fact'' conception in the delay (second) interview, but had a ''Distance'' conception in the retention (final) interview.
[b]Students stated the ideas including all of ''Distance,'' ''Orbit,'' and ''Perihelion & Aphelion.''

after a relatively long period of time. Researchers as well as practicing teachers need to pay particular attention to the group of students who can simply recall the scientific fact without offering other justifications or involving deep thinking, because these students may learn science through rote memorization and soon regress to some alternative conceptions after science instruction. This part of the analysis also encourages other researchers in the field, when given enough samples, to investigate students' concepts through such a review of their ideational path.

Discussion and Conclusions

This study has reported on an experimental investigation into changing students' alternative conceptions about the causes of seasons. As revealed in previous research (e.g., Atwood & Atwood, 1996; Trumper, 2001), many students had a common alternative conception that seasons were determined by the earth's distance to the sun. Although this research involved only a limited sample of junior high school students, it was found that the instruction guided by the frameworks of the conflict map might be a potentially effective way of acquiring and retaining scientific understandings about the causes of seasons in light of a long-term study. Although the conflict map is mainly based on the use of cognitive conflict, the conflict map, such as the one shown in this study and those in other related studies (Tsai, 2000, 2001, 2003), adequately integrates students' existing experiences or knowledge,[7] new theory, anomalous data, and other conceptual as well as perceptual supports to facilitate the development of scientific conceptions. Tsai (2003) reported that instruction guided by the frameworks of the conflict map is effective in helping students develop more integrated and richer cognitive structures with regard to simple series electric-circuits. However, follow-up studies are necessary to explore some other instructional effects of the conflict map. For instance, researchers can investigate how the instruction guided by the conflict map may enhance students' motivation, or how students in the conflict map instruction and other types of instruction may differ in the use of reflective judgments and cognitive strategies.

The conflict map–guided instruction also includes some important features for promoting conceptual change shown by previous research, such as small-group interactive talks and discussions (Mason, 2001) or fostering metaconceptual awareness (i.e., allowing opportunities for students to express their representations and beliefs [Mikkila-Erdmann, 2001; Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001]). The conflict map provided a useful framework, including a series of events, phenomena, and concepts, for students to engage in deeper exploration and discussion by helping them to reconceptualize or make more connections between existing experiences or knowledge and new conceptions. Thus, they could construct better representations for the target scientific conceptions. In particular, exploration and discussion about the discrepant event and critical event in the conflict map, for example, are conducted in small groups and these students are allowed to explicitly express their representations about the phenomenon derived from these events. The group discussions may have provided students the opportunities to confront their existing nonscientific views and search for a more fruitful and intelligent view to interpret phenomenon. This supposition is, to some extent, consistent with Lonning's (1993) statement that cooperative learning strategies enhance conceptual change instruction, and it also supports the conclusion by Thorley and Treagust (1987) that interpersonal conflicts and interactions can stimulate pupils' knowledge development and conceptual change.

Although the traditional instruction in the study also involved small-group discussion (in the first instructional period), it did not show an effect similar to that guided by the conflict map. The conclusions derived from this study suggest that, for group discussion to be effective for student conceptual change or conceptual understanding, the content of student group discussion should be adequately conflicting to stimulate or to challenge their existing conceptions or cultural knowledge. The discussion accompanied by ‘‘discrepant event’’ and ‘‘critical event’’ involved in the conflict map instruction may provide appropriate content for group discussion, thus facilitating the process of conceptual change and learning. On the other hand, the task for small-group discussion in traditional instruction may not be conflicting enough, and its content is more constrained for fostering students’ thinking.[8] Nevertheless, more direct studies should be conducted to examine the effects of instruction guided by the conflict map on students’ thinking and their representations of the scientific conceptions, and also to assess how the conflict as induced by the map actually influences their learning and conceptual understanding.

This study also revealed some other informative findings. For example, a detailed analysis of students’ ideas across a series of interviews strongly implies that students, who can simply recall the scientific fact immediately after the instruction, will very likely regress to some alternative conceptions after a relatively long period of time. Their knowledge learned in science classrooms is surface level or fact recall that is forgotten over time. Previous studies have shown that many students in science classrooms tend to merely recall or memorize the scientific information without deep thinking (Chin & Brown, 2000; Tsai, 1998b, 1999b). Or, most of the science curriculum, teaching, and assessment request only fact-based knowledge or answers (Duschl, 1990). All of these may lead to the situation that many science students, even after some years of formal instruction, hold alternative conceptions, the same as those prior to instruction (Wandersee et al., 1994). There are, at least, the following practical implications for teaching: First, science teachers need to provide more opportunities for students to justify the scientific facts acquired. They should be encouraged to not only acknowledge the scientific knowledge, but also strengthen the validity as well as the usefulness of the knowledge. The assessment in science also should not simply evaluate students’ factual knowledge in science—it should also explore the reasoning behind the knowledge and its connections to other knowledge. The use of interviews (Bell, 1995), concept maps (Novak, 1998; Novak & Gowin, 1984), and two-tier tests[9] (Treagust, 1988) may be more effective for fulfilling these purposes. Moreover, teachers need to pay particular attention to the group of students who can simply recall scientific fact without offering other justifications, as these students may learn science likely through rote memorization and may soon return to some alternative conceptions after science instruction.

