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How Does Cognitive Conflict Affect Conceptual Change Process in High School Physics Classrooms?

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ABSTRACT

The purpose of this study was to examine the role of cognitive conflict in the conceptual change process. Ninety-seven high school students in Korea participated in this study. Before instruction, we conducted pretests to measure learning motivation and learning strategies. During instruction, we tested the students' preconceptions about Newton's 3rd Law and presented demonstrations. After this, we tested the students' cognitive conflict levels and provided students learning sessions in which we explained the results of the demonstrations. After these learning sessions, we tested the students' state learning motivation and state learning strategy. Posttests and delayed posttests were conducted with individual interviews. The result shows that cognitive conflict has direct/indirect effects on the conceptual change process. However, the effects of cognitive conflict are mediated by other variables in class, such as state learning motivation and state learning strategy. In addition, we found that there was an optimal level of cognitive conflict in the conceptual change process. We discuss the complex role of cognitive conflict in conceptual change, and the educational implications of these findings.

Key words: cognitive conflict, learning motivation, learning strategy, conceptual change

I. Introduction

The importance of cognitive conflict in human development has been recognized by many psychologists (e.g., Niaz 1995). Since Posner *et al.*(1982) proposed that cognitive conflict defined as dissatisfaction with existing concepts is critical to the process of conceptual change, many teaching strategies in science education have been designed to facilitate cognitive conflict as a means of encouraging students' conceptions change (Hewson & Hewson, 1984; Thorley & Treagust, 1987; Niaz, 1995; Druyan, 1997; Chinn & Brewer, 1998; Kwon & Lee, 1999).

However, even with the relatively rich research in conceptual change using conflict strategies, very few researchers have gathered explicit empirical evidence about the conceptual change process triggered by cognitive conflict. This is one reason for the current debate about the effects of cognitive conflict upon students' learning. Some researchers have argued that even though students' ideas can be confronted with contradictory information through instruction, such a cognitive conflict approach frequently does not elicit a positive result from the learner (Champagne *et al.*, 1985; West & Pines, 1985; Alvermann & Hague, 1989; Hewson & Thorley, 1989; Dreyfus *et al.*, 1990; Dekkers & Thijs, 1998). Hewson *et al.*(1998) indicated that there are

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different views of the role of cognitive conflict, that is, it may be considered either constructive and destructive.

Thus, it would be beneficial to the research community to understand more specifically the role of cognitive conflict in the conceptual change process before incorporating its principles in actual pedagogical strategies. The purpose of this study is to find experimental evidence on the role of cognitive conflict in the conceptual change process.

Specifically, the following research questions were addressed:

First, does cognitive conflict influence the process of conceptual change?

Secondly, how does cognitive conflict affect conceptual change process?

Thirdly, how do students' trait characteristics(motivation and learning strategy), which are considered a relatively enduring predisposition (like intelligence), affect the conceptual change process?

Ⅱ. Theoretical Perspectives

Cognitive conflict is a perceptual state in which one notices the discrepancy between one's cognitive structure and the environment (external information), or between the different components (e.g., one's conceptions, beliefs, sub-structures and so on) within one's cognitive structure (Lee & Kwon, 2001).

Researchers have employed diverse terminology according to their research concerns when they have explained a cognitive conflict situation. Thus, there are many terms with meanings similar to cognitive conflict that have been used by individual researchers:

> cognitive dissonance (Botvin & Murray, 1975 Murray *et al.*, 1977), cognitive gap (Furth, 1981), conceptual conflict (Johnson & Johnson, 1979), discrepancy (Siegel, 1979 Zimmerman & Blom, 1983), disequilibrum (Smedslund, 1961; Murray *et al.*, 1977; Damon & Killen, 1982; Murray, 1983), internal conflict (Bodlakova, 1988), paradoxes (Movshovitz-Hadar & Hadass, 1990), psychic conflict (Cantor, 1983), and socio-cognitive conflict (Bearison *et al.*, 1986).

