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Toward An Understanding and Use of Cognitive Conflict in Science Instruction (I) : Definition and Model

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ABSTRACT

The idea that students must experience cognitive conflict before conceptual change can occur is not new. In light of this idea, many teaching strategies have been applied in educational practices. However, there is not much literature about how students are experiencing cognitive conflict, how this experience affects students learning processes, and how we use that knowledge to improve our science instruction. This study aimed to propose possible answers about these questions. In this paper, we conducted the first question as a first part of our research. To do this, we reviewed related literature and analyzed protocols that were produced in previous studies. As a result, a model of cognitive conflict was developed. This study's findings may lead to further understanding and use of students' cognitive conflict, which has a complex role in science instruction.

Key words: cognitive conflict process model, conceptual change, anomalous situation

I. Introduction

Within any learning situation, conflicts among ideas or opinions are inevitable. They will occur, no matter what the teacher does. Learning situations are filled with conflicts among students, between the teacher and the student, and between what a student presently understands and new information being learned. And the current evidence indicates that, in most classrooms, conflicts are avoided and suppressed, and that teachers and students lack the skill and procedures needed for effective conflict management. By avoiding and suppressing certain types of conflicts, teachers lose valuable opportunities to increase student motivation, creative insight, cognitive development, and learning. Conflicts have the potential for producing both highly constructive or highly destructive outcomes, depending on how they are managed. (pp. 51-52, Johnson & Johnson, 1979)

The idea that students must experience cognitive conflict before meaningful learning can occur is not new. A considerable number of researchers have argued that cognitive conflict is a necessary pre-condition of learning described as conceptual change (Stavy & Berkovitz, 1980; Posner, Strike, Hewson, & Gertzog, 1982; Hashweh, 1986; Kwon, 1989, 1997). In light of this idea, many teaching strategies have been designed to facilitate conceptual change that use cognitive conflict as a means of producing students' conceptual changes (Hewson & Hewson, 1984; Thorley & Treagust, 1989; Niaz, 1995; Druyan, 1997; Lee, 1998).

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However, some researchers have argued that cognitive conflict strategies do not consistently lead to conceptual change. They claim that even though students' ideas can be confronted with contradictory information through instruction, it frequently does not result in meaningful conflict for a learner (Alvermann & Hague, 1989; Champagne, Gunstone, & Klopfer, 1985; Dreyfus, Jungwirth & Eliovitch, 1990; Hewson & Thorley, 1989; West & Pines, 1985, Dekkers & Thijs, 1998). Hewson *et al.* (1998: 201) described different views on cognitive conflict and its impact on conceptual change:

> There are different views of the role of conflict and whether it is explicitly needed in instruction. Some authors see conflict as a means of helping students recognize that their conceptions might be problematic, while others regard students conceptions as an opportunity – the foundation for future learning – and play down the importance of conflict.

Despite the rich research history in conceptual change, no consensus among science educators has emerged regarding the effectiveness of cognitive conflict on conceptual change learning. Thus, as Johnson & Johnson (1979) mentioned in the statements at the beginning of this paper, we still do not know how to use cognitive conflict in our science classroom.

At this point, we should enunciate some basic questions. For example, what is the definition of cognitive conflict in learning? what are some kinds of cognitive conflict? what are the signs of cognitive conflict? how is cognitive conflict aroused? However, there is very little research that has tried to answer these questions in detail, or tried to consider possible cognitive conflict situations and comparing other research (definitions, terminologies, etc).

We believe that in order to understand the real effects of cognitive conflict on learning science, we should first answer some basic questions. In this study, we have tried to answer these questions. Based on this research, we shall further discuss the diverse ways of using cognitive conflict in science classrooms in a subsequent paper.

Ⅱ. Theoretical Base

1. What is cognitive conflict?

This question is about the definition of cognitive conflict. Even though there have been many studies of cognitive conflict in the fields of developmental psychology, education, and science education, it is still difficult to find literature that explains the definition of cognitive conflict in detail. It is also difficult to find the definition of cognitive conflict in any dictionary.

There are many terms with meanings similar to cognitive conflict that have been used by most researchers, including terms such as cognitive dissonance (Botvin & Murray, 1975; Murray, Ames, & Botvin, 1977), cognitive gap (Furth, 1981), conceptual conflict (Johnson & Johnson, 1979), discrepancy (Siegel, 1979; Zimmerman & Blom, 1983), disequilibrum (Damon & Killen, 1982; Murray, 1983; Murray, Ames, & Botvin, 1977; Piaget, 1967, 1980, 1985), internal conflict (Bodlakova, 1988), paradoxes (Movshovitz-Hadar & Hadass, 1990), psychic conflict (Cantor, 1983), and socio-cognitive conflict (Bearison, Magzamen, & Filardo, 1986; Doise & Mugny, 1984; Perret-Clermont, 1980)

However, there is little difference among the meanings of those terms. For example, Smedslund (1961) used the word "equilibration" that was first described by Piaget (1985). He suggested that equilibration may be similar to Festinger's cognitive dissonance or Heider's balance mechanisms.

