Development of an Instrument for Measuring Cognitive Conflict in Secondary-Level Science Classes

Gyoungho Lee,1 Jaesool Kwon,2 Sang-Suk Park,2 Jung-Whan Kim,2 Hyeok-Gu Kwon,2 Hac-Kyoo Park3

1Department of Physics Education, College of Education, Shilim-dong, Kwanak-gu, Seoul National University, Seoul 151-742, Korea
2Department of Physics Education, Korea National University of Education, Kangnae-myun, Chongwon-gun, Chungbuk 363-791, Korea
3Department of Physics, Woosuk University, Cheon-ju, Cheonbuk 565-701, Korea

Received 28 June 2001; Accepted 14 August 2002

Abstract: Based on conceptual change theory, cognitive conflict is known as an important factor in conceptual change even though there are still questions about its positive and negative effects on science learning. However, there is no reliable method by which to assess the cognitive conflict students experience in their learning. The purpose of this research was to develop an instrument for measuring secondary students’ cognitive conflict levels as they learned science. The results of this study indicate that our instrument is a valid and reliable tool for measuring cognitive conflict levels. Factor analysis supported the model that cognitive conflict consists of four constructs: recognition of an anomalous situation, interest, anxiety, and cognitive reappraisal of the conflict situation. Implications for instruction and possibilities for future research are discussed. © 2003 Wiley Periodicals, Inc. J Res Sci Teach 40: 585–603, 2003

Cognitive conflicts have long been a part of psychological theories of cognitive change (Cantor, 1983). Despite many shifts of emphasis, the Piagetian account of development has always considered the concept of cognitive conflict, or the internal experience of opposing contradictions, to be absolutely central in cognitive development. The concept figured in Piaget’s earliest writings, and