Cognitive Conflict and Causal Attributions to Successful Conceptual Change in Physics Learning

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ABSTRACT

The purpose of this study is to investigate the relationships between cognitive conflict and students' causal attributions and to find out what kinds of attributions affect successful resolution of cognitive conflict in learning physics. Twenty-nine college students who attended a base general physics course took an attribution test and a conceptual pretest related to action and reaction concept. Of these, twenty students who revealed alternative conceptions were selected. They were confronted with a discrepant demonstration and took part in the cognitive conflict level test, a posttest, and delayed posttest. Those students who experienced high levels of cognitive conflict were selected and interviewed to find out what kinds of attributions affect resolving the conflict. When confronted with the discrepant event, the students who attributed success outcomes to "effort" experienced higher levels of cognitive conflict than those to "task difficulty." However, those students who revealed high levels of cognitive conflict and attributed success outcomes to effort did not always produce conceptual change. They had different perspectives on effort and conducted different effort activities to resolve the cognitive conflict. In addition, these effort activities appeared to include their motivational beliefs, metacognitive and volitional strategies. The results of this study indicate that in order for the conflicts to lead to change, students need to have the perspective on effort implying the use of the self-regulated learning strategy and to conduct effort activities based on them. Beyond cold conceptual change, this article suggests that there is a management strategy of cognitive conflict in the classroom context.

Key words: cognitive conflict, causal attribution, perspective on effort, self-regulated learning strategy

I. Introduction

Students' conceptual changes have been a dominant area of research in science education for more than two decades. Many researchers of constructivism in science education have argued that cognitive conflict is an important factor in conceptual change, even though there are still questions about its positive and negative effects on science learning (Chan, Burtis, & Bereiter, 1997; Druyan, 1997, 2001; Hashweh, 1986; Hewson & Hewson, 1984; Johnson, Johnson, & Tjosvold, 2000; Kim & Bao, 2004a, 2004b; Lee & Kwon, 2002; Lee & Kwon, 2003; Kwon, Lee, & Kim, 2003; Kwon, 1997, 1989; Posner *et al.*, 1982).

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Piaget (1950) proposed that cognitive conflict is disequilibrium within a student's cognitive structure that motivates transitions from one stage of cognitive reasoning to another. Berlyne (1957, 1966) emphasized that cognitive (or conceptual) conflict creates epistemic curiosity which motivates the search for new information and the reconceptualization of the knowledge one already has. Bruner (1961) insisted that conceptual conflict was necessary for discovery learning and could be created by (1) presenting events that are discrepant with what the student already knows and understands, (2) presenting "mysterious" events that seem inexplicable on the basis of students' present knowledge, and (3) having students argue and disagree with the teacher or each other. Johnson (1970) and Johnson and Johnson (1995) indicated that since knowledge results from social processes, then conflict among ideas, theories, and conclusions becomes an essential part of building a conceptual structure that everyone agrees is valid.

Cognitive conflict strategy has guided research and instructional practices in science learning for many years (Limón, 2001). Nevertheless, many studies have indicated that the discrepant event does not necessarily change students' own conceptions in many teaching and learning approaches that emphasize cognitive conflict (Chan *et al.*, 1997; Chinn & Brewer, 1998, 1993; Mason, 2001; Kang, Scharmann, & Noh, 2004; Kim & Bao, 2004a; Kwon *et al.*, 2000; Niaz, 1995; Park *et al.*, 2001; Tao & Gunstone, 1999). Moreover, some research showed that some students maintained their conceptions or reverted back to their alternative conceptions from scientific conceptions later even though they experienced high levels of cognitive conflict (Cho, Kim, & Kwon, 2004; Kim & Bao, 2004a, 2004b; Lee, 2000; Lee & Kwon, 2002).

While previous studies have researched the resistance of students' scientific conceptions to change even if students experienced high levels of cognitive conflict, few have investigated why and how this happened. Science education research in the area of cognitive conflict has focused on rather the supposed underlying epistemological aspects (logical structure, rational process etc), and lacked attention to affective aspects as well as motivational constructs in students' science learning (Demastes *et al.*, 1996; Kwon, 2000; Limón, 2001; Pintrich, Marx, & Boyle, 1993; Strike & Posner, 1992; Vosniadou, 1994; 1999; Vosniadou *et al.*, 2001).

Recent studies in an edited volume by Sinatra and Pintrich (2003) emphasize the role of the learner's intentions in knowledge change and suggest models of intentional conceptual change. Especially, Pintrich and Sinatra (2003) stated there are three important assumptions or characteristics of intentional conceptual change, as follows:

- Intentional conceptual change is a goal-directed activity with the goal being a change in conceptual understanding.
- Intentional conceptual change involves some metacognitive or metaconceptual awareness or consciousness by individuals that they need to change their understanding or that they have a goal of understanding.
- Intentional conceptual change involves some internal agency, volitional control, or self-regulation on the part of individuals as they strive toward this goal of changed understanding (pp. 430-431).

In addition, they argued that more research is needed to examine the interaction of contextual and individual factors to better explain how and why some individuals not only realize discrepancies but also take the action necessary to restructure their knowledge.

We are interested in how students' motivational beliefs about themselves as learners, and how the roles of individuals in a classroom learning community, can facilitate or hinder conceptual change. The cognitive model of motivation based on cognitive psychology emphasized that several types of internal events seem to play an important role in students' motivation, including: (1) cognitive conflict, (2) causal attributions for what led to success (or failure) in reaching goals of interest in the past, and expectations about success (or failure) with respect to reaching future goals, and (3) memories of what others did before reaching a goal (Gagné, Yekovich, & Yekovich, 1993; Pintrich & Schunk, 2002; Stipek, 2002; Weiner, 1994). Especially, the cognitive conflict and the causal attributions that affect determining future behavior might play an important role in students' conceptual change. In addition, Kim (2002) found out that the characteristics of students' causal attributions for successful/unsuccessful understanding of the concepts were related to motivation styles, learning strategies, and volitional strategies. However, little research has been done which studied the relationships between students' cognitive conflict and attributions in conceptual change.