For instance, Smedslund (1961) used the word 'equilibration' as Piaget (1985) had described it. Smedslund argued that equilibration may be similar to Festinger's cognitive dissonance or Heider's balance mechanisms.

'How does cognitive conflict affect the learning process?' Many researchers have tried to answer this question (see Table. 1). According to Piaget's theory (1967, 1980), when a child recognizes cognitive conflict (disequilibrium), this recognition motivates him or her to attempt to resolve the conflict. Piaget called the process of resolving conflict, 'equilibration'. According to him, equilibration means a process of self-regulation that maintains a balance between 'assimilation' and 'accommodation.'

Festinger's cognitive dissonance theory resembles Piaget's theory (Misiti & Shrigley, 1994). Festinger (1957) suggested that perceptions of an inconsistency among an individual's cognitions generates psychological discomfort-or cognitive conflict (his term, cognitive dissonance)-and that this aversive state motivates individuals to attempt to resolve the dissonance.

Berlyne (1960, 1963, 1965) said that conceptual conflict has high arousal potential, motivating attempts to resolve it by seeking new information or by trying to reorganize the knowledge one already has.

Keller (1984) proposed the ARCS model of motivation. The ARCS model defines four major components of motivation (Attention, Relevance, Confidence, and Satisfaction). Keller (1987) argued that attention is one of the elements of motivation, and it can be aroused when students experience cognitive conflict (his terms, incongruity and conflict)

Biggs (1990) argued that inquiry methods of teaching should either draw upon existing interests, or present students with baffling demonstrations or paradoxes, in order to arouse their motivation. He said that if students' interest can be aroused, then deep learning is likely to result.

Table 1. The role of cognitive conflict in the learning process

Researcher	Learning Process
Piaget (1967, 1980)	Disequilibrium - motivation - equilibration
Festinger (1957)	Cognitive dissonance - motivation - resolving dissonance
Berlyne (1965)	Conceptual conflict - motivation
Keller (1987)	Conflict - motivation (attention)
Biggs (1990)	Paradox - motivation - learning strategy

Posner *et al.*(1982), based on epistemology, assumed that students will not change alternative theories unless they experience cognitive conflict with their current conceptions: 'if taken seriously by students, anomalies provide the sort of cognitive conflict (like a Kuhnian state of crisis) that prepares the student's conceptual ecology for an accommodation (p. 224).' Although the authors did not explain the detailed process of conceptual change facilitated by cognitive conflict, they argued that cognitive conflict is a necessary condition of conceptual change.

In summary, discrepant science situations invite students to experience cognitive conflict. This experience drives students in search of new knowledge and motivates students to regulate their thinking process to resolve conflict. In other words, cognitive conflict engenders motivation, and this motivation creates the possibility for a deep learning strategy.

O'Neil and Abedi (1996) found the "state versus trait" distinction useful for both cognitive and affective measurement. According to them, states are situation-specific and are known to vary in intensity and change rapidly over time. For example, they defined state metacognition as a transitory state of people in an intellectual situation. On the other hand, traits are considered to be relatively enduring predispositions or personal characteristics (e.g., intelligence or aptitude). For instance, O'Neil and Abedi (1996) defined trait metacognition as a relatively stable individual difference variable and observed that individuals respond to intellectual situations with varying degrees of state metacognition.

Using this explanation as an analogy, we can suppose that there are state and trait learning motivation(and state/trait learning strategies). The learning motivation and learning strategies aroused in the conceptual change process are state characteristics because these are situation-specific variables.

Keller (1983) made a distinction between state motivation and trait motivation. According to him, there are two different kinds of motivation in the conceptual change process: trait motivation, which is a relatively enduring predisposition, and state motivation, which is affected by the given situation (e.g., cognitive conflict, teacher, and task). Trait motivation as well as state motivation can affect conceptual change. Many researchers (Dreyfus *et al.*, 1990; Pintrich et al., 1993; Elizabeth & Galloway, 1996; Rhoneck *et al.*, 1998; Barlia & Beeth, 1999) have found that motivation as a personal characteristic is an important variable in conceptual change.

