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RESEARCH REPORT

Enhancing science instruction: the use of 'conflict maps'

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This paper proposes the use of 'conflict maps' as a way of enhancing science teaching and learning. The conflict map emphasizes not only the use of discrepant events, but also the resolution of the conflict between students' alternative conceptions and the scientific conception, using critical events or explanations and relevant perceptions and conceptions that explicate the scientific conception. The use of conflict maps is consistent with a conceptual change model suggested by science educators; hence, it is expected that the conflict map could help students overcome alternative conceptions and thus promote conceptual change. The conflict map, which clearly displays students' alternative conceptions and scientific conceptions, could be used as an instructional aid, helping science teachers construct or implement lesson plans, or as a metacognitive tool, helping learners monitor their ideas and the processes of conceptual change.

Introduction

In the past two decades, an important contribution of science educators has been to explore and assess students' 'misconceptions' or 'alternative conceptions', because many educators believe that students' 'prior knowledge' could highly influence subsequent learning (Ausubel *et al.* 1978, Novak 1977, Wandersee *et al.* 1994). This pedagogical principle shapes the foundation of so-called 'constructivist' theories. A sheer number of studies documenting student alternative conceptions show that these conceptions are content-dependent and that they are resistant to change through conventional teaching strategies (Tsai 1998a; 1999a). Numerous researchers continue to investigate students' alternative conceptions in various content domains (e.g. Sneider and Ohadi 1998, Thomas and Schwenz 1998, Tytler 1998, Borges and Gilbert 1999). From the perspective of 'alternative conceptions', science learning does not simply add correct information; rather, it should replace strongly held conceptions (i.e. alternative conceptions) (Dole and Sinatra 1998, Posner *et al.* 1982). However, knowing students' alternative conceptions does not mean that educators or teachers have potential methods to promote such conceptual change. This paper, based on the theoretical frameworks of constructivism, proposes an idea of using 'conflict maps' to address student alternative conceptions. Conflict maps could be a promising instructional tool or a metacognitive tool with which to enhance science teaching and learning.

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The 'conflict map'

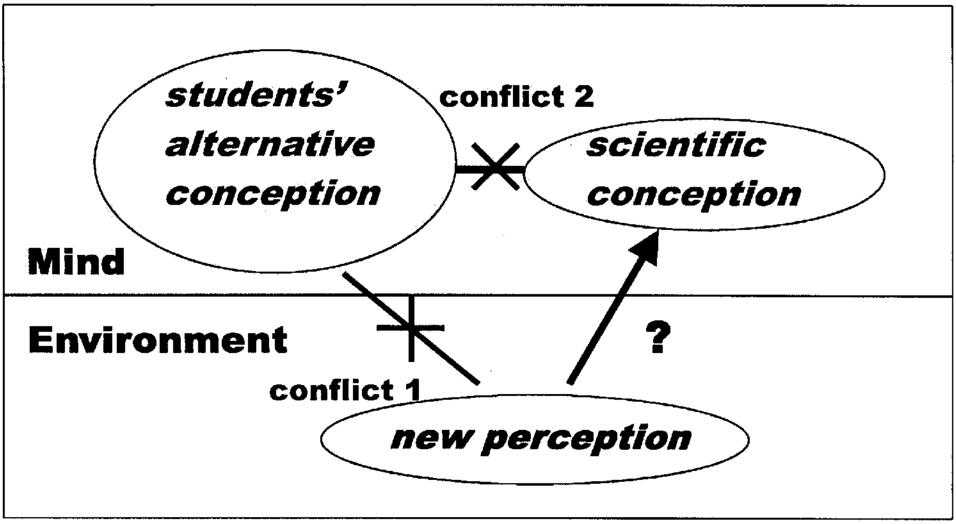
Numerous studies have concluded that students' alternative conceptions are persistent and resistant to alteration by traditional teaching strategies (e.g. Clement 1982, Gunstone 1987, Tsai 1998a; 1999a). Even when teachers present some counterexamples or anomalous data to expose the inadequacy of students' alternative conceptions, these ideas are in many cases tenacious (Chinn and Brewer 1993; 1998, Park and Kim 1998, Shepardson and Moje 1999). For instance, Champagne *et al*. (1985) recorded students' responses after seeing that a heavier object and a lighter object would fall down at the same speed. Those middle school students had the following responses:

- They wrote their observations that in fact the heavier object fell faster but they were surprised by the fact that the speeds were nearly the same.
- They tried to weigh the two objects carefully as they suspected that the objects were of the same weight.
- They released the objects from a much higher point as they doubted that the difference in descent times was too small to be observed over the short distance used in the original demonstration.
- They continued arguing that they could not observe differences in the rates of fall due to the insensitivity of the experimental procedure.

In sum, these students tried to 'protect' their original conception - the heavier object would fall faster. Consequently, believing is seeing, but seeing is not believing. This is compatible with Rowell's ideas about the 'conservatism of equilibration' (Rowell 1989: 148) and 'maximum gain/minimum cost principle' for the process of equilibration (Rowell 1983: 70). Students are conservative toward anomalous data because these responses would cost little cognitive effort. Their resistance to change shows the remarkable power of their alternative conceptions, while some contradictory evidence does not necessarily convince them that their existing conceptions are not satisfactory (Dreyfus *et al*. 1990, Duit 1991, Rowell and Dawson 1983). This leads to the following discussion on the inadequacy of simply using 'discrepant events'.