Therefore, the purpose of this study is to investigate the relationships between students' causal attributions and levels of cognitive conflict, and to find out what kinds of attributions affect resolving cognitive conflict and successful and less successful understanding of the concepts in learning physics. By analyzing the results, this article suggests we need to develop management strategies of cognitive conflict in the classroom context.

Ⅱ. Cognitive Conflict and Attribution Theory

Some researchers have insisted that student's motivation to learn affects the level of cognitive conflict and conceptual change in learning (Kwon, Lee, & Kim, 2003; Lee, 2000; Pintrich, 1999; Sinatra & Pintrich, 2003). Motivation is usually defined as an internal state that arouses, directs, and maintains behavior. Motivation is a vast and complicated subject encompassing many theories. Historically, there have been four kinds of approaches to motivation (Graham & Weiner, 1996; Woolfolk, 2004): The behavioral view, the humanistic view, the cognitive view, and the sociocultural view. Especially among them, in many ways, cognitive theories of motivation developed as a reaction to the behavioral views. One of the central assumptions in cognitive approaches is that people respond not to external events or physical conditions (Weiner, 1994), such as hunger, but rather to their interpretations of these events. Likewise in this context, cognitive theories emphasize intrinsic motivation. People are seen as active and curious, searching for information to solve personally relevant problems. Bernard Weiner's attribution theory (Weiner, 1980) is a good example. This cognitive explanation of motivation begins with the assumption that we all ask "Why?" in our attempts to understand our success and failures. Students may ask themselves, "Why did I understand this physics concept so well?," "What's wrong with my problem solving?" Students may attribute their successes and failures to ability, effort, mood, knowledge, luck, help, interest, clarity of instructions, the interference of others, unfair policies, and so on. Attribution theories of motivation describe how the individual's explanations, justifications, and excuses influence motivation.

Weiner (1980) is one of the main educational psychologists responsible for relating attribution theory to school learning. According to Weiner, most of the attributed causes for success or failures can be characterized in terms of three dimensions: Every cause for success or failure can be categorized on these dimensions. For example, luck is external (locus), unstable (stability), and uncontrollable (responsibility). Weiner believes that these three dimensions have important implications for motivation. The internal/external locus, for example, seems to be closely related to feelings of self-esteem. The stability dimension seems to be closely related to expectations about the future.

If people feel that they are not in control of their own lives, their self-esteem is likely to be diminished. Likewise, students' perceptions of their attributions for resolving cognitive conflict and successful/unsuccessful understanding of physics concepts can affect the process of conceptual changes in learning physics. The cognitive model of motivation based on cognitive psychology emphasizes that the internal mediating events - such as cognitive conflict, causal attributions for what led to success or failure in reaching goals of interest in the past, expectations about success or failure with respect to reaching future goals, and memories of what others did before reaching a goal - mutually play an important role in students' motivation to early proposed goal (Gagné *et al.*, 1993; Stipek, 2002; Pintrich & Schunk, 2002).

Ⅲ. Research Methods

We started with quantitative research. Once we investigated the first question - the relationship between students' attributions and characteristics of cognitive conflict - we made use of an interpretive research design based on principles of naturalistic inquiry (Sherman & Webb, 1988). We sought to investigate the relationships between students' causal attributions and levels of cognitive conflict, and to find out what kinds of attribution affect resolving cognitive conflict and successful and unsuccessful understanding of the concepts in learning physics.

1. Participants and procedure

The participants in the study were twenty-nine college students who attended a general physics course. The researcher taught them the mechanics part of general physics during a lecture period. As shown in Figure 1, they took an attribution test (Lee, 1993), and a scientific concept test at the middle of the semester. All students took a test to examine their conceptions on action and reaction in mechanics. Twenty students who revealed alternative views of action and reaction were selected. They were confronted with a discrepant demonstration ("Fan-cart"[1] - "Can a fan move a cart?" like the picture as shown in Figure 1) that contradicted their

1) The demonstration was done with an apparatus called a "fan-cart." It was used as a cognitive conflict task in this study as shown in Figure 1 (Clark, 1986a, 1986b; Jargodzki & Potter, 2001; Hewitt, 1988, 2003; Martinez & Schulkins, 1986; Rutledge, 1986; Wallingford, 1986). The task is to have students predict how a cart moves when a fan is turned on and to examine what explanation they suggest when the result is different from their prediction. In particular, the experiment is focused not simply on whether the cart moves or not, but on the characteristics of students' response and their explanation after observing the result of the experiment to verify their prediction and drawing a free-body diagram. In the task, students' predictions may vary according to the ideal conditions related to the air and the surface of the floor, the distance between the fan and the board, the angle at which air from the fan strikes the board, the size and shape of the board, etc. (Kim et al., 2001; Cognitive Conflict Strategy Research Group, 2003). For example, if all the wind produced by the fan strikes and bounces backward from the sail (if the air molecules experience elastic collisions with the sale), the cart will move to the right on the floor that has no friction. In addition, it is possible that the cart could be driven forward by suitably "dishing" the sail to redirect the air rearward. On the other hand, if the air collides inelastically with the sail, because of the distance between the fan and the board the velocity of the air decreases prior to striking the sail, the cart will not move at all.

Actually, based on the our experiment, we found the air does not collide elastically with the flat sail (cardboard) in very close distance (3.0 cm) between the fan and the flat sail. We tied the fan-cart to the ceiling with a string like a swing. Then according to the distance between the fan (Power = 96 W, weight = 2.025 kg) and the board, we measured the angle the string made with the vertical and the tension in the string. In addition, we measured the weight (3.375 kg) of the fan-cart and the length (2.413 m) of the string. By using these values and Newton's equation, you can calculate the net force acting on the fan-cart and find that the air and the sail are not elastic collisions. This is an useful and interesting experiment (Cognitive Conflict Strategy Research Group, 2004).

existing conceptions about action and reaction, and took part in a cognitive conflict level test (CCLT) (Lee *et al.*, 2003), a posttest, and delayed posttest to determine their conceptual change.