This study also illuminated some methodological reflections for future research. The investigation of students’ scientific conceptions and alternative conceptions can be conducted using a method similar to phenomenographic analysis, such as that shown in this study. This kind of analysis can classify students’ ideas into several exclusive subcategories. Researchers and educators can have a more detailed and refined picture of students’ ideas toward a specific topic. In this way, students’ conceptions in science are not simply viewed as either scientific or nonscientific or right or wrong; rather, they are different in various ways. As the present analysis has illustrated, even among students expressing scientifically correct conceptions there may be differences in the quality of their ideas, possibly leading to different consequences in a later interview. The use of some distinct subcategories may well differentiate students’ ideas, and thus assist researchers in examining students’ conceptions in greater detail and with better precision. Furthermore, this study, by conducting three interviews, has attempted to explore students’ possible changes of ideas through tracking their passages on these subcategories. These analyses were conducted by tracking individual students’ ideas across different interviews, not by group performance on average. Our investigation also explored students’ conceptual development for relatively a long time (8 months). Researchers in the field can also administer a series of interviews and use a similar method to explore students’ concepts through a similar review of their ideational path.

Notes

[1]The students do not necessarily see the map, although Tsai (2000) has proposed that educators can encourage students to construct their own conflict map after the instruction and then to use it as a metacognitive tool. The conflict map, in this study, was mainly perceived as a practical guide for implementing instruction.

[2]Earth revolves around the sun in an elliptical orbit at an average distance from the sun of 150 million kilometers. At Perihelion (closest to the sun), which occurs in the Northern Hemisphere's winter, the earth is 147 million kilometers from the sun. At Aphelion (furthest from the sun), which occurs in the Northern Hemisphere's summer, the earth is 152 million kilometers distant. At the Northern Hemisphere's summer solstice, the sun's rays directly strike the Tropic of Cancer, 23.5° North latitude. Therefore, the Northern Hemisphere is at its maximum tip toward the sun. When the sun is directly over the Tropic of Capricorn, 23.5° South latitude, at the Northern Hemisphere's winter solstice, the Southern Hemisphere is maximally tilted toward the sun. At both Fall and Spring equinoxes, the sun is directly over the equator. The rotation of the earth causes day and night, whereas the revolution of the earth around the sun and earth's tilted axis are responsible for the seasons.

[3]The dotted line indicated a suggested instructional sequence, which presented discrepant event first, then critical event, scientific concept, relevant concepts, and finally supporting perceptions.

[4]Although there is value in having the same teacher instruct both the traditional and experimental groups in terms of controlling extraneous variables, such as teacher's age, gender, years of teaching experience, etc., there might be some concerns regarding confounding effects such as the teacher's perceptions of the new experimental approach and comparability of the two groups. In this study, care was taken to ensure that an appropriate comparison was made between the traditional and experimental teaching approaches. Specific attention was paid to the level of availability of relevant resources for each treatment and students' learning objectives between groups (i.e., topics and principles introduced in the groups). Besides, the participating teacher was fully aware of the possible extraneous variables that might damage the validity of the study.

[5]However, students in this subcategory did not mention the different seasons between the Northern and Southern Hemispheres. If a student stated both the ideas of "Distance Negligible" and "N & S Hemispheres" then that student should be categorized in the subcategory "NS & DN." Hence, these subcategories were exclusive to encode students' interview responses.

[6]The percentage was totaled by the subcategories of "N & S Hemispheres," "Distance Negligible," and "NS & DN."

[7]Although this study did not present data for students' existing (prior) experiences and knowledge, for ninth graders in Taiwan, the concepts of rotation and revolution and the cultural knowledge about different seasons in different hemispheres, listed in the conflict map of this study, could be perceived as already existing. In fact, the concepts of rotation and revolution were taught previously in the same semester for the participant classes.

[8]In this sense, the factor "cognitive conflict" induced according to the conflict map is not confounded with the factor "group discussion." The cognitive conflict used adequately is still the key to success in group discussion or conceptual change.

[9]The two-tier test is a two-level question presented in a multiple-choice format. The first tier assesses students' factual knowledge in science, whereas the second tier explores students' reasons for their choice made in the first tier. Hence, the second tier investigates students' explanatory knowledge or their "mental models." Because the two-tier test is in a multiple-choice format, it is much easier for teachers to score or interpret students' responses. In this way, even with numerous students, a teacher can efficiently diagnose their alternative conceptions. For details about two-tier tests, refer to Treagust (1988) and Tsai and Chou (2002).

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