The inadequacy of simply using discrepant events

Discrepant events are designed to provide novel evidence to challenge students' alternative conceptions. The free fall demonstration is an example of this. However, students in many cases do not *accommodate* their alternative conceptions to scientific ones through experiencing these discrepant events. Accommodation occurs when new perceptions can not fit into one's existing conceptions. He or she then tries to fit the perceptions by adjusting existing conceptions (Bodner 1986). (In this paper, perception or percept indicates some direct interpretations of phenomena or events that obtained from the five senses or from imaginative acts, whereas conception or concept indicates some ideational frameworks that are constructed from a series of relevant observations, experiences or perceptions.) Figure 1 shows that, in fact, there are two conflicts for the process of accommodation: one exists between new perception and students' alternative conception (conflict 1) and the other one exists between their alternative conception and the scientific one (conflict 2). Conflict 1 is the key idea of discrepant events.



This figure is modified from an illustration of Hashweh's (1986) paper. The ideas of using conflict maps are also inspired and further extended from Hashweh's paper.

Figure 1. The inadequacy of discrepant events.

Many educators assume that conflict 2 can be resolved by overcoming conflict 1. This assumption however is not always true (Hashweh 1986). Indeed, what educators often observe is that students try to adjust the new perception to fit their existing conception, working on the process of assimilation, not accommodation (figure 2). That is, they try to adjust or distort the perception to conform to their alternative conceptions. This is precisely what the subjects in Champagne *et*

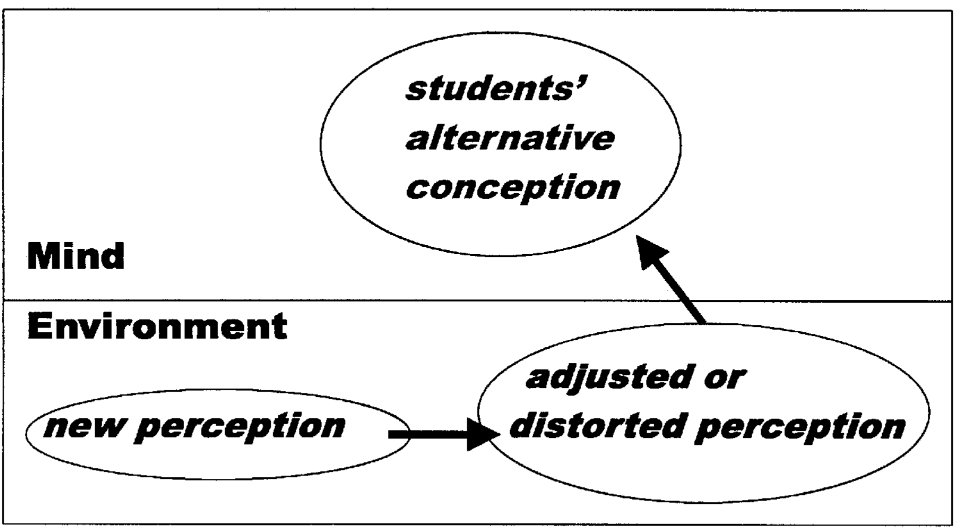


Figure 2. Students' typical responses to discrepant events.

al's (1985) study did. In other words, simply noting the discrepant event is not necessarily followed by a restructuring of students' existing ideas. The perceptions stimulated from discrepant events try to resolve the conflict 1; however, to achieve 'conceptual change,' students need to resolve both conflict 1 and conflict 2 and moreover to acquire relevant conceptual and perceptual support about the target concept that will be taught. To state it more specifically, conflict 1 could be resolved by discrepant events, while conflict 2 could be fully resolved when the following four conditions are fulfilled:

Condition 1 of resolving conflict 2. Students should have minimal understandings about the scientific concepts that will be studied. For example, to overcome students' 'the heavier/the faster' alternative conception about free fall motion, teachers should make the concepts of gravity or acceleration of gravity intelligible for students. That is, the scientific concepts should be understandable for students.

Condition 2 of resolving conflict 2. The learning process should involve a critical event or explanation to address conflict 2 'directly'. For example, 'the heavier/the faster' alternative conception stems from students' prior daily experiences, because under the condition of air resistance, a heavier object obviously will fall faster than a very light object. Therefore, science teachers could demonstrate that a feather and a coin will fall at the same rate (from the same height) in a vacuum. Such a demonstration could be viewed as an example of a critical event, directly targeting conflict 2. In other words, the design of a critical event should refer to the possible origins of students' alternative conceptions and then use scientific concepts to explain or 'cover' the alternative conceptions (because students' alternative conceptions, to a certain extent or in certain situations are often plausible). The difference between a discrepant event and a critical event is that a discrepant event usually uses one or two percepts to challenge students' alternative conceptions, while a critical event tries to directly justify the conflict between the conceptual frameworks of student alternative conceptions and those of scientific concepts.

Condition 3 of resolving conflict 2. There should be some other scientific concepts supporting the target scientific concepts that will be taught. For example, the law of universal gravitation could help students understand why all objects on Earth have the same acceleration due to gravity. This then leads them to the conclusion that a heavier object and a lighter object released from the same height will fall at the same speed. Moreover, the ideas related to acceleration and Newton's second law of motion could be relevant concepts supporting the target scientific concept.