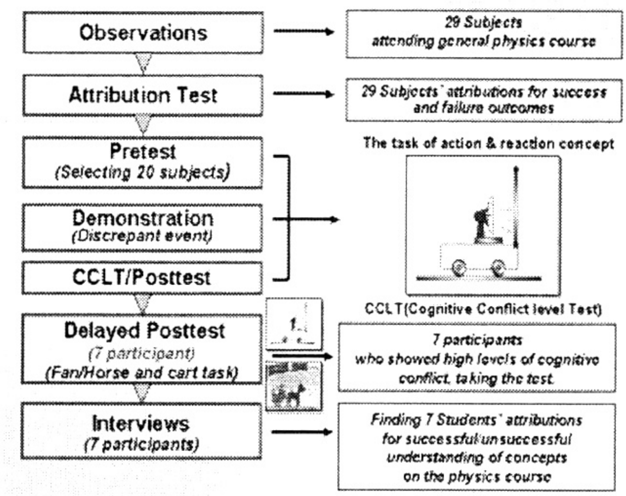


Fig. 1. The procedure of this study

The posttest was administered after CCLT. Two weeks later, we taught students the action and reaction principle in general physics class. In particular, we introduced "the horse-cart problem" (Hewitt, 1997) to them and discussed it with them in the class. The delayed posttest was administered one month later, after the posttest to the seven students who experienced high levels (more than third level) of cognitive conflict. For a case studies, they were interviewed to find out what kinds of attributions affect resolving cognitive conflict and successful/unsuccessful understanding the concepts in physics learning.

2. Data collection and analysis

Attribution test and cognitive conflict level test

The attribution test based on the Rotter's Criterion (Rotter, 1966) was conducted. This test (Lee, 1993) was used to determine the internal and external locus of control. It consisted of 40 questions about five kinds of attributions for success and failure, such as ability, effort, task difficulty and luck. Each attribution consisted of 8 items: 4 items related to success outcome, and the others related to failure outcome. All items were on a 5-point Likert scale (0 = "not at all true," 4 = "very true"). According to the total scores of all items, we can find a type of each attribution for success and failure among five kinds of attributions.

To see the level of students' cognitive conflict, the cognitive conflict level test (CCLT) developed by Lee and his colleagues (Lee *et al.*, 2003; Lee & Kwon, 2003) was conducted. This test included four components of cognitive conflict: recognition of contradiction; interest; anxiety; and cognitive reappraisal. It consisted of 12 items that could test cognitive conflict (with 3 items for each measurement component of cognitive conflict). Each item involves the 5-point Likert scale. The larger the total test score, the higher the level of cognitive conflict. We classified four levels of cognitive conflict according to the total test scores. The range of the first level is 0-25%, the second level is 26-50%, the third level is 51-75%, and the fourth level is 76-100%. Among 20 students, only two students belonged in the first level and second level, eight students belonged in the third level, and the others belonged in the fourth level. Finally, the seven students who had the interview voluntarily came under third or fourth level [such as Bana (88%), Choo (81%), Janna (71%), Leena (88%), Nam (65%), Sami (54%), and Young (71%)]. These students had experienced more than 50% degrees of cognitive conflict. ANOVA was used to investigate relationships between attributions and cognitive conflict.

Pretest, posttest and delayed posttest

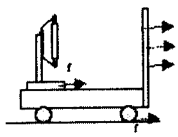
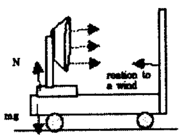
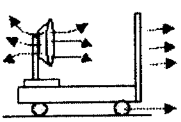
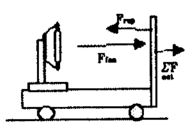
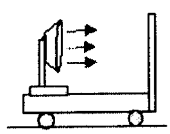
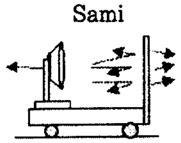
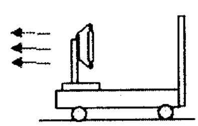
The pretest was designed to assess students' existing alternative conceptions about action and reaction (Newton's third law). This test question is to ask "a fan-cart problem" as shown in Figure 1 ("A cart is installed on a stable table. If you set up an operating fan, will the cart move? If so, in what direction? Why do you think so?"). In answering these questions, the students predicted and explained the result by drawing the free-body diagram. After the pretest, we selected students who had alternative conceptions.

Table 1 shows the conceptions that students presented to us in pretest. Then those students who had triggered high levels (more than third level) of cognitive conflict took the delayed posttest. As can be seen, they didn't consider the pair of action and reaction forces in the interaction and didn't think that both forces occur simultaneously, or that these forces act on different objects. In other words, those students commonly had misconceptions that the cart moves in a specific direction by erratically expressing the points on the fan and the cart, to which force is applied, or expressing only one out of action and reaction. Thus, they didn't correctly apply Newton's equation to the problem. As a result, based on the misconceptions, they explained the cart could move to the right or left in operating the fan. We confronted them with the discrepant demonstration showing the result and conducted the cognitive conflict level test (CCLT) and a posttest about "the fan-cart problem" to them. The purpose of the test was to find out how students responded to the result of the demonstration. We asked them whether they would accept the result of the demonstration, and offer an explanation for the data, and change their current conception.

After the posttest, two weeks later, between the posttest and the delayed posttest, the researcher taught the students the action and reaction principle in general physics class. Especially we introduced "the horse-cart problem" (Hewitt, 1997) to them and discussed it with them in the class. In this problem, we think of the horse as believing its pull on the cart will be canceled by the opposite and equal pull by the cart on the horse, thus making acceleration impossible. It is a classic problem that stumps many college students.