Berlyne (1960) proposed a reason for using conceptual conflict instead of other terms:

> Our own concern with conceptual conflict leads us in different directions from those pursued by Festinger (cognitive dissonance) and Abelson (cognitive imbalance). We are interested primarily in conflicts arising out of the denotative content rather than the affective tone of beliefs or thoughts and also in the relations between such conflicts and the pursuit of knowledge. (p. 285)

Hewson and Hewson (1984) used conceptual conflict rather than cognitive conflict because they intended to focus on conceptual problems in science learning. Like these examples, researchers chose a term according to their research concerns (for example, conceptions, schema, function in cognitive development, etc.). This is the reason why various terms exist when explaining the cognitive conflict situation.

In some literature, we could find a few definitions of cognitive conflict. For example;

> Cognitive conflict is "awareness of a momentary disequilibrium" in the system of schemas (Mischel, 1971, p. 331).
>
> In a social sense, cognitive conflict generally means some perceived contradiction between the subject's opinion and the opinions of others (Damon & Killen, 1982, p. 348).
>
> Cognitive disequilibrium or conflict induced by awareness of contradictory discrepant information (Bodlakova, 1988, p. 2).
>
> If a child eventually becomes aware of the fact that he holds two contradictory views about a situation and they both can not be true. This step is referred to as cognitive conflict or disequilibrium (Gredler, 1992, p. 225).
>
> Cognitive conflict is created when ones expectations and predictions, based on ones current reasoning, are not conformed. It is disequilibrium (Wadsworth, 1996, p. 151).
>
> Cognitive conflict is defined as a conflict between cognitive structure (i.e., an organized knowledge structure in the brain) and environment (i.e., an experiment, demonstration, peers opinion, book, or something like that), or a conflict between conceptions in cognitive structure (Kwon, 1989, p. 6).

As we can see, cognitive conflict is a broad concept and not well-defined. This might make researchers confused about using the term cognitive conflict. After integrating the many terms that have been used to explain and define diverse cognitive conflict situations, we offer our own definition of cognitive conflict. Cognitive conflict is a perceptual state where one notices the discrepancy between ones cognitive structure and environment (external information), or between the components of ones cognitive structure (i.e., ones conceptions, beliefs, sub-structures and so on, which are in cognitive structure). In this definition, cognitive structure means, as Langfield-Smith (1994) stated, "any mental representation used to organize knowledge, beliefs, values, or other data whether hypothetical or neurological".

Cognitive conflict is strongly related to cognition because it is aroused by cognitive sources (e.g., recognizing incompatible data). This is the difference between cognitive conflict and general conflict, because conflict is aroused by incompatible motives and needs, as noted in the following definition:

> Conflict is a perceptual state involving the executive function of the organism where the immediate choices in the organisms repertoire, together with the outcome of these choices, are seen to involve incompatible motives and needs (Parker & Archer, 1994, p. 665).

However, if cognitive conflict is aroused, its features include not only cognitive (e.g., recognition) but also affective features (e.g., interest, anxiety). We will consider this in detail in the section on the cognitive conflict process model.

In summary, cognitive conflict is a psychological state that is different from general conflict, which is aroused by confronting incompatible ideas or data. In the state of cognitive conflict, there are both cognitive and affective features.

2. What are the kinds of cognitive conflict?

Many researchers have described how cognitive conflict is aroused. For instance, Strauss (1972) presented two kinds of cognitive conflict (his word, disequilibrium). One is external, adaptational disequilibrium by means of prediction-outcome conflict. The other is internal, organizational disequilibrium through structural mixture conflict.

Siegel (1979) described three different kinds of cognitive conflict (his word, discrepancy): (a) internal cognitive conflict (between two competing ideas); (b) external social conflict (between two external events or sources of information); and (c) internal-external conflict (between an internal and external event).

Kwon (1989) presented three types of cognitive conflict. He thought Piagetian cognitive disequilibrium was a kind of cognitive conflict between one's cognitive structure and environment. Using Hashwehs (1986) analysis, Kwon also considered metacognitive conflict as another cognitive conflict that is a conflict between cognitive schemata. This cognitive conflict would be aroused when one might examine his/her own cognition without contacting his environment. In the Piagetians disequilibrium concept, there is a similar meaning to this kind of cognitive conflict; Hashweh made its concept clear.

In addition to these two kinds of cognitive conflicts, Kwon (1989) suggested a third kind of cognitive conflict. This kind of cognitive conflict can be aroused when a new conception, which might be scientific conception recently learned, is not compatible with an individuals past experience and/or unfamiliar with his/her old conceptions. Figure 1 shows Kwon's three kinds of cognitive conflict.