Condition 4 of resolving conflict 2. There are some other perceptions or thought activities to sustain the scientific concepts being taught. For example, Galileo proposed a thought experiment that could be a relevant perception to the target concept. The thought experiment describes tying a heavy object and a light object together with a very thin (almost immaterial) string, such that the combined body can be argued to *both* fall faster *and* more slowly. It will fall faster because the combined object is heavier than two unattached objects; however, it will also fall more slowly because the slower object (the light object) is supposed to retard the motion of the faster one (the heavy object). Therefore, these two objects will fall at the same speed (for details, see Nersessian 1992). Furthermore, gravitational phenomena on other planets could provide additional perceptions to support the target scientific concepts.

In sum, the condition 2 is used to address conflict 2 'directly,' but the other three conditions are used as other related supports facilitating the resolution of conflict 2. According to these theoretical frameworks, if students are not aware of the existence of conflict 1 or if the first condition of resolving conflict 2 is not fulfilled, they will retain their original alternative conceptions, that is, the 'undisturbed outcome' summarized by Gilbert *et al*. (1982). If students acknowledge the existence of conflict 1 and achieve the first condition, but not the second, third or fourth condition of clarifying conflict 2, students may have the following possible instructional outcomes: 'two perspectives outcome' (i.e. students acquire one set of conceptual frameworks that only apply to school science and retain another set of knowledge to explain real life phenomena), 'reinforced outcome' (i.e., students defend their alternative conceptions by reinterpreting or distorting scientific conceptions and then scientific views are used to 'reinforce' their existing alternative conceptions), or 'mixed outcome' (i.e. students try to reconcile two seemingly incompatible theories; hence, they may make some peripheral changes to their existing alternative conceptions).

The construction of a conflict map

Based on the discussion above, one could construct a conflict map of overcoming students' 'the heavier/the faster' alternative conception, shown as figure 3. This conflict map is an extension of the map in figure 1 produced by adding some other conceptual and perceptual support for the target scientific concept. Figure 4 also illustrates a conflict map with which to address students' alternative conception that light bulbs use up electricity or electric current in a series circuit. The dis-

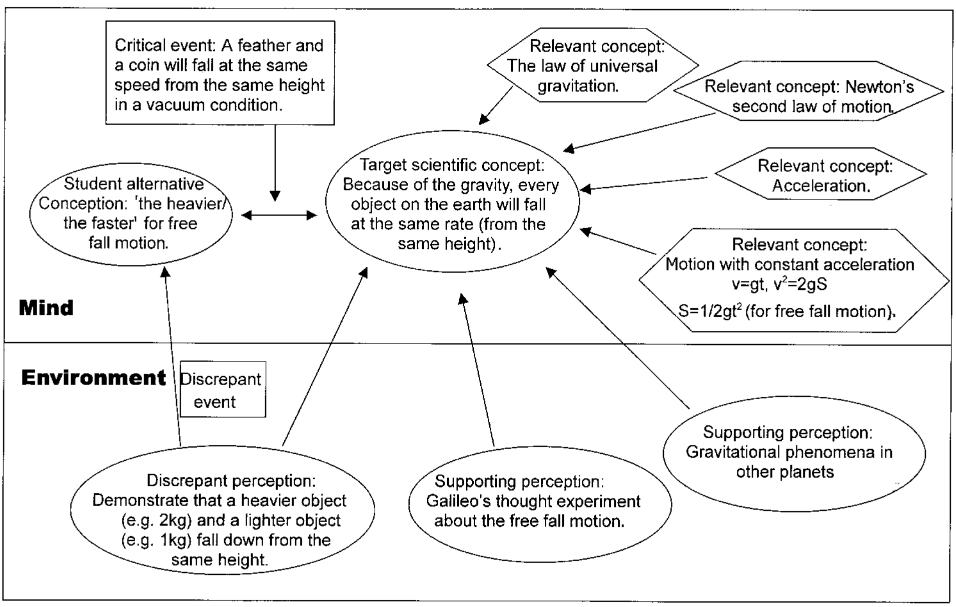


Figure 3. A conflict map about free fall motion.