The delayed posttest was planned to assess students' conceptual changes and the test was administered one month later after the posttest to the seven students who experienced high levels (more than third level) of cognitive conflict. It consisted of the fan-cart problem and the horse-cart problem as shown in Figure 1. To solve the horse-cart problem, students should consider Newton's second law and Newton's third law. The test was conducted by interview about instance (IAI) (Osborne & Freyberg, 1985). When a student rightly explained both of the

Table 1. Students' conceptions regarding 'the fan-cart problem' in pretest

Students' Free-Body Diagram	Students' Conception	Characteristics
Bana 	It moves to the right. Static friction works on the floor of the fan and the force of the wind to push a cardboard. After the wind bounces backward from the cardboard, it strikes the fan and at this time the static friction acts on the base plane of the electric fan. This friction is called a static friction. I think this is similar to a paddle and a boat. The action of the paddle is like the wind from the fan and the water is like the cardboard; The relation of the wheel and the ground is like the boat and the water. So the cart moves to the right, because of the static friction acting on the fan. In addition, there is only slight friction between the wheel and the floor.	Does not consider that action and reaction always come in a pair and forget that the there is a reaction to the wind of the electric fan.
Choo 	It moves to the left. The cart will move to the left due to the reaction to an action, if the wind from the fan pushes the cardboard, and the cardboard will create the reaction. We must look for the forces acting on a object when we think of acceleration of the object. so what we have to look for here is the forces exerted on the cart. Because the cardboard is attached to the cart, they may be considered one object. As a result, a normal force (N) and gravity (mg) act on the cart in the y direction and are in equilibrium. But an x direction reaction to the wind moves the cart in the x axis direction.	Does not recognize the reaction which will push the fan to the left. Does not understand action and reaction act on both the fan and the cardboard. Does not consider action and reaction at the same time.
Jana 	It moves to the right. If the strong wind of the electric fan blows to the cardboard, the cart will move to the right. If the wind pushes the cardboard, the cart will move to the right because of the wind. The example that this experiment was applied to daily life is similar to the situation that causes a yacht to go forward on the river. We raise a sail when we want a yacht to sail forward. If the force of a wind works on a sail, and a sail receives the force, then a yacht will go forward. This experiment is an application of Newton's second law and third law.	Does not recognize that when the fan pushes air, the air also pushes the fan and two forces cannot cancel out each other.
Leena 	It moves to the right. We must turn the fan blades in order to produce a wind from the fan. There is an x and a y axis to the cart. Let's agree that the wind can move an object in daily life. An object exposed to a wind moves in the direction of the wind. In this case, the force to act on an object like this picture is based on a wind, thus the cart moves by the wind. $F_{electric\ fan}$ means the force of the wind from the fan, and $F_{repulse}$ means the reaction of the cardboard to the wind. In this case, $F_{electric\ fan}$ is stronger than $F_{repulse}$. Thus the cart moves to the same direction as $F_{electric\ fan}$. The reason why $F_{repulse}$ is weaker than $F_{electric\ fan}$ is the repulsive wind spreads to the side.	Does not recognize the reaction which will push the fan to the left. Does not understand action and reaction act on different objects. Does not consider action and reaction at the same time.
Nam 	It moves to the right. It seems to be similar to the principle that makes a yacht move. A sail on a yacht uses the force of a wind and moves forward. If we assume that a wind of the electric fan is similar to a natural wind in the sea, a cart to a yacht, and a cardboard to a sail, it is easy to understand a movement of a cart. Of course, the yacht moves wholly only in a direction of the wind. Of course, motion of the water can affect a movement of the yacht but we can disregard water force because it is static in this experiment. Therefore the force to push a sail moves this cart. The cart moves quickly if the wind is stronger, and if the cardboard is larger, If the net force acting on the cart decreases, this cart will move more slowly.	Does not understand action and reaction act on different objects. Does not consider action and reaction at the same time.
Sami 	It moves to the left. If the fan makes a wind, a force to push the fan arises to the left because of the reaction. I have seen that an electric fan moved to the left when I made the wind of the fan faster in a little friction surface between the fan and the floor. These phenomena mean that a force to push an electric fan backward exists. Therefore, the electric fan and the cart will move backward if there is little friction between the electric fan and the floor.	Does not understand action and reaction act on different objects. Does not consider action and reaction at the same time.
Young 	It moves to the left. If the direction of a wind is to the right, the cart would move to the right. But in the case of this experiment, the cart moves to the left, because the cardboard changes the direction of the wind backward. Therefore, I think the cart will not move to the right. Rather it will move to the left. A fan is a tool which causes the air to move fast. Therefore, at the back of the fan, there is a little air, and there is a lot of air at the front of the fan. Therefore, the cart moves to the left too because a density difference comes into being, so stream of a wind flows to the left.	Does not understand action and reaction act on different objects. Does not consider action and reaction at the same time.

instances with scientific conceptions, we regarded him to have changed from alternative conceptions to scientific conceptions about the action and reaction.

Participant observations, interview, documents analyses

Data was collected by several sources for triangulation during the semester (Mathison, 1988). First, participant observations were conducted throughout the general physics course to capture students' learning style and learning volition, etc. Second, documents, such as notes, journals, and exams created by students as they took the course, were collected. Third, semi-structured and in-depth interviews were conducted to find out what kinds of attributions affected resolving the cognitive conflict and successful/unsuccessful understanding of the concepts in learning physics, and what their perspectives on attributions mean in the process of conceptual change. Students were asked to answer questions and explain the reasons for their answers. Triangulation on data collection and analyzing were implemented.

Ⅳ. Results

1. Relationship between cognitive conflict and students' attributions

The first purpose of this study concerned the relationships between students' causal attributions and cognitive conflict to the anomalous situation. As shown in Figure 2, the distribution of students' attributions to success was as follows: 60% of students believed that they succeed because of their efforts; 15% of students for their abilities; and 25% of students for easiness of tasks. Many students attributed successful/unsuccessful outcomes to effort. There is evidence for cultural differences in beliefs about the causes of achievement outcomes. Some research has found that Asians attributed outcome more to effort and less to ability than Americans (Chen & Stevenson, 1989). This emphasis is consistent with traditional Asian philosophy that assumes malleability in humans and stresses the importance of striving for improvement (Stipek, 2002). Culturally different beliefs about the causes of achievement outcomes suggest that these perceptions, to some degree, are socialized. Parents and teachers within our culture, therefore, may influence students' perceptions of the cause of achievement outcomes, and affect students' perspectives on effort to resolve the cognitive conflict when confronted with discrepant events.