In the same way, we propose that there are two different learning strategies: trait and state learning strategies. in the trait learning strategy, predispositions remain relatively constant, while the state learning strategy is variable according to the context (e.g., cognitive conflict, teacher, and task). Many researchers have found that learning strategy has an important role in conceptual change (Thorley, 1990; Gunstone, 1992; BouJaoude, 1992; Beeth, 1993; Pintrich *et al.*, 1993; Rhoneck *et al.*, 1998).

In addition, cognitive conflict is affected by students' developmental levels (Sigel, 1979). Dreyfus and his colleagues (1990) argued that a state of meaningful conflict depends on students' ability: their levels of cognitive development and their conceptual knowledge. Lee(1998) found that the levels of preconceptions affect the levels of cognitive conflict in the conceptual change process.

Ⅲ. Research Methodology

1. Participants

Two tenth grade classes from a Korean junior high school were assigned to this study. The participants were 97 students, 50 male (52%) and 47 female (48%). The school was located in Seoul, Korea. The same teacher taught both classes.

2. Instrument

1) Test of Newton's 3rd Law concepts

A test was constructed by the researchers to assess the students' understanding of Newton's 3rd Law, both before and after instruction. The test consisted of three multiple choice items with a short-answer essay concerning the following situations: strong and weak magnets, balances, and a cart with an electric fan. One item was distributed to the students during each class time (see Appendix 1).

Scoring. Students' responses to the conception tests and the interview were evaluated with the scheme listed in Table 2. We modified a similar scheme that was used in previous studies (Abraham *et al.*, 1994; Lump & Staver, 1995). Sound understanding was awarded 2 points, partial understanding was awarded 1 point, and other (incorrect understanding) received 0 point. Content validity and item clarity were established through content-expert analysis prior to administration.

2) Learning Motivation

Test of trait motivation. The test was a 30-item Likert instrument, adapted from the questionnaires of Harter (1981). This test consisted of five subscales, which measured as follows: preference for challenge vs. preference for easy work, curiosity/interest vs. pleasing teacher/getting good grades, independent mastery vs. dependence on teacher, independent

Table 2. Evaluation scheme for students' preconceptions

Degree of understanding	Criteria for scoring	Numerical Score
Sound understanding	Responses that contain all parts of the scientifically accepted concept	2
Partial understanding	Responses that contain a part of the scientifically accepted concept	1
Partial understanding with a specific misconception	Responses that contain a part of the scientifically accepted concept, but that also contain a misconception	0
Specific misconception	Responses that contain a misconception	0
Misconception with low confidence	Responses that contain a misconception, and that lack confidence in their expression	0
No understanding	Blank, no explanation, repeats question, irrelevant or unclear response	0

judgment vs. reliance on teacher's judgment, and internal criteria vs. external criteria (5 items each). The Cronbach alpha reliability was 0.54-0.84.

Test of state motivation. The test was developed and used by Keller (1993). It consists of four subscales, which measure attention, relevance, confidence, andsatisfaction. The Cronbach alpha reliability was 0.81-0.88. Park (1997), used 30 items from the original instrument, and reported a Cronbach alpha reliability coefficient of 0.59-0.73 when the test was used with a sample of Korean secondary students. We used the same test instrument that Park used.

3) Learning Strategy

Test of trait learning strategy. The test was selected and used by Jeon and Noh (1997) from the questionnaire on approaches to learning and studying (Center for research on learning and instruction 1995). It was a 20-item Likert instrument and consisted of two subscales, one measured deep learning strategy (10 items) and another measured surface learning strategy (10 items). In the previous study (Noh *et al.*, 1997), the Cronbach alpha reliability was 0.82 for the deep learning strategy, and 0.71 for the surface learning strategy.