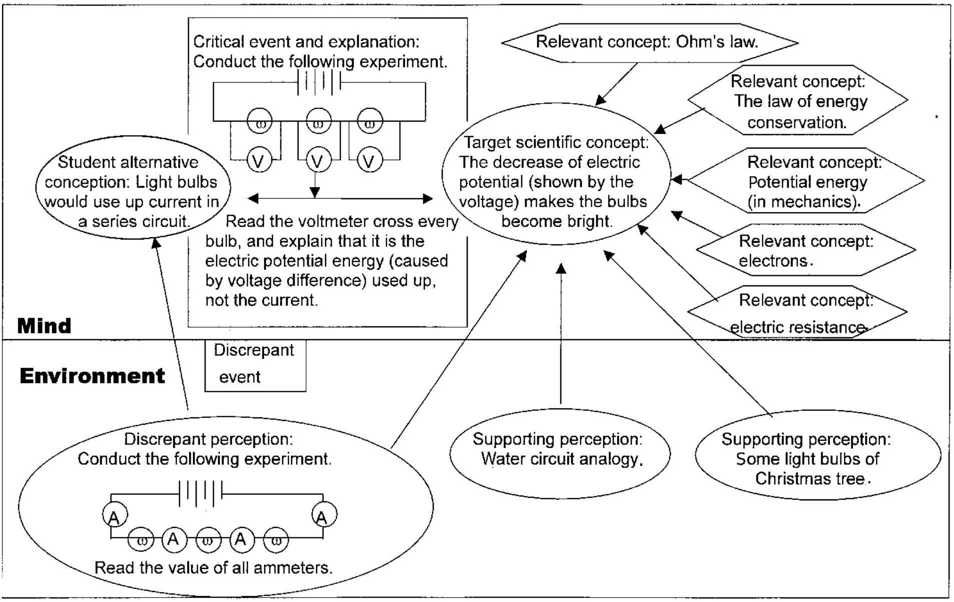


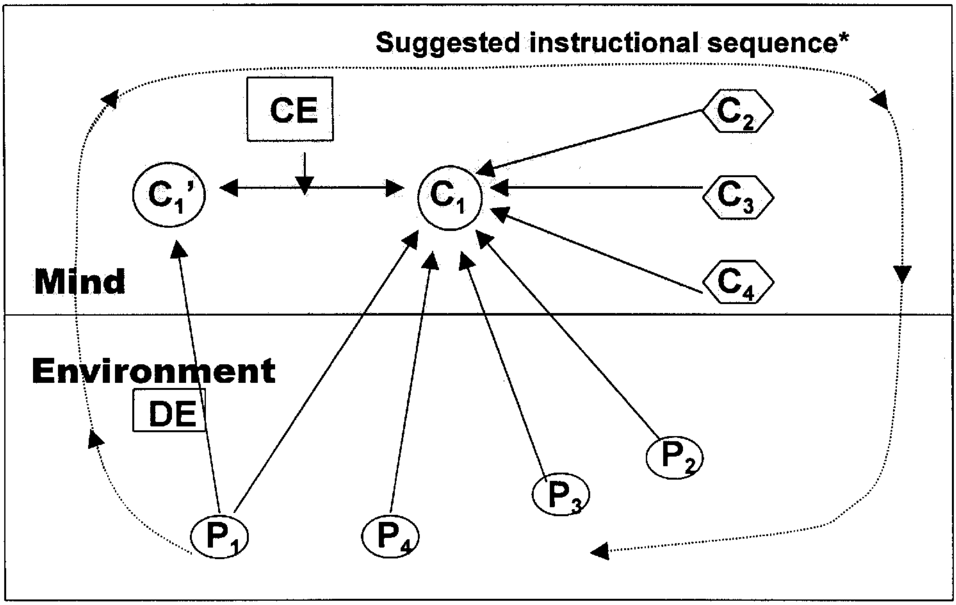
Figure 4. A conflict map about electric circuit.

crepant event is designed to show that the current in the circuit is equal anywhere. However, students ask if the current is not being used up, what is lighting the bulbs? The critical event is designed to show and further explain that the decrease of electric potential (shown by voltmeters) makes the bulbs become brighter. Ohm's law, the law of energy conservation, the ideas of potential energy (in mechanics), electrons and electric resistance could be considered as other conceptual supports for the target concept. Moreover, the lights on a Christmas tree (part of the light bulbs are in series) or the water circuit analogy could be used as other perceptions to explain the scientific concept that will be taught.

The conflict maps displayed in figure 3 and figure 4 contain the following components:

1. Students' alternative conception.
2. Discrepant event (resolving conflict 1).
3. The target scientific concept being taught (fulfilling the first condition of explicating conflict 2).
4. Critical event or explanation (satisfying the second condition of clarifying conflict 2).
5. Other relevant scientific concepts (achieving the third condition of resolving conflict 2).
6. Other perception supports (fulfilling the fourth condition of explicating conflict 2).

In other words, this map has effectively addressed conflict 1 and all of the conditions of resolving conflict 2. A typical conflict map should be similar to the format illustrated in figure 5. Science educators could use these frameworks to draw conflict maps of overcoming students' other alternative conceptions and then use them to conduct science instruction. The suggested teaching sequence could



P_1: The perception inducing a discrepant event
DE: discrepant event (caused by P_1)
C_1': Student alternative conception
C_1: the scientific conception that will be taught (i.e., the target scientific concept)
CE: critical event or explanation
C_2, C_3, and C_4: relevant scientific conceptions
P2, P3, and P4: other supporting perceptions

*There is an exception in the teaching sequence that C_1 should be presented earlier than CE; that is, the suggested sequence is DE (or P_1), C_1, CE, C_2, C_3, C_4 and finally P_2, P_3, P_4.

Figure 5. A typical conflict map.

be DE (or P1) first and then C1, CE, C2, C3 and finally P2, P3, P4, shown as figure 5 (see later discussion). The use of conflict maps is based on the following pedagogical assumptions:

- Meaningful conceptual learning requires perceptual supports derived from relevant events, examples or phenomena.
- Learning is an active process of knowledge construction. Students understand new concepts on the basis of prior experiences and existing concepts.
- Meaningful learning involves students constructing integrated knowledge structures, which contain their prior knowledge, experiences, new (scientific) concepts and other relevant knowledge.