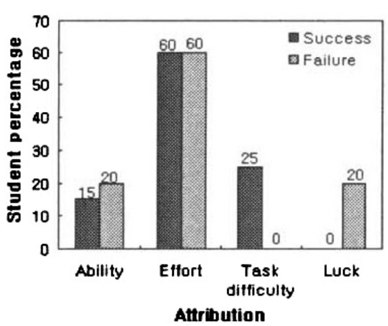


Fig. 2. Distribution of students' attributions for success and failure outcomes

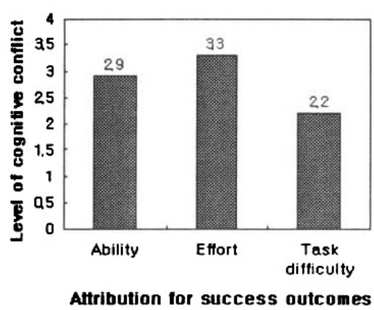


Fig. 3. Level of cognitive conflict by students' attribution for success outcomes

Table 2. Results of descriptive statistics on the cognitive conflict scores by students' attribution for success outcomes

	N	M[1)]	SD
Ability	3	35.33	3.78
Effort	12	39.00	4.47
Task difficulty	5	26.60	10.26
Total	20	35.35	7.98

1) The total score: 48 (The total average: 4)

Table 3. Results of ANOVA on the cognitive conflict scores by students' attributions for success outcomes

Source of variation	SS	df	MS	F	p
Between groups	542.68	2	271.34	6.88	.006
Within groups	669.86	17	39.40		
Total	1212.55	19			

Table 4. Scheffe test in mean differences among three groups having different attributions for success outcomes

	Effort	Task difficulty
Ability		
Effort		**
Task difficulty		

** p ⟨ .01

As shown in Figure 3, Table 2, and Table 3, the result of ANOVA analysis on the level of cognitive conflict among three groups of different attribution to success showed significant differences ($F = 6.89$, $p < .01$). Especially, the results indicated that the group who attributed success outcomes to "effort" experienced higher levels of cognitive conflict than the group to "task difficulty" (such as Table 4). Thus, it seems very important to find out how those who experienced high levels (third and fourth level) of cognitive conflict change or maintain their alternative conceptions about action and reaction after they are confronted with the discrepant demonstration that contradicts their existing conceptions.

2. The characteristics of students' attribution and conceptual change

The second research purpose concerned what kinds of students' attributions for cognitive conflict resolution and successful/unsuccessful understanding of physics concepts were, and how the attributions affect the process of the conceptual change.

For a case studies, seven students who showed high levels of cognitive conflicts were selected and interviewed to find out what attributions influence resolving of cognitive conflict and successful/unsuccessful conceptual understanding in learning physics. The following figures show the results of the attribution interview.

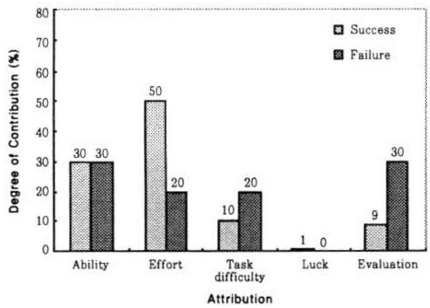


Fig. 4. Bana's attributions

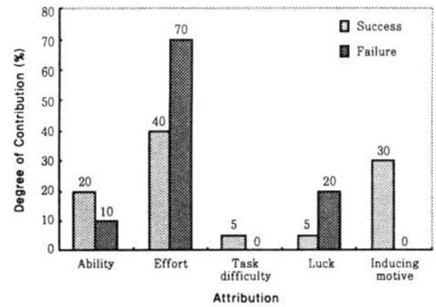


Fig. 5. Choo's attributions

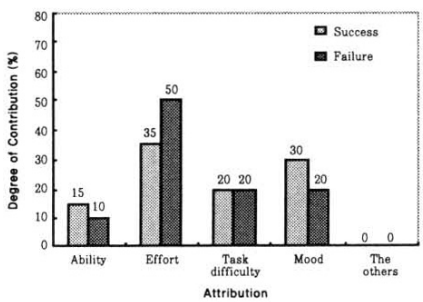


Fig. 6. Jana's attributions

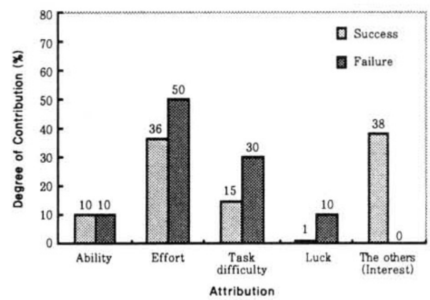


Fig. 7. Leena's attributions

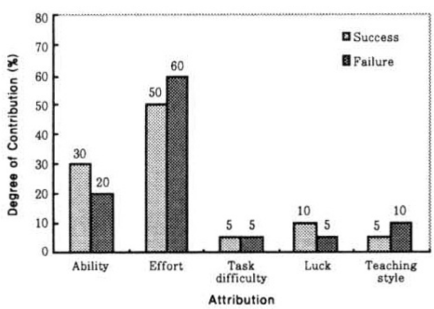


Fig. 8. Nam's attributions

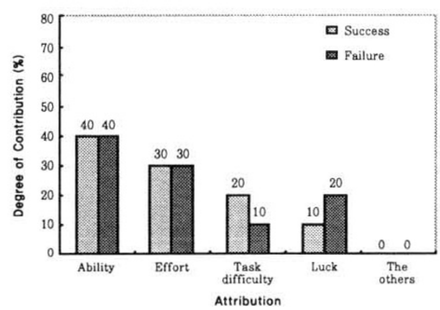


Fig. 9. Sami's attributions

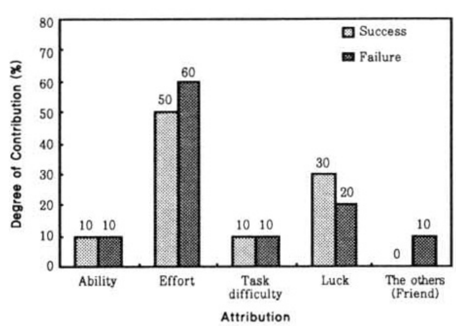


Fig. 10. Young's attribution

In the above figures, the percentiles mean the rate of contribution that students think in understanding successful/unsuccessful conceptual understanding in learning physics. As shown in Figure 9, Sami attributed successful/unsuccessful understanding the concepts and resolving the conceptual conflict to "ability". However, except for Sami, the six students argued that effort played a very important role in successful resolution of cognitive conflict and conceptual change in learning physics (as shown in Figures 4, 5, 6, 7, 8, 10). However, as the results of informal interviews, they each have been found to have different perspectives on effort to resolve the cognitive conflict and understand the physics concepts. For example, as shown in Table 5, Sami regarded making an effort for successful understanding of physics concepts and resolving the conceptual conflict in physics learning as "only doing many exercises before the test."