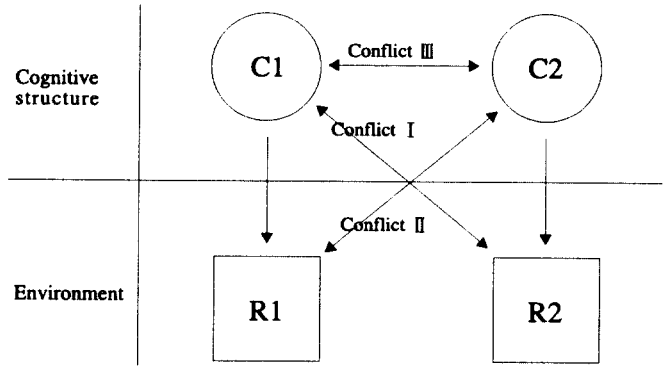

Fig. 1. Kwon's cognitive conflict model (Kwon, 1989)

This diagram is a modified version of Hashweh's original diagram (Hashweh, 1986). Kwon (1989) explained three kinds of cognitive conflict using this diagram (figure 1). The upper part represents cognitive structure and the lower part represents environment. C1 represents students' nave model and it would be mostly a misconception. C2 represents a scientific conception to be learned. R1 represents an environment that could be well explained by C1, while R2 is any environment that is well explained by C2. R1 and R2 do not represent only one single external phenomenon; they represent a whole bunch of observations and stimuli from one's environment. In this diagram, cognitive conflict by Piaget is conflict between C1 and R2 (Type I), cognitive conflict by Hashweh is a conflict between C1 and C2 (Type III). The other kind of cognitive conflict is the conflict between C2 and R1. Kwon proposed this as another kind of cognitive conflict (Type II).

This diagram clearly shows the three kinds of cognitive conflicts. However based on our definition of cognitive conflict, C1 and C2 do not have to be only pre/new conceptions that one learned over time. They could be also beliefs, sub-structures, total structure, or something that exist in cognitive structure simultaneously.

According to Vosniadou and Ioannides (1998), there are two different theories in the cognitive structure (her words, conceptual structure): framework theory and specific theory. Framework theories consist of ontological and epistemological presuppositions. Specific theories consist of a set of interrelated propositions or beliefs that describe the properties and behavior of physical objects. Framework and specific theories provide the basis for generating situation specific representations of mental models, during problem solving.

For example, let's think about the internal force mental model: a moving object has force until it stops. This mental model is related to a belief that "Force is a property of physical objects that are heavy and/big". This belief is constrained by the underlying presupposition that "Force is a property of inanimate or animate objects" and "The movement of inanimate objects is a phenomenon that needs explanation and this explanation should be causal".

Vosniadou and Ioannides (1998) define the mental model as dynamic and generative representations that can be manipulated mentally to provide causal explanations of physical phenomena and to make predictions about the state of affairs in the physical world. According to them, misconceptions, as a mental model, are viewed as students' attempts to interpret scientific information within an existing framework theory that constrains information contradictory to the scientific view.

diSessa (1993) has developed an alternative account of students' mental models. He argues that students mental models (for example, motion is caused by force) are not stable and students infer a force that seems to be sensitive to the particular context in which they see motion. He proposed the idea P-prims (Phenomenological primitives) to explain this situation.

P-prims are elements of cognitive structure that can be activated under various circumstances. Maintaining agency (continuing effect maintained by a cause), as a P-prim, is involved in the mental model "Motion implies a force". This maintaining agency can cause diverse mental models under specific circumstances: an engine maintains the motion of a car; a supply of energy keeps a bulb lit, etc.

The notion of phenomenological primitives that capture aspects of the physical reality is analogous in many respects to the beliefs of a specific theory in Vosniadous theoretical framework (Vosniadou, 1994). diSessa and Vosniadou view misconceptions to be spontaneous constructions which are often generated on

the spot, during testing situation, and not deeply held specific theories (beliefs or P-prims).

Largely, there are three kinds of cognitive conflict (see figure 1). However, from the narrow perspectives, we could see diverse kinds of cognitive conflict between cognitive structure and others since cognitive structure has many elements, which have different levels and stable conditions: for example, framework theory level conflict, belief or P-prims level conflict, mental model (misconception) level conflict, etc.

3. What are the signs of cognitive conflict?

Many researchers have tried to observe cognitive conflict and found diverse signs of it. For example, Miller (1944) observed hesitancy, tension, vacillation, and complete blocking in the cognitive conflict situation. Berlyne (1960) explained that conceptual conflict had something like these characteristics: doubt, perplexity, contradiction, conceptual incongruity, confusion, and irrelevance. Berlyne (1960, 1970) thought the children's degree of uncertainty (about anomalous information) was the major sign (indicator) of the degree of their cognitive conflict (his word, conceptual conflict). He measured cognitive conflict by subjective uncertainty (provided by the children themselves) and response latency. Smedslund (1961) found hesitation (reaction time), looking back and forth, uneasiness, and tension when children were in cognitive conflict situation. Zimmerman and Blom (1983) measured student's cognitive conflict by observing the degree of uncertainty, and response latency by using a similar method to Berlyne's. Movshovitz-Hadar and Hadass (1990) found students expressions in a state of a cognitive conflict from videotaped discussions. They said students showed expressions of curiosity arousal and of an inner drive to resolve, as well as expressions of frustration, satisfaction with coping with inability to proceed, and contentment with feeling self-confident about a shaky state.