These three assumptions correspond to tenets of 'constructivism,' (Anderson 1992, Taylor and Fraser 1991, Tsai 1998a). Constructivist theory also emphasizes the importance of presenting hands-on and real-life experiences for students, concurring with the use of perceptions (or some demonstrations and concrete events) in conflict maps.

The sources of conflicts

In order to design proper critical events in conflict maps, it is important to explore some possible sources of the conflicts between student alternative conceptions and scientific conceptions. Tsai (1999b) proposed the following major conflict sources:

(1) Conflicts between students' intuition and scientific views: Students often rely on their intuition when interpreting scientific phenomena. For example, students have some intuitive conceptions about the electric circuit.
(2) Conflicts between students' daily observations and scientific conceptions: Because students have intensive daily experiences in observing the motion of objects, numerous students' alternative conceptions in mechanics come from this type of conflict. Two well-documented alternative conceptions categorized in the type are 'the heavier/the faster' for free fall motion and the Aristotelian 'motion implying force' theory.
(3) Conflicts between people's common language and scientists' language: Scientists have coined some terms when introducing scientific conceptions, but many of them are the same as those people commonly use. However, there is some discrepancy between people's common language and a scientific definition of the same word. For example, 'friction', in common language, should exist on two relatively moving surfaces, but this view can not contain scientists' ideas about 'static friction'.
(4) Conflicts between students' ontology and scientists' ontology: Chi (1992) divided scientific knowledge into three distinct ontological categories - matter, events and abstractions. Earlier research suggests that students usually treat the concepts of heat, light, forces and electric current as substance-based entities. That is, these concepts are classified into the 'matter' ontological category. Physicists, nevertheless, conceive of them as a kind of constraint-based 'events', that is, their existence rests on the values or status of other variables. Research about students' alternative conceptions and ontology has recently received much attention (Mariani and Ogborn 1995, Tyson *et al*. 1997).
(5) Mixing with what students learned from previous instruction: This source of student alternative conceptions may not be a kind of conflict, rather, it is a kind of confusion. For example, students may believe that air pressure contributes to an object's weight, as they already acquire the scientific idea from prior instruction that objects are weightless in interplanetary space where there is no air pressure. Students' widespread misconception that the difference in distance between the earth and the sun causes the four seasons could also be classified into this category.

The use of conflict maps and conceptual change model

The research literature about student misconceptions or alternative conceptions frequently cites the 'conceptual change model' proposed by Posner *et al*. (1982) and Strike and Posner (1985). They assert that the following conditions are necessary for students to restructure their alternative conceptions during the process of conceptual change.

1. There must be dissatisfaction with existing (alternative) conceptions.

2. A new conception must be intelligible.
3. A new conception must appear initially plausible.
4. A new conception should be fruitful or open to new areas of inquiry.

The discrepant event in the conflict map (i.e. P1 or DE in figure 5) could fulfil Posner *et al*'s (1982) first condition for conceptual change. The instruction of target scientific concept (i.e. C1 in figure 5, the first condition for resolving conflict 2 proposed earlier in this paper) could fulfil Posner *et al*'s second condition. The third condition could be possibly achieved when the critical event and relevant scientific concepts are introduced (i.e. CE and C2, C3, C4 in figure 5, corresponding to the second and third conditions of overcoming conflict 2 outlined earlier). Other perceptions (and perhaps, other scientific concepts) related to the target scientific concept could possibly help learners achieve the fourth condition (i.e. P2, P3, P4 and perhaps C2, C3, C4 in figure 5). In other words, the rationale of conflict map is consistent with the theoretical frameworks of conceptual change model. Hence, the suggested instructional sequence in figure 5 is DE (or P1) first and then C1, CE, C2, C3, C4 and finally P2, P3, P4. It is expected that the use of conflict maps could help students overcome alternative conceptions and then work on the process of accommodation.

Earlier research (e.g. Hewson and Hewson 1984, Shiland 1997) reveals that science teachers and textbooks devote much time and effort to Posner *et al*'s (1982) second condition, that is, in making the new conception intelligible to students. However, the use of conflict maps, in contrast to traditional instruction, could enable teachers to consider fulfilment of the three other conditions, since most of the instructional components of the maps (e.g. DE, CE, C2, C3, P2, P3) address those conditions.

Because of the high consistency between the conceptual change model and the ideas of conflict maps, the use of conflict maps could make the status of conceptual change more explicit for teachers and students. Table 1 outlines the descriptors and ways of representation of the four conditions of the conceptual change model (Treagust 1997, Thorley and Stofflett 1996) and then provides corresponding components of conflict maps. Through using or exploring the components displayed in conflict maps, teachers (or perhaps students) could understand learners' (or their own) status of conceptual change in a more explicit way. For instance, teachers could use students' understanding about the discrepant event as an indicator of students' dissatisfaction with their alternative conceptions. Hence, conflict maps could serve as a metacognitive tool for teachers or even for students to monitor the processes of conceptual change. Beeth's (1998) study has revealed that making the status of conceptual change explicit could support student metacognition that facilitates science learning. The information presented in table 1 also somewhat confirms an aforementioned conclusion that traditional science instruction may spend most of its time and effort to making the new concept intelligible, because traditional teaching mostly uses linguistic expressions, exemplars, images or analogies in introducing the new concept. Table 1 also suggests that the design of critical events (attaining the plausibility of the new concept) could consider the following features of learners' conceptual ecology: past experiences, lab experiences, extreme cases, thought experiments or ontological categories. These features are somewhat similar to 'the sources of conflicts' presented previously.