Table 5. Students' perspectives on effort to understand successfully physics concepts and conceptual change in posttest and delayed posttest

Student	Student's perspectives on effort	*Posttest	**Delayed posttest
Bana	· Doing study for the each day's lesson. · Rewriting and summarizing first, and then trying to understand it. · Collecting my portfolios related to the day's lesson each day and using them to understand scientific concepts deeply. · Using my own learning strategy: reading and understanding the text first; closing the text and reflecting what I understand; writing the content to be learned on a sheet of paper and comparing them with the text.	△	○
Choo	· Before the day of the test, taking a look at the text and solving the problems. · (When I can't solve the problem) Always checking a correct answer with the solution.	⊖	■
Jana	· Concentrating my attention on what teacher says in instruction, but I am not accepting all that teacher explained; rather, I reflect what it means and apply it to the real life. · Often thinking deeply on the concepts learned.	△	○
Leena	· Studying the concepts very hard and trying to understand them thoroughly. · Often reflecting what they mean.	△	○
Nam	· Before the test, studying what teacher explained in the instruction. · Memorizing only the proofs and formulas to be taught. · Solving only the problems that teacher addressed. · Listening carefully to what teacher explained.	⊖	■
Sami	· Only doing many exercises before the test.	⊖	■
Young	· Investing more time than other students in understanding the concepts and making up my mind to sincerely study.	⊖	■

* ⊖: A student accepting the data, offering an explanation for the data, and altering the alternative conception into another alternative conception; △: A student accepting the data, offering an explanation for the data, but not altering the alternative conception.
** ■: A student having the alternative conceptions of action and reaction; O: A student having the scientific conceptions of action and reaction.

On the other hand, Bana had the perspectives on effort as follows, and he stated that he has always used these strategies to study and understand physic concepts in the course. "Doing study for the each day's lesson," "rewriting and summarizing first, and then trying to understand it," "collecting my portfolios related to the day's lesson each day and using them to understand physics concepts deeply independent of preparing for an exam," and "using my own learning strategy: (1) reading and understanding the text first; (2) closing the text and reflecting on what I understand; (3) rewriting the content to be learned on a sheet of paper and comparing them with the text."

Effort is at the heart of self-regulated learning (Boekaerts, 1997). One goal of physics teaching is to free students from the need for a teacher so the students can continue to learn natural science and environments independently throughout their lives. To continue learning independently throughout life, a student should be a self-regulated learner. self-regulated learners have academic learning skill and the will to learn (McCombs & Marzano, 1990; Murphy & Alexander, 2000). Knowledge, motivation, and volition (self-discipline) influence skill and will. Knowledge especially means metacognitive learning strategies. Volition, an old-fashioned word for will power, is to know how to protect yourself from distractions and how to cope when you feel anxious, drowsy, or lazy (Corno, 1993; Corno & Kanfer, 1993; Dewitte & Lens, 2000; Husman, McCann, & Crowson, 2000; Pintrich, 1999; Snow, Corno, & Jackson, 1996; Valle *et al.*, 2003). Where motivation denotes commitment, volition denotes follow-through. In order to manage emotion and motivation, students should have volitional strategies. These strategies are proposed to influence the initiation and maintenance of effort toward intended goals (McCann & Garcia, 2000; Pintrich & Sinatra, 2003).

As shown in Table 5, like Bana, Jana, and Leena, some students' perspectives on effort imply that they have been applying the metacognitive, motivational, and volitional strategies to resolving the cognitive conflict and understanding physics concept. In the interview, they stated they have always used these strategies in learning and understanding physic concepts in the course.

Bana's perspectives on effort and his conceptual change

Especially, Bana's perspectives on effort include three factors of self-regulated learning. He said that his doing effort to resolve the cognitive conflict was (1) trying to understand scientific concepts deeply independent of preparing for an exam and (2) rewriting and summarizing first, (3) then trying to understand it, (4) and collecting his portfolios related to the day's lesson each day. These effort activities mean that he has intrinsic motivation to seek out and conquer challenges as we pursue personal interests and exercise capabilities, and he is also a good learner to be motivated to learn physics.

As to the factor of cognitive and metacognitive strategies, he stated that when/after being confronted with discrepant events, to make an effort for understanding physics concepts and resolving the cognitive conflict, he generally used his own learning strategies. These were (1) reading and understanding the concept in text (Rehearsal), (2) reflecting on what he understands (Metacognition), and (3) writing the contents to be learned on a sheet of paper and comparing them with the text (Metacognition). What is very interesting and important to us is that he was taught the strategies by the math teacher when he was in high school. These learning tactics were related to metacognitive strategies (Georghiades, 2004; Pintrich, 2002; Pintrich & De Groot, 1990; Schunk & Zimmerman, 1998). As Bana said, metacognitive strategies that support self-regulated learning can be taught by the teacher. Some researchers recommended embedding instruction on metacognitive skills into the regular instruction, like science, physics, and math, rather than doing it as a separate curriculum (Brown & Pressley, 1994).

For the factor of volition, he contended that he could make an effort any time if he wants to work. He recognized effort as a dimension of stability regardless of the other environments. He had strong will power. According to action-control theory (Kuhl, 1985), volition plays a mediating role between the intention to learn and the use of learning strategies (Corno & Kanfer, 1993; Garcia, McCann, & Turner, 1998; Husman, McCann, & Crowson, 2000; Snow *et al.*, 1996; Valle *et al.*, 2003).