Test of state learning strategy. We modified the items of the trait learning strategy test(Center for research on learning and instruction 1995) in order to adapt it to the specific state of the science class. For instance, the item 'I try to figure out how things I learn in science class are connected to things in the contents of different subjects or different units' was changed to 'I tried to figure out how things I learned in today's physics class were connected to things in the contents of different subjects or different units.' The test consisted of 18 items and two subscales: the deep learning strategy (9 items) and the surface learning strategy (9 items). In this study, the Cronbach alpha reliability was 0.85 for the deep learning strategy, and 0.79 for the surface learning strategy.

4) Cognitive Conflict Level Test (CCLT)

Students' cognitive conflict in the class was assessed with an instrument developed by the authors and their colleagues (Lee *et al.*, 2003). The test was a 12-item Likert instrument and consisted of four sub-scales in cognitive conflict: recognition of anomaly, interest, anxiety, and reappraisal of cognitive conflict situation (see Appendix 2). Kwon (1999) reported a Cronbach alpha reliability coefficient of 0.77 for recognition of anomaly, 0.87 for interest, 0.75 for anxiety, and 0.82 for reappraisal of conflict situation when the test was used with a sample of Korean secondary students.

3. Design

Participants were administered a series of tests. Before starting the unit, we conducted pretests to measure learning motivation and learning strategy. During one class time, we tested the students' prior conceptions about Newton's 3rd Law with one item and presented a demonstration that, we expected, might be ananomalous situation to a student who answered incorrectly. After this, we tested the students' cognitive conflict levels with the Cognitive Conflict Level Test.

We provided students a brief instruction session in which we explained the interaction of forces in the result of demonstration. We gave students a short reading about Newton's 3rd Law. After that, we tested the students' learning motivation and learning strategy in the classroom.

In this study we used three different test items about Newton's 3rd Law, each of which had a different context. Therefore, we repeated the same procedures three times to test the students' conceptual change process, using three different Newton's 3rd Law items. In order to measure the students' conceptual changes, a posttest (one day after the class) and a delayed posttest (three days after the first class) were conducted with individual interviews.

4. Analysis

A path analysis was conducted to obtain a coherent picture of the possible causal relations among the levels of preconception, cognitive conflict, trait/state motivation, trait/state learning strategies, and conceptual change. Path analysis requires prior assumptions about causal ordering. The assumptions in this analysis are as follows: because among the levels of preconception, trait learning motivation (before class), and trait learning strategy (before class), were pretested before the class, they could affect the other variables. Because cognitive conflict was aroused prior to state learning motivation (in class) and state learning strategy (in class), and conceptual change, cognitive conflict could affect these variables. Based on Piagetian theory, learning motivation (in class, as state) could affect learning strategy (in class, as state) and conceptual change. Furthermore, learning strategy (in class, as state) could affect conceptual change, but not vice versa.

In the data analysis, since the purpose of this study was to examine the role of cognitive conflict in the conceptual change process, we used the data of students who had the possibility of experiencing cognitive conflict. Students corresponding to these cases were students who answered incorrectly in the preconception tests (the total number of cases was 158).

Ⅳ. Results

The path coefficients based on standardized regression weights are shown in Figure 1. The causal paths show that trait learning motivation (before class) and preconception affected cognitive conflict (0.49 and 0.45, respectively). Cognitive conflict and trait learning motivation (before class) had an effect on state learning motivation (in class) (0.16). Trait and state learning motivation (before and in class) and trait learning strategy (before class) affected state learning strategy (in class) (0.14). However, only state learning strategy (in class) had a direct effect on conceptual change (0.40). In addition, conceptual change on the delayed posttest was affected only by conceptual change on the posttest (0.76). In addition, the minimum score of cognitive conflict in the cases of changing into scientific conceptions was 1.67(maximum score is 4).