In summary, many researchers found a lot of signs of cognitive conflict that could be observable, and they used these signs as the indicators of the degree of cognitive conflict. According to these literatures, we could infer the psychological constructs of cognitive conflict. For instance, uncertainty, doubt, perplexity, contradiction, conceptual incongruity, irrelevance, and disbelief are the signs of cognitive conflict when one recognizes anomaly that contradicts one's expectation. Thus, recognition of anomaly would be one construct of cognitive conflict. As other signs of cognitive conflict, to hesitate to respond and/or to look back and forth are the behaviors when one tries not only to solve the conflict but also to decide to continue to do so or not. In one's internal state, one reappraises the conflict situation. So reappraising cognitive conflict situation is another construct of cognitive conflict.

Based on Anderson and Bourke's (2000) affective area classification, we classified many affective signs of cognitive conflict into two categories: interest and anxiety. For instance, expressing curiosity arousal is included in interest as a construct of cognitive conflict. Tension, uneasiness, and frustration are included in anxiety as a construct of cognitive conflict. In all, there are four psychological constructs in cognitive conflict: recognition of anomaly, reappraisal of cognitive conflict situation, interest, and anxiety.

Analyzing the protocols of previous research

We analyzed protocols of two previous studies (Lee, 1990; Lee, 1998) where the researchers presented anomalous situations (i.e., demonstrations that were not incompatible with students prediction) to students and observed their responses. From these analyses, we found some verbal and nonverbal signs of cognitive

conflict. According to the four constructs of cognitive conflict, we classified the signs as follows:

(1) Recognition of anomaly

When students recognized that their predictions were not consistent with the result of a demonstration, they asked a question, wondered and muttered the result to themselves, or said the result was strange:

"Umm ··· (rub one's chin).. Why does it?"
"Oh! It is same (height)."
(With a deep sigh) "it is strange."
"I cannot understand; it is strange"
(Looks the teacher with a amazing look)

(2) Interest

After seeing the anomalous result, students expressed their interests by laughing or appearing curious.

(3) Anxiety

In this case, we could find the verbal statements of students when they watched the anomalous result. They confessed it was difficult to solve the conflict problem by them.

"Ah! I know nothing about it."
"I fell into confusion."
"Ah! I have a headache about that (problem)."
"I cannot understand why the net force is zero. Even though it seems to be 2 N, I think the statement in the card is very like too. So I am troubled by the problem."

(4) Cognitive reappraisal of conflict situations

When students watched anomalous results, many of them reserved their judgments about whether the problem was solved. A student did not move and thought about the result for a long time. Another one looked at the experiment set closely and repeated thoughts.

"I cannot explain the result well but ···."
"Centrifugal force? Inertial force? Centripetal force?" (While grumbling to himself, trying to understand the problem)

Ⅲ. The Cognitive Conflict Process Model

The cognitive conflict process model is a model to explain how students experience cognitive conflict, another words, how cognitive conflict is aroused. We have developed and introduced a cognitive conflict process model at many national/international science education conferences since 1998.

In this section, we introduce a recent version of the cognitive conflict process model. This model has three stages (see Figure 2): preliminary stage, conflict stage, and resolution stage.