In posttest[2)], he accepted the result of the demonstration, and offered an explanation for the data. However, he refused to change the current conception. Table 6 indicates his response to anomalous data. In the pretest, he predicted the fan would move to the right. He reasoned that if the wind reflected by a plate exerted a force on the fan, and at the bottom of the fan, static friction would push the cart. After the demonstration, he stated that the intensity of the wind was not strong enough to move the cart, and to move the cart we need the force of the wind more than a normal force of the fan. The reason why he didn't alter the current theory was he believed if he used a fan making much stronger wind, the cart could move to the right. According to the taxonomy proposed by Chinn and Brewer (1998), his response to the anomalous data is in the category of "reinterpretation." He explained the data within his current theoretical framework without changing his current theory.

In delayed posttest, however, he changed the alternative conception into scientific conception through self-regulated learning. He rightly applied Newton's second law and third law to the fan-cart problem and the horse-cart problem. He understood action and reaction always come in a pair, and the forces in the pair, which always act on different objects, are equal in magnitude and opposite in direction. In addition, he drew the forces correctly in the free-body diagram. His explanation about the fan-cart is as follows:

> "Without the friction on the ground, if the cart is at rest, the force of wind impact on the cardboard would be balanced by the reaction force on the fan. Thus with the net force on it being zero, it is in a state of equilibrium."

The reason why he changed the alternative conception was, as he said in above Table 5, he did his best to make an effort to resolve the cognitive conflict and to understand the situation after he was confronted with the demonstration (the fan-cart). As Table 5 shows, according to Weinert, Schrader, and Helmkel (1989), Bana's effort activities seem to be not quantitative effort but qualitative effort based on self-regulated learning. As shown in Table 5, like Bana, Jana and Leena also showed similar perspectives on effort and indicated the similar process of conceptual change.

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2) In posttest, we found that the students' responses to anomalous data fell into the two types among the eight types proposed by Chinn and Brewer (1998) - reinterpretation, theory change. Table 6 showed the types. Thus as shown in Table 5, the results of posttest were classified as the two types.

Table 6. The results of students' responses to anomalous data

Student	Does the Individual Accept the Data as Valid?	Does the Individual Offer an Explanation for the Data?	Does the Individual Alter the Current Theory?	Response
Bana	Partially Yes	Yes	No	Reinterpretation
	I admit the result. I observed directly, and thought I had a misconception. However, strength of wind seemed to be too weak. I admit the result, but admit just 50% in a process.	I thought strength of the wind seemed to be too weak. When I lifted the electric fan, Normal force was 0, and when I put it on the cart(Normal force was not 0), the cart did not move. Thus I guess we need strength of wind that is stronger than the normal force supporting the fan. I don't know the quantitative equation, but I think static friction is proportional to μN (friction $\propto \mu N$).	I want to repeat further experiment by strength of a strong wind. But I admit the result partially, because I can't disregard this strength of a wind in the experiment. But I didn't change my thoght.	
Choo	Yes	Yes	Yes	Theory change
	I think my thought seems to be wrong.	I guessed that the cart would move because there was the fan on the cart, so the cart and the fan must move together. But I didn't think so. Because I saw the experiment results, I found the section which I had not considered.	I was able to know what I thought was wrong while observing the experiment.	
Jana	Partially Yes	Yes	No	Reinterpretation
	I admit the result, because I saw the phenomenon. But I wonder if there are some variables that I didn't consider.	The experiment result that I thought about was the situation and principle in case that I lifted an electric fan. I was able to confirm that according to a position of an electric fan, forces to work on the cart were different. The reason is because a movement of cart changes according to a position of an electric fan.	Because I cannot know a certain reason yet, thus I think my thought is easily changed.	
Leena	Partially Yes	Yes	No	Reinterpretation
	I had considered only F electric fan, F repelling force. By the way, I think there is frictional force on the experiment table. Then, frictional force of (-) x axis as well as F repelling is acted in (-) x axis. Therefore, if we can consider three kinds of force, ? F net force = 0, thus the cart doesn't move. Can not the cart move if we remove friction? If there is no friction, the cart will move to the right. But if there is friction, it can't move.	if add one more, because F electric fan = F repelling is almost equal. and in case of removing frictional force, F electric fan + F repelling = 0, F net force = 0. Therefore the cart will not move. If the distance between the fan and the cardboard is close and the strength of a wind is stronger, the cart can move.	Basically my idea is no change. There is no change in thinking which F electric fan and F repelling act. I knew that frictional force that did not consider in the experiment situation must be considered. Difference of F electric fan and F repelling may not be so big.	

(Continued)

Student	Does the Individual Accept the Data as Valid?	Does the Individual Offer an Explanation for the Data?	Does the Individual Alter the Current Theory?	Response
Nam	Yes As I have observed the experiment result, my idea seems to be wrong.	Yes The cart moved due to the force of the wind that the cardbord of the cart receives by action and reaction rule. These forces are action and reaction and cancel out. Also, because friction is stronger than force of a wind, I think the cart will not move.	Yes There is no special problem in design of experiment, and because when I lift electric fan and the fan blew wind and when I put down on the cart and the fan blew wind, reaction of the cart differs. When I put down electric fan on the cart, it moved.	Theory change
Sami	Yes At the moment when I observed the experiment result, I thought the direction of a wind does not change without reasonable cause because wind force is a kind of force. In addition, I suddenly remembered action and reaction.	Yes Compared with my first thought, I modified it and now thought direction of force did not change. Forces becomes equilibrium, because a degree of force as wind interacts acted to opposite direction. Point to keep in mind in this problem is that the cardbord and the fan have adhered on the cart. If the fan was detached in the cart, force of electric fan might have become force that is inflicted from outside. Reactive force to the force is based on only the fan, but the cart becomes equilibrium, because action that the fan exerts on the cardboard and reaction to action are internal fores on present setting.	Yes I found the point that was wrong in my ideas. Reason that I haven't thought well occurred.	Theory change
Young	Yes I could not find reasonable cause that density difference of air can work the cart.	Yes Initially, I would explain that the cart did not move, because the force that electric fan acted on the cart and certain other force were canceled out mechanically. But I could not know what a certain other force is really. Once I put down the fan on the cart, normal force grows because total weight increases here and frictional force grows. I will explain that like this.	Yes There is no proper reason that my explanation is reasonable.	Theory change