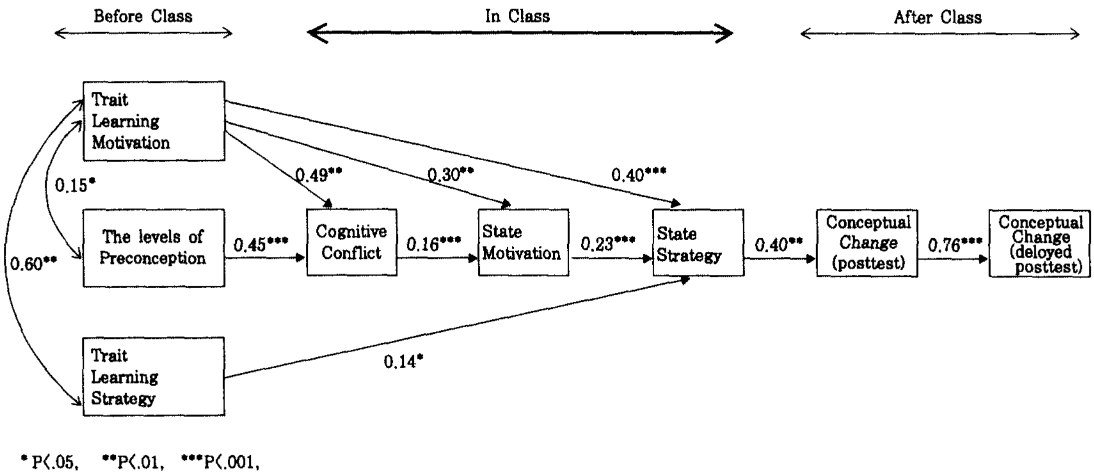

Fig. 1. Path analysis of the preconception, cognitive conflict, learning motivation, and learning strategy to conceptual change

In summary, cognitive conflict had positive effects on the state learning motivation. And state learning motivation had positive effects on the state learning strategy. State learning strategy had positive effects on conceptual changes. On the other hand, trait learning motivation had positive effects on the process of conceptual changes. And trait learning strategy had positive effects on the state learning strategy. The levels of prior conceptions had positive effects on cognitive conflict, significantly.

The result shows that the effects of cognitive conflict were mediated by learning motivation and learning strategies that were aroused in the class. This result supports the previous research (Chan *et al.*, 1997). They (1997) found that the level of knowledge-processing activity exerted a direct effect on conceptual change and that this activity mediated the effect of cognitive conflict (their term, conflict).

Among causal paths, we found that while other relationships in the causal path are proportional, the relationship between cognitive conflict and state learning motivation is different from the others. Figure 2 shows the result.

The levels of cognitive conflict are divided into five levels (Table 3). The first level ranges from 0.0 to below 0.5. In Figure 2, until the fourth level is reached, state learning motivation continues to increase with the levels of cognitive conflict. However after the fourth level, state learning motivation actually decreases with increased cognitive conflict, even though the

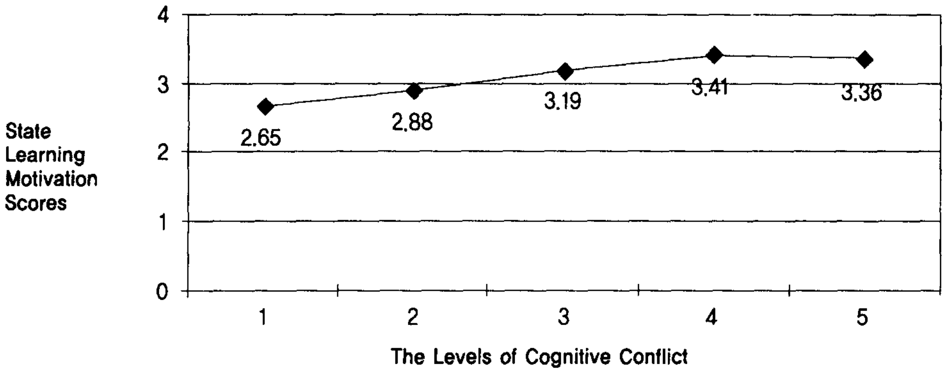

Figure 2. The relationship between levels of cognitive conflict and learning motivation in classrooms

Table 3. Cognitive conflict levels by CCLT scores

Level of cognitive conflict	Scores of Cognitive Conflict Level Test	Number of cases
1	0.0 - 0.5 below	1
2	0.5 - 1.5 below	13
3	1.5 - 2.5 below	67
4	2.5 - 3.5 below	66
5	3.5 - 4.0	22

difference between state motivation levels of fourth and fifth levels of cognitive conflict is not significant statistically.