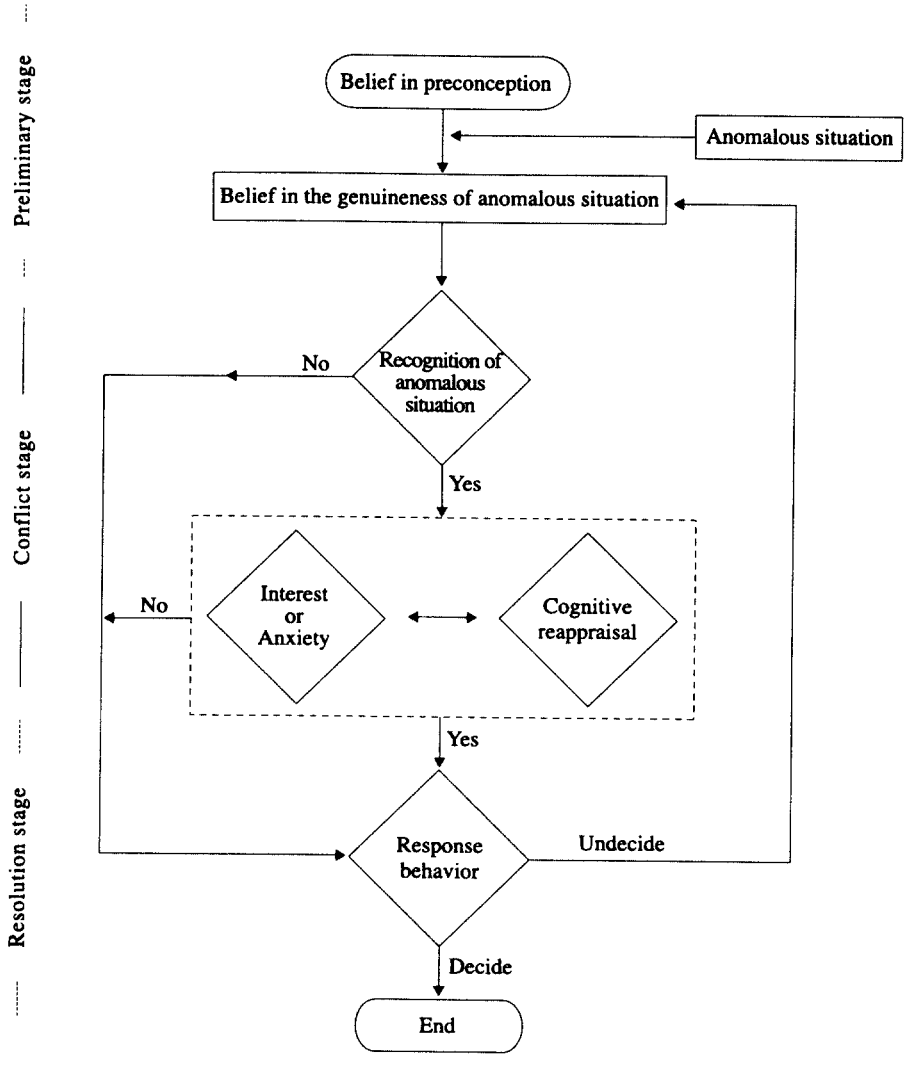

Fig. 2. Cognitive conflict process model

The preliminary stage is the stage prior to cognitive conflict. In this stage, there is the process of believing students their own preexisting conceptions and accepting anomalous situations as truth. If students would not have preconception and/or if they consider an anomalous situation as a deceit, then they would not experience cognitive conflict (see figure 2).

In the conflict stage, cognitive conflict process is defined as after a learner (1) recognizes an anomalous situation, (2) expresses interest or anxiety in resolving the cognitive conflict, and (3) engages in cognitive reappraisal of the situation. For instance, when a learner recognizes that a situation is incongruous with his/her conceptions, he/she should be interested in and/or anxious about this situation. After these stages or simultaneously with these, he/she would reappraise his/her cognitive conflict situation in order to resolve it or to quit it.

This conflict stage is consistent with the findings of a research by Movshovitz-Hader and Hadass (1990). In their research, they found some examples of cognitive conflict process as follows,

1. A student recognized anomaly and felt interest and anxiety simultaneously:
(in a state of cognitive conflict) "It (the result of demonstration) is kind of a shock, its fun··· no··· its··· mind stretching."
2. A student felt anxiety, but after reassessing his/her cognitive conflicts, he/she escaped cognitive conflict situation by solving the problem: "I was threatened in the beginning and controlled it. Then I was able to start thinking and worked it out."
3. A student escaped his/her cognitive conflict situation by giving up solving the problem: "I was helpless. I could not wait to hear the solution."

According to the cognitive conflict process model, there are four psychological constructs in cognitive conflict: recognition of anomalous situation, interest, anxiety, and cognitive reappraisal. These psychological constructs are came from the main signs of cognitive conflict that were found in the previous studies (see section II-3). In terms of the constructs of cognitive conflict, we can understand why cognitive conflict has the potential for producing either highly constructive or highly destructive outcomes in students learning.

For example, constructive cognitive conflict could be aroused when a student recognizes anomaly clearly, experiences strong interest and/or appropriate anxiety, and reappraises the cognitive conflict situation deeply. However, if a student does not recognize the anomaly, ignores it, or he/she does not like to be in conflict state, then the cognitive conflict in this situation might be negligible. And if a student feels frustrated or threatened instead of being interested, his/her cognitive conflict might be destructive.

In the resolution stage, a learner will try to resolve cognitive conflict in any way. The results of resolving this conflict will be expressed as an external response behavior. Examples of response behaviors are those suggested by Chinn and Brewer (1998) such as ignoring, rejection, uncertainty, exclusion, abeyance, reinterpretation, peripheral theory change and theory change.

In our recent research (Kwon, Park, Kim, Lee, & Lee, 2000), we investigated students cognitive conflict with four tenth-grade students from a high school in Korea. From students interviews in this research, we found some examples of cognitive conflict process (see the interview protocol below).

In the beginning of this research, the four students were pretested on mechanics and electric circuit concepts. We met each student individually and presented the demonstrations that would be anomalous situations to each student. We asked them to express their thoughts and feelings about anomaly. After this, we gave them the cards (see Figure 3) that include the expressions of the main constructs of cognitive conflict: recognition of anomaly, reappraisal of cognitive conflict situation (hesitation to response), interest, and anxiety. We asked them to find cards that represented their thought and/or feelings and to arrange the cards according to the time order they thought and felt in the cognitive conflict situation.