Choo's perspectives on effort and her conceptual change

As the results of interviews, Choo, Nam, Sami, and Young had the similar perspectives on effort and made an effort to resolve the conceptual conflict and successfully understand the physics concepts. As shown in Table 5, Choo contended that making an effort for them was (1) taking a look at the text and solving the problem before the day of the test, and (2) always checking a correct answer with the solution when she could not solve the problem. Like Choo, Nam also said that effort activities for them meant (1) studying what teacher explained in the instruction before the test, (2) memorizing only the proofs and formulas to be taught, and (3) solving only the problems that teacher addressed on. Young and Sami also focused on the quantitative effort. These students were passive and had the extrinsic motivation in learning physics.

In posttest, as shown in Table 6, those who focused on only the quantitative effort also believed the anomalous data, gave an explanation for the data, and changed the current theory. Based on Chinn and Brewer (1998), this response to the anomalous data is in the category of "theory change", in which students abandon their current beliefs. However, the changed theory didn't mean a scientific conception but another alternative conception. for example, before the demonstration, as shown in Table 1, Nam predicted the cart would move to the right, because she thought if a current would exert a force on the plate to the right, just as if a wind would push a sail, and a yacht could sail before the wind. She didn't consider the pair of action and reaction forces in the interaction between the fan and the current. After the demonstration, she changed the conception into another conception. She insisted that the cart was at rest because action and reaction forces canceled out.

One month later, in the delayed posttest, she maintained the alternative conception. As shown in Table 5, like Nam, Choo, Sami, and Young also showed similar perspectives on effort and indicated the similar process of conceptual changes.

Most educational psychologists portray students as being motivated to learn, willing to put in effort and capable of monitoring their own effort. Unfortunately, as we can see from the results of the interviews, this is not realistic. Effort is at the heart of self-regulated learning, but researchers do not agree on its conceptualization. Alexander (1995) made a distinction between mindful and mindless effort, and Weinert *et al.* (1989) distinguished between qualitative and quantitative effort. The former type of effort refers to the quality of strategy use. This is the extent to which effort is expended to process the material extensively (deep level processing) and in a context-sensitive way. The latter refers to time allocation (e.g., sitting before one's books, or cramming before an exam in a surface level processing style). Mindful and qualitative effort includes using metacognitive strategies and volitional strategies. In delayed posttest, like Bana, Jana, and Leena, those who spent high qualitative and mindful effort achieved the scientific understandings. However, like Choo, Nam, Sami, and Young, those who spent more quantitative and mindless effort reverted to alternative conceptions.

Therefore, through the physics instruction, in order to facilitate students becoming self-regulated learners who are able to manage the cognitive conflict, physics teachers need to know student's perspectives on effort and effort activities to resolve conceptual conflict and to understand physics concepts.

In summary, even though students experienced high levels of cognitive conflict, not all of them changed their alternative conceptions into scientific conceptions. However, of these, the students who not only had the perspectives on effort implying the use of the self-regulated learning strategies and used these strategies, showed conceptual changes in delayed posttest as shown in Table 5.

V. Conclusions and Implications

When confronted with anomalous situations, students who attribute success outcomes to "effort (internal factor)" may experience higher levels of cognitive conflict than those who attribute success outcomes to "task difficulty (external factor)." However, those students who revealed high levels of cognitive conflict and attributed success outcomes to effort did not always produce conceptual changes. They had different perspectives on effort and conducted different effort activities to resolve the cognitive conflict and to understand physic concepts. In addition, these effort activities appeared to include their motivational beliefs, metacognitive strategies and volitional strategies. The results of this study indicate that in order for the conflicts to lead to change, students need to have the perspective on effort implying the use of the self-regulated learning strategy and to conduct effort activities based on them in their learning process.

In the early 1980s, the conceptual change model (CCM) specified the conditions for conceptual change: for a student to undergo conceptual change, she or he has to become dissatisfied with the existing conception and find the new conception intelligible, plausible, and fruitful. Since its inception, the CCM has been very influential and widely accepted, but in recent years it has increasingly been seen as inadequate. The criticisms are mainly leveled at its rational nature; namely, that it neglects noncognitive factors (e.g., motivational and volitional factor, and classroom contextual factors) that may also affect conceptual change. Sinatra and Pintrich (2003), in a further explication of the CCM, also contended that a wide range of factors need to be taken into account in conceptual change.

Therefore, to explain students' conceptual change in the classroom context, we need to develop a model of conceptual change including students' motivational beliefs and metacognitive and volitional strategies. Before the physics teacher confronts students with a discrepant demonstration, he needs to use the way to increase intrinsic motivation for learning physics. As a matter of fact, we can lead horses to water, but we can't make them drink. What is important, we can increase the likelihood of their drinking if we feed them a pail of salt before bringing them to the trough. Like the preceding, before the students are confronted with a discrepant event, it is important for them to know why they study and understand the physics concept. Through the understanding, students can try actively to make an effort for resolving the cognitive conflict. After the instructor confronts them with the demonstration, he should teach the new scientific concept and metacognitive strategies to resolve the conflict. In addition, he needs to introduce volitional strategies to spread the scientific conception and to maintain it after a long time. This model of strategies to include motivational beliefs and metacognitive and volitional strategies is called management strategy of cognitive conflict (MSCC).

Recently, in order to develop the MSCC, we designed and tested an easy-to-use instrument to monitor the status of students' cognitive conflict and anxiety in the conflict situations and the effects on students' motivations in learning (Kim & Bao, 2004a). This tool is called the In-class Conflict and Anxiety Evaluation (ICAE). We can easily implement ICAE in classrooms to identify the types of constructive and destructive cognitive conflict that students may reveal in their learning. The ICAE could be a crucial tool for further research on the MSCC to help students become a self-regulated learner in learning physics.

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