Therefore, Figure 2 shows that there is an optimal level of cognitive conflict that affects learning motivation. This result explains comparatively why cognitive conflict has little affect on learning motivation in the path analysis result (the path coefficient is 0.16).

This result resembles the graph of the Zone of Curiosity (Day 1982). According to the Zone of Curiosity, if one is presented with a stimulus with a moderate degree of uncertainty, he or she is motivated to resolve conceptual conflict. In this situation, there is an optimal level of arousal. With too much uncertainty, the individual becomes overwhelmed or anxious. With too little stimulation, on the other hand, the result is disinterest and a lack of motivation often characterized by boredom.

Likewise, we could interpret the result of the relationship between levels of cognitive conflict and state learning motivation in science class. With appropriate cognitive conflict, an individual will be motivated to resolve it. However, with too much or too little cognitive conflict, the individual will not be motivated since he or she feels threatened or bored.

V. Conclusions and Implications

This study has examined the role of cognitive conflict in the process of conceptual change while considering other important variables in the process such as students' preconception, state motivation, and state learning strategies. The path analysis suggests that cognitive conflict had direct/indirect effects on the conceptual change process.

However, cognitive conflict in itself is not sufficient. In other words, it needs to be mediated by other variables: state learning strategy (in class) exerts a direct effect on conceptual change and mediates the effects of preconception, cognitive conflict, trait learning motivation, and trait learning strategy (before class). In addition, there is an optimal level of cognitive conflict in the conceptual change process. The levels of cognitive conflict are determined by students' diverse characteristics (for example, students' preconceptions, trait learning motivation, and trait learning strategies).

As trait characteristics, learning motivation and learning strategy continuously affect the conceptual change process. Therefore, as Pintrich *et al.* (1993) argued, the pathways of conceptual change are not merely a matter of a rational learning process.

This study demonstrates the complex role of cognitive conflict in the conceptual change process. Within any learning situation, cognitive conflict among ideas or data is inevitable. Yet, if we do not recognize its potential for producing both highly constructive and highly destructive outcomes, we will lose valuable opportunities to increase students' motivation and learning.

In order to maximize the effect of cognitive conflict and to lead to successful conceptual change, it is important to manage cognitive conflict well, from its production to its resolution, with consideration of students' diverse variables and their complex interactions.

Furthermore, in the future, we should have more concern for developing macro and integrated approaches that take into consideration the diverse variables of the teaching and learning environment. As we try to overcome the limitations of the study (it is somewhat restricted in its approach and theoretical foundation), we can more directly address the question of how to create instruction that will facilitate conceptual change.

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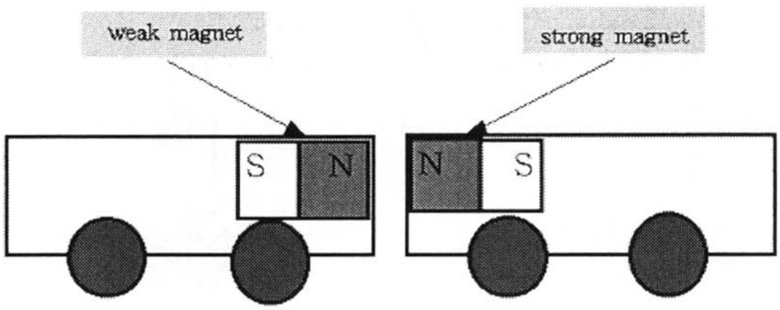
Appendix 1

Test I

Name:
Student ID Number:

This is not an exam. I want you to respond to the questionnaire as accurately as possible, reflecting your own ideas in this class. Your answers to this questionnaire will be analyzed for further study.