Table 1. Using conflict maps as a metacognitive tool to make the status of conceptual change explicit.

Status of conceptual change	*Descriptors* (*Treagust 1997*)	*Ways of representation or relevant features in learners' conceptual ecology* (*Thorley and Stofflett 1996*)	*Correspnding conflict map conditions*	*Relevant components the conflict map*
Dissatisfaction	I must be aware of my personal ideas I must perceive some conflict between my ideas and scientists' ideas I must feel uncomfortable with existing ideas	Anomalies Past experiences Epistemological commitments	Resolving conflict 1	■ C1' (misconception) ■ P1 ■ Discrepant events (DE)
Intelligibility	I must know what the concept means I should be able to describe it in my own words I can give examples I can find ways of representing my ideas to others	Linguistic expressions Criterial attributes Examplars Images Analogies of metaphors Kinesthetic or tactile representations Other modes of representation (e.g. auditory or olfactory)	Fulfilling the first condition of resolving conflict 2	■ C1
Plausibility	It must first be intelligible I must believe this is how the world actually is It must fit in with other ideas or concepts I know or believe	Consistency with other accepted ideas Beliefs about causes and effects Past experiences Laboratory experiences Extreme cases (thought experiments) Analogous situations Epistemological beliefs Ontological categories Common sense and intuitive beliefs	Fufilling the second and third conditions of resolving conflict 2	■ Critical events (CE) ■ C2, C3 . . . ■ Sometimes, P2, P3
Fruitfulness	It must first be intelligible It should be plausible I can see it as something useful I can apply it to other ideas It gives me new ideas for further investigation or exploration It is a better explanation of things	Anomalies Past experiences New events Other knowledge	Fulfilling the fourth condition of resolving conflict 2	■ P2, P3, P4 . . . ■ Sometimes, C2, C3

Figure 6 further links the resolution of conflict 1 and conflict 2 with the conditions of conceptual change and their consequent outcomes summarized by Gilbert *et al.* (1982). If teachers know the status of students' conceptual change, they could predict their possible learning outcome. For example, according to figure 6, if a student is dissatisfied with an existing (alternative) conception, but the new (scientific) conception is not intelligible to him (or her), his (or her) learning will result in an 'undisturbed' outcome. If a student acknowledges the dissatisfaction of existing conception as well as the intelligibility of the scientific conception, but he (or she) does not well perceive its plausibility or fruitfulness, he (or she) may acquire either two-perspective, reinforced or mixed outcomes after science instruction.

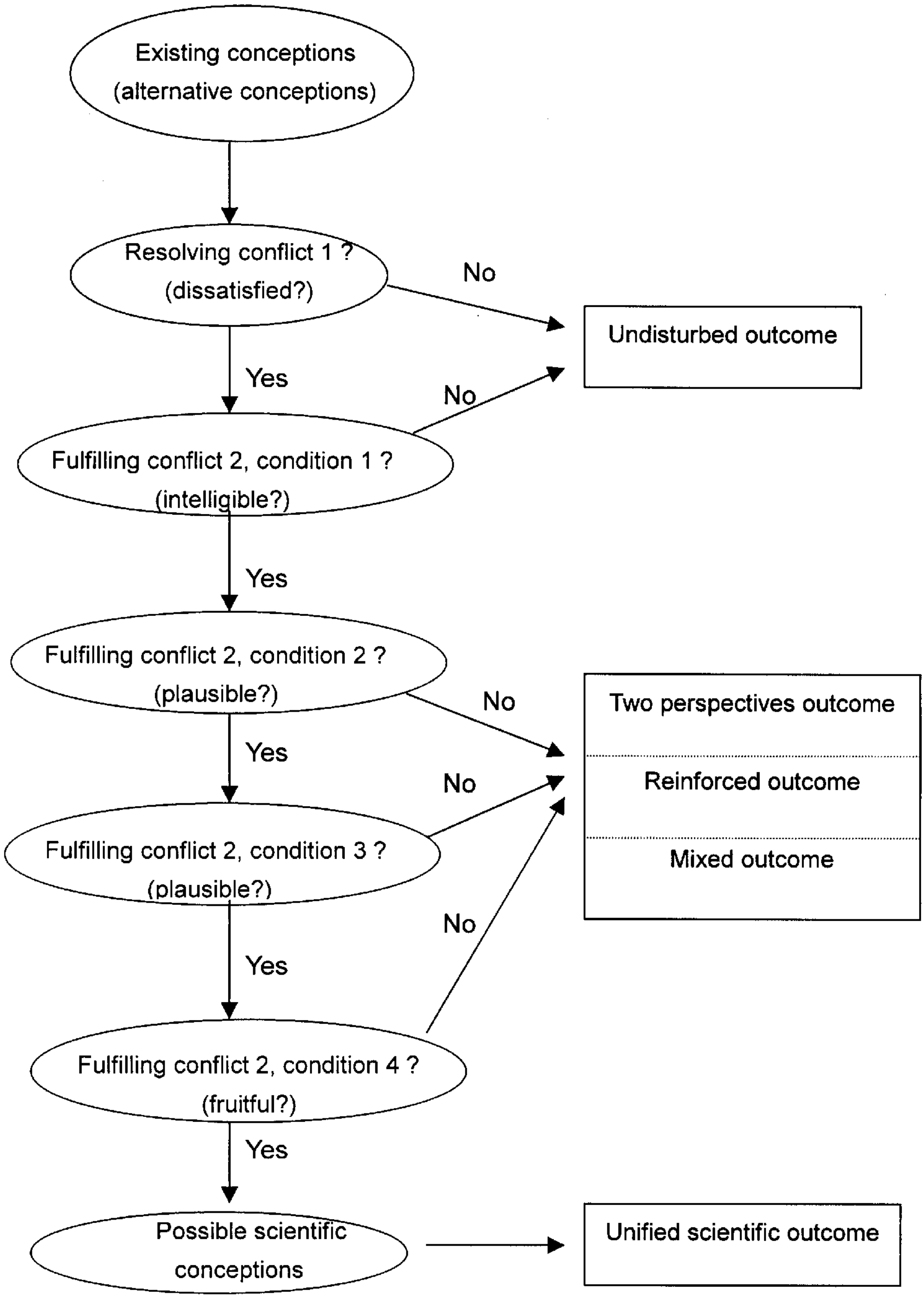
The applications of using conflict maps in science instruction

Conflict maps could have the following practical applications in science instruction. First, science teachers could employ the frameworks of conflict maps to organize science lessons and then develop instructional plans that take students' alternative conceptions into account. Second, science teachers could present the frameworks of conflict maps to students after conducting all of the teaching activities involved in the maps. The frameworks could help students construct more integrated and scientifically sound knowledge structures about the target scientific concepts. Finally, students could draw their own conflict maps to review their ideas and monitor their processes of conceptual change, acting as a metacognitive tool.

Concept maps (Novak and Gowin 1984) and other mapping techniques (e.g. flow-map method, Anderson and Demetrius 1993, Bischoff and Anderson 1998, Tsai 1998b; 1999c; 1999d) have, to a certain extent, successfully assessed students' conceptual frameworks in science. Conflict maps could also be viewed as a visual tool to represent a series of instructional components with which to address students' alternative conceptions. It could further be viewed as a metacognitive tool for students to document their conceptual change.

The limitations of using conflict maps

One may argue that the use of conflict maps is still based upon the paradigm of 'cold' conceptual change, a rational lens with which to view conceptual change. Students' conceptual change involves content (or conceptual), epistemological, ontological, emotional and other factors (Pintrich *et al.* 1993, Tsai 1998c; 1999b; 1999e; 1999f, Tyson *et al.* 1997). The use of conflict maps, at least in the content domain, could be a potential tool with which to assist students' conceptual change. The use of conflict maps, coupled with student changes in some other domains (e.g. epistemological, ontological), could successfully address student alternative conceptions in science. It should be noted that the conflict map does not assert that the discrepant event or critical event *per se* could induce conceptual change; rather, it suggests that conceptual change is possibly achieved through conducting a series of discrepant events, critical events, the instruction of relevant conceptions and the presentation of related perceptions. The instructional activities shown in conflict maps could also be easily integrated with 'constructivist' teaching strategies such as peers cooperative learning. For example, the instruction about discrepant events



This figure is a modified and extended illustration from that presented in Dole and Sinatra's (1998) paper.

Figure 6. The relationship between the use of conflict maps, conceptual change model and possible instructional outcomes.

could provide students with the opportunity to socially negotiate the outcomes or possible causes of discrepant events.

Teachers' views about using conflict maps

In order to establish teachers' views about use of conflict maps, 76 pre-service science teachers and 30 practising science teachers completed a questionnaire. The pre-service teachers were enrolled on courses in a teacher education programme in a national university of Taiwan. The practising science teachers who came from various regions of Taiwan completed the questionnaire when attending a summer workshop on enriching science knowledge and science teaching skills. These teachers had an average of about eight years of high school science teaching. Before answering the questionnaire, all of these teachers (including pre-service and practising teachers) had been instructed to the theory of constructivism. Almost every one of them had conducted in-depth interviews exploring secondary school students' alternative conceptions. They were then asked to try to construct their own individual conflict map (or maps), aimed at overcoming some alternative conceptions which they had elicited in the interviews. The questionnaire employed a 5-1 Likert scale and the administration of the questionnaire was anonymous. The results of the questionnaire are presented in table 2.

Most of the surveyed pre-service and practising teachers liked the idea of using conflict maps (item 1) and also agreed that the process of developing conflict maps helped them design better instructional plans about the target scientific concepts (items 2, 3). Many of them believed in various applications of using conflict maps in science instruction (items 9, 12). The effectiveness of using conflict maps was also well perceived by most of them (items 4, 13 and 14). They also presumed that current science teachers would like the idea of using conflict maps, as well as having the competence and willingness of using the maps (items 15, 16 and 17). Many of these teachers, nevertheless, reflected that the construction of conflict maps was not an easy process (item 5); therefore, it is recommended that teachers cooperate with one another to develop appropriate conflict maps for students.

Conclusions

This paper suggests using conflict maps to enhance science instruction. Although its usefulness, in current stage, is still limited in scope, the ideas of conflict maps may prompt practical applications to numerous alternative conception studies which have been conducted in the last two decades.