The following excerpt illustrates a portion of the dialogue in the interview with Student 1.

Interviewer: (presents a demonstration to Student 1)
Student 1: (looks at the demonstration kit and the answer sheet by turning it and thinking for a while)
Interviewer: "Could you say now your feelings or thoughts?"
Student 1: "It is little short of a miracle, and I feel futility. I would like to know the reason for the result."
Interviewer: "I made four cards which include some sort of feelings and thoughts about this situation. Please

□ **Recognition of anomaly**
- When I saw the result, I had doubts about the results.
- When I saw the result, I was surprised by it.
- The difference between the result and my expectation made me felt strange.

□ **Interest**
- The result of experiment is interesting.
- Since I saw the result, I have been curious about it.
- The result of experiment attracts my attention.

□ **Anxiety**
- The result of the experiment confuses me.
- Since I cannot solve the problem, I am in agony.
- As I cannot understand the reason for the result, I feel depressed

□ **Reappraisal of cognitive conflict situation**
- I would like to ascertain further whether my idea is incorrect or not.
- I need to think about the reason for the result a little longer.
- I need to find a proper explanation of the result.

Fig. 3. Four cards

arrange these cards, reflecting on your thoughts and feelings that were experienced as time went by."

Student 1: (arranges the cards)

Interviewer: "Do you have any other feelings or thoughts about the result except these (which were mentioned in the cards)?"

Student 1: "No."

Interviewer: "Do you think the result of this demonstration is right?"

Student 1: "Yes, because it is experimental result."

Interviewer: "Could you explain the result?"

Student 1: "I do not know. I saw the result for the first time."

(Talking to oneself) "Is it related with the principle of a lever?"

After watching the demonstration that was an anomalous situation to Student 1, the student recognized the demonstration as an anomalous result. He felt futility but showed curiosity to know the reason. Until the end of the interview, he tried to resolve his cognitive conflict. Thus, we could see that Student 1 experienced cognitive conflict such as the process that was proposed in the cognitive conflict process model.

This process is different from strategies for anomaly resolution proposed by Darden (1992). Darden analyzed prior work by philosophers of science on anomalies. Then he proposed systematic strategies for anomaly resolution. The anomaly resolution entails several stages: (1) confirm the anomalous data, (2) localize the problem, (3) resolve the anomaly, and (4) assess the resulting theory.

However, the Student 1 (in the excerpt on the previous page) did not try to confirm the anomaly by reproducing anomalous data or reanalyzing the problem. He just accepted the anomaly since it was the experimental result. We can find some affective response (e.g., sort of miracle, feel futility) instead of any specific strategy for anomaly resolution proposed by Darden, like localizing the problem, employing monster-barring, altering a component, etc.

This shows that the ways of theory change of scientists are different from the ways of students as discussed in the previous research (e.g., Pintrich, Mark, & Boyle, 1993; Strike & Posner, 1992). We need more concerns on anomaly resolution (in other words, cognitive conflict resolution), considering the specific features of students' cognitive conflict. We will discuss this issue in the second paper of our research in detail.

This model contains two assumptions: (1) the students' diverse characteristics and learning environment factors will affect the cognitive conflict process. There is much literature to support this assumption. For instance, Lee (2000) found that students' learning motivation, learning strategies, and preconceptions levels affected students' cognitive conflict in learning physics. Recently, Limón (2001) found that the successful applications of the cognitive conflict strategy are closely related to the complexity of variables intervening in the context of school learning, and introduced variables that might contribute to inducing a meaningful cognitive conflict (table 1).

Table 1. Variables that might contribute to inducing a meaningful cognitive conflict (adapted from Limón, 2001)

Variables related to the learner	Prior knowledge Motivation and interests Epistemological beliefs (about learning and teaching and about the subject-matter to be learned) Values and attitudes towards learning Learning strategies and cognitive engagement in the learning tasks Reasoning abilities
Variables related to the social context in which learning takes place	Role of peers Teacher-learner relationships
Variables related to the teacher	Domain-specific subject-matter knowledge Motivation and interests Epistemological beliefs about learning and teaching and about the subject-matter taught Values and attitudes towards learning and teaching Teaching strategies Level of training to be a teacher

(2) the components of the cognitive conflict will strongly affect the response behavior. For instance, Kwon, Lee, Park, Kim, & Lee (2000) investigated the relationship between students' cognitive conflict and their response behavior in learning high school physics. In their study, they found that anxiety among the components of cognitive conflict had positive and negative effects on response behavior.