Two carts which have strong and weak magnetic respectively, were held by hands. When the carts were released, predict the movement of two carts.



1) The cart which have weak magnetic would be pushed more than the other cart.
2) The cart which have strong magnetic would be pushed more than the other cart
3) The two carts would be pushed with the same distance.
4) Other case

The reason for your answer:

Use the scale below to answer the question A. If you think the statement is very true of you, circle 4 if a statement is not at all true of you, circle 0. If the statement is more or less true of you, find the number between 0 and 4 that best describes you.

0	1	2	3	4
not at all true of me				very true of me

A. I am confident of my idea about this problem. 0 1 2 3 4

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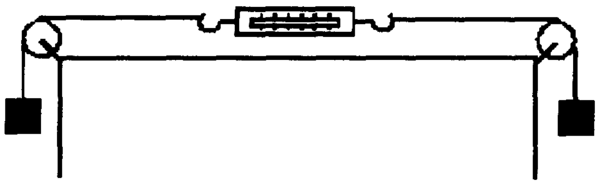
Test II

Name:
Student ID Number:

This is not an exam. I want you to respond to the questionnaire as accurately as possible, reflecting your own ideas in this class. Your answers to this questionnaire will be analyzed for further study.

There is a string balance that is connected with two weights by ropes. They are in a stationary state. The two-fixed pulleys have no friction. When each of the weights pull the balance by 2N respectively, predict the scale of the string balance? (The mass of the string balance is so small that we can ignore the mass)



The reason for your answer:

Use the scale below to answer the question A. If you think the statement is very true of you, circle 4 if a statement is not at all true of you, circle 0. If the statement is more or less true of you, find the number between 0 and 4 that best describes you.

0	1	2	3	4
not at all true of me				very true of me

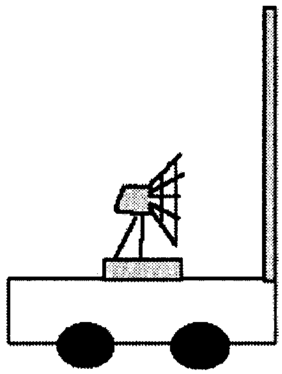
A. I am confident of my idea about this problem. 0 1 2 3 4

Test Ⅲ

Name:
Student ID Number:

This is not an exam. I want you to respond to the questionnaire as accurately as possible, reflecting your own ideas in this class. Your answers to this questionnaire will be analyzed for further study.

There is a cart to which a electric fan and a broad and perpendicular plank are attached. When a rattling wind blows from the electric fan to the plank, predict the movement of the cart.
* The electric fan and the plank are fixed to the cart tightly.



How wil the cart move?

The reason for your answer:

Use the scale below to answer the question A. If you think the statement is very true of you, circle 4 if a statement is not at all true of you, circle 0. If the statement is more or less true of you, find the number between 0 and 4 that best describes you.

0	1	2	3	4
not at all true of me				very true of me

A. I am confident of my idea about this problem. 0 1 2 3 4

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Appendix 2

COGNITIVE CONFLICT LEVEL TEST (CCLT)

All items are on a 5-point Likert scale (0=not at all true of me, 4=very true of me). Use the scale below to answer the questions. If you think the statement is very true of you, circle 4. If a statement is not at all true of you, circle 0. If the statement is more or less true of you, find the number between 0 and 4 that best describes you.

0	1	2	3	4
not at all true of me				very true of me

Recognition of anomaly
1.When I saw the result, I had doubts about the result.
2.When I saw the result, I was surprised by it.
3. The difference between the result and my expectation made me felt strange.

Interest
4. The result of the experiment is interesting.
5. Since I saw the result, I have been curious about it.
6. The result of the experiment attracts my attention.

Anxiety
7. The result of the experiment confuses me.
8. Since I cannot solve the problem, I am in agony.
9. Since I cannot understand the reason for the results, I feel depressed.

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