Moreover, the development in computer network technology suggests that teachers may be able to design and share conflict maps. First, the well-designed conflict maps could be displayed on the World Wide Web (www), accessible to all teachers. Teachers could also submit their conflict maps to the www site to share their ideas. Moreover, the www environment could provide cooperative environments where science teachers could criticize others' conflict maps, discuss students' alternative conceptions and collaboratively design appropriate discrepant events, critical events, relevant conceptions and perceptions to overcome students' alternative conceptions. It is expected that the frameworks of conflict maps could provide instructional guidelines for teachers to remotely collaboratively design lesson plans through such internet environments. In the paradigm of con-

Table 2. Science teachers' views about using conflict maps.

Question	*strongly agree*		*agree*		*neutral*		*disagree*		*strongly disagree*	
	Pre-service[a] #, (%)	*Practising*[b] #, (%)	*Pre-service* #, (%)	*Practising* #, (%)	*Pre-service* #, (%)	*Practising* #, (%)	*Pre-service* #, (%)	*Practising* #, (%)	*Pre-service* #, (%)	*Practising* #, (%)
1. I like the idea of using conflict maps.	14 (18)	11 (37)	52 (68)	14 (47)	9 (12)	5 (17)	0	0	1 (1)	0
2. The process of constructing conflict maps furthers my understanding about students' ideas.	29 (38)	13 (43)	42 (55)	15 (50)	4 (5)	2 (7)	1 (1)	0	0	0
3. The process of developing conflict maps gives me more integrated knowledge structures about the scientific concepts that will be taught.	28 (37)	12 (40)	44 (58)	15 (50)	3 (4)	3 (10)	1 (1)	0	0	0
4. Compared to traditional teaching methods (e.g. text-book reading and almost one-way lecturing), the use of conflict maps is expected to achieve better learning outcomes for students.	30 (39)	11 (37)	37 (49)	13 (43)	8 (11)	5 (17)	1 (1)	1 (3)	0	4 (13)
5. The construction of conflict maps is an easy process.	3 (4)	2 (7)	7 (9)	3 (10)	25 (33)	10 (33)	31 (41)	11 (37)	10 (13)	0
6. I am eager to view other teachers' conflict maps.	28 (37)	8 (27)	41 (54)	16 (53)	7 (9)	6 (20)	0	0	0	0
7. I am eager to explore whether my conflict map(s) is (are) useful for my (the) students.	33 (43)	12 (40)	38 (50)	14 (47)	5 (7)	4 (13)	0	0	0	0
8. In order to construct the conflict maps, I have read some other relevant literature.	27 (36)	10 (33)	38 (50)	10 (33)	6 (8)	5 (17)	4 (5)	3 (10)	1 (1)	2 (7)
9. I believe that the use of conflict maps could be applied to various perspectives of science instruction.	22 (29)	8 (27)	43 (57)	13 (43)	7 (9)	8 (27)	4 (5)	1 (3)	0	0

10. If possible, I would like to read more relevant information about conflict maps.	17 (22)	9 (30)	47 (62)	12 (40)	10 (13)	9 (30)	1 (1)	0	1 (1)	0
11. I will use conflict maps to assist my science instruction.	13 (17)	8 (27)	52 (68)	14 (47)	8 (11)	7 (23)	3 (4)	1 (3)	0	0
12. I believe that the idea of using conflict maps should be widely applied to current secondary science education.	22 (29)	10 (33)	44 (58)	13 (43)	9 (12)	6 (20)	0	1 (3)	1 (1)	0
13. I believe that the conflict map is an effective tool in enhancing science instruction.	20 (26)	10 (33)	49 (64)	16 (53)	6 (8)	4 (13)	0	0	1 (1)	0
14. I believe that the conflict map could be a good metacognitive tool for secondary school students.	22 (29)	4 (13)	43 (57)	12 (40)	7 (9)	10 (33)	4 (5)	3 (10)	0	1 (3)
15. Practising science teachers will like the idea of using conflict maps.	6 (8)	8 (27)	30 (39)	15 (50)	26 (34)	6 (20)	12 (16)	1 (3)	2 (3)	0
16. I believe that after some relevant instruction, (current) science teachers have the competence to use conflict maps in enhancing science teaching.	10 (13)	11 (37)	51 (67)	14 (47)	12 (16)	4 (13)	3 (4)	1 (3)	0	0
17. I believe that after some relevant instruction, (current) science teachers have the willingness to use conflict maps to assist teaching.	9 (12)	3 (10)	45 (59)	18 (60)	17 (22)	6 (20)	3 (4)	2 (7)	2 (3)	1 (3)

a. n = 76 for pre-service science teachers
b. n = 30 for practising science teachers

structivism, learners are encouraged to work collaboratively with their peers. Similarly, science teachers should be encouraged to work with other teachers. As suggested previously, science teachers may cooperate with one another to reduce the difficulty of designing proper conflict maps for students. Internet or www-based environments may provide a potential avenue for achieving this.

In conclusion, the use of conflict maps could help students seek a stable and desirable equilibration between the conceptual schema they have already assembled and the perceptual information arising from the environment. The clarification as well as the connections among relevant alternative conceptions and scientific ideas are also explored and emphasized. Educators often lament that science students tend to employ rote learning strategies for scientific knowledge and what they have provided are isolated bits of science facts. It is anticipated that the use of conflict maps may facilitate students' meaningful learning in science, as well as help students construct more integrated knowledge structures.

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