Ⅳ. Conclusions and Implication

Based upon this study, the following conclusions can be drawn:

- Cognitive conflict is a perceptual state where one notices the discrepancy between one's cognitive structure and environment (external information), or between the elements of one's cognitive structure (i.e., one's conceptions, beliefs, sub-structures and so on, which are in cognitive structure).
- There are three kinds of cognitive conflict. However, according to which element of cognitive conflict is involved, there are diverse kinds of cognitive conflict between cognitive structure and others: framework theory level conflict, belief or P-prims level conflict, mental model (misconception) level conflict, etc.
- There are four main signs of cognitive conflict: recognition of anomaly, interest, anxiety, and cognitive reappraisal of conflict situation. These signs are the psychological constructs of cognitive conflict. Thus, even though cognitive conflict is aroused from our cognitive recognition (cognition, that is why we call it cognitive conflict instead of conflict), cognitive conflict has both affective and cognitive features.
- Cognitive conflict is aroused by recognizing a discrepant event and is followed by feelings of interest/anxiety and with reappraising conflict. According to how students experience cognitive conflict, the cognitive conflict might have constructive, destructive, or meaningless potentials.

When teachers attempt to use cognitive conflict strategy with demonstration, question, discussion, and so on, they could use the cognitive conflict process model so as to anticipate students' cognitive conflict and to facilitate their conceptual change more likely. In addition, this model would be helpful for teachers to encourage students to think about how they experience cognitive conflict and to compare their experience with the cognitive conflict process model. This could help students develop a deeper understanding of their learning.

Establishing the validity of a model is an on-going process. In further research, the cognitive conflict process model should be tested more extensively. In addition, as Johnson and Johnson (1979) said, managing cognitive conflict is very important because in every learning situation, students frequently experience cognitive conflict. In order to manage cognitive conflict effectively, it is needed to study how to measure students' cognitive conflict and how to apply our understanding about cognitive conflict to everyday science classrooms. Based on this research, we will examine these issues further in the next paper.

References

Anderson, L. W., & Bourke, S. F. (2000). *Assessing affective characteristics in the schools.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Bearison, D. J., Magzamen, S., & Filardo, E. K. (1986). Socio-cognitive conflict and cognitive growth in young children. *Merrill-Palmer Quarterly*, 32, 51-72.

Berlyne, D. E. (1960). *Conflict, arousal, and curiosity.* NY: McGraw-Hill.

Berlyne, D. E. (1970). Childrens reasoning and thinking. In P. H. Mussen (Ed.), *Carmichaels manual of child psychology* (Vol. 1, pp. 939-981). NY: Wiley, 3rd ed.

Bodrakova, W. V. (1988). *The role of external and cognitive conflict in childrens conservation learning.* Unpublished doctorial dissertation, City University of New York.

Botvin, G., & Murray, F. (1975). The efficacy of peer modeling and social conflict in the acquisition of conservation. *Child Development*, 46, 796-799.

Cantor, G. N. (1983). Conflict, learning, and Piaget: comments on Zimmerman and Bloms "Toward an empirical test of the role of cognitive conflict in learning." *Developmental Review*, 3, 39-53.

Chinn, C. A., & Brewer, W. F. (1998). An empirical test of a taxonomy of responses to anomalous data in science. *Journal of Research in Science Teaching*, 35, 623-654.

Damon, W., & Killen, M. (1982). Peer interaction and the process of change in childrens moral reasoning. *Merrill-Palmer Quarterly*, 28, 347-367.

Darden, L. (1992). Strategies for anomaly resolution. In R. N. Giere (Ed.), *Cognitive models of science* (Vol. 15, pp. 251-273). The University of Minnesota Press.

Dekkers, P. J. J., & Thijj. G. D. (1998). Making productive use of students' initial conceptions in developing the concept of force. *Science Education*, 82, 31-51.

diSessa, A. (1993). Towards an epistemology of physics. *Cognition and Instruction*, 10(2 & 3), 105-225.

Doise, W., & Mugny, G. (1984). *The social development of intelligent.* NY: Pergamon Press.

Dreyfus, A., Jungwirth, E., & Eliovitch, R. (1990), Applying the "cognitive conflict" strategy for conceptual change - some implications, difficulties, and problems. *Science Education*, 74, 555-569.

Druyan, S. (1997). Effect of the kinesthetic conflict on promoting scientific reasoning. *Journal of Research in Science Teaching*, 34, 1083-1099.

Elizabeth, L. L., & Galloway, D. (1996). Conceptual links between cognitive acceleration through science education and motivational style: A critique of Adey and Shayer. *International Journal of Science Education*, 18, 35-49.

Furth, H. G. (1981). *Piaget and knowledge. Theoretical foundation.* Chicago IL: University of Chicago Press.

Gredler, D. E. (1992). Learning and instruction: Theory into practice. NY: Macmillan.

Hashweh, M. Z. (1986). Toward an Explanation of Conceptual Change, *European Journal of Science Education*, 8, 229-249.

Hewson, P. W., & Hewson, M. G. A. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instructional Science*, 13, 1-13.

Hewson, P. W., Beeth, M. E., & Thorley, N. R. (1998). Teaching for conceptual change. In B. J. Fraser & K. G. Tobin (Ed.), *International handbook of science education* (pp. 199-218). Kluwer Academic Publishers.

Johnson, D. W., & Johnson, R. T. (1979). Conflict in the classroom: Controversy and learning. *Review of Educational Research*, 49, 51-70.

Kwon, J. (1989). A cognitive model of conceptual change in science learning. *Physics Teaching (written in Korean)*, 7, 1-9. Korean Physics Society.

Kwon, J. (1997, May). The necessity of cognitive conflict strategy in science teaching. Proceeding of the International Conference on Science Education: Globalization of Science Education, Seoul, Korea.

Kwon, J., Lee, G., Park, H., Kim, J., & Lee, Y. J. (2000, April). *The relationship between the characteristics of cognitive conflict and response to anomalous situations when learning science.* Paper presented at National Association for Research in Science Teaching, New Orleans.

Kwon, J., Park, H., Kim, J., Lee, Y. J., & Lee, G. (2000). *The analysis of the relationship between cognitive conflict characteristics (levels and patterns) and response patterns of students confronted with anomalous situation in learning science.* Research Report on Subject Education RR98-VI-11, Ministry of Education in Korea.

Langfield-Smith, K. (1994). Cognitive map. In V. S. Ramachandran (Ed.), *Human Behavior* (pp. 647-653). NY: Academic Press.

Lee, G. (1990). *The response behavior of students who confronted with cognitive conflict situations.* Unpublished master dissertation, Korea National University of Education.

Lee, G. (2000). *The effects of cognitive conflict, learning motivation, and learning strategies on high school students conceptual changes in physics.* Unpublished doctoral dissertation, Korea National University of Education.

Lee, Y. J. (1998). *The effect of cognitive conflict on students conceptual change in Physics.* Unpublished doctoral dissertation, Korea National University of Education.

Limón, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: a critical appraisal. Learning and Instruction, 11, 357-380.

Miller, N. E. (1944). Experimental studies of conflict. In J. M. Hunt (Ed.), *Personality and the behavior disorders* (Vol 1, pp. 431-465). NY: Ronald.

Mischel, T. (1971). Piaget: cognitive conflict and the motivation of thought. In T. Mischel (Ed.), *Cognitive development and epistemology* (pp. 311-355). NY: Academic Press.

Movshovitz-Hadar, N., & Hadass, R. (1990). Preservice education of math teachers using paradoxes. *Educational Studies in Mathematics*, 21, 265-287.

Murray, F. B. (1983). Equilibration as cognitive conflict. *Developmental Review*, 3, 54-61.

Murray, F. B., Ames, G., & Botvin, G. (1977). The acquisition of conservation through cognitive dissonance. *Journal of Educational Psychology*, 69, 519-527.

Niaz, M. (1995). Cognitive conflict as a teaching strategy in solving chemistry problems: A dialectic-constructivist perspective. *Journal of Research in Science Teaching*, 32, 959-970.

Parker, A., & Archer, T. (1994). Conflict Behavior. In V. S. Ramachandran (Ed.), *Human Behavior* (pp. 665). NY: Academic Press.

Perret-Clermont, A. N. (1980). Social interaction and cognitive development in children. *European Monographs in Social Psychology* (Vol. 19). London: Academic Press.

Piaget, J. (1967). The mental development of the child. In D. Elkind (Ed.), *Six Psychological studies.* NY: Random House.

Piaget, J. (1980). *Adaptation and intelligence. Organic selection and phenocopy.* Chicago, IL: University of Chicago Press.

Piaget, J. (1985). *The equilibration of cognitive structure: the central problem of intellectual development.* Chicago, IL: University of Chicago Press.

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

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66, 221-227.

Strike, K. A., & Posner, G. J. (1992). A revisionist theory of conceptual change. In R. A. Duschl & R. J. Hamilton (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 147-176). State University of New York Press.

Roy, A. W. N., & Howe, C. J. (1990). Effects of cognitive conflict, socio-cognitive conflict and imitation on childrens socio-legal thinking, *European Journal of Social Psychology*, 20, 241-252.

Sigel, I. E. (1979). On becoming a thinker: A psychoeducational model. *Educational Psychologist*, 14, 70-78.

Smedsland, J. (1961). The acquisition of conservation of substance and weight in children. *Scandanavian Journal of Psychology*, 2, 156-160.

Stavy, R., & Berkovitz, B. (1980). Cognitive conflict as a basis for teaching quantitative aspects of the concept of temperature. *Science Education*, 64, 679-692.

Strauss, S. (1972). Inducing cognitive development and learning: A review of short-term training experiments. *Cognition*, 1, 329-357.

Thorley, N. R., & Treagust, D. F. (1987). Conflict within dyadic interactions as a stimulant for conceptual change in Physics. *International Journal of Science Education*, 9, 203-216.

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction*, 4, 45-69.

Vosniadou, S., & Ioannides, C. (1998). From conceptual development to science education: A psychological point of view. *International Journal of Science Education*, 20, 1213-1230.

Wadsworth, B. J. (1996). *Piagets theory of cognitive and affective development.* NY: Longman.

Zimmerman, B. J., & Blom, D. E. (1983). Toward an empirical test of the role of cognitive conflict in learning. *Developmental Review*, 3, 18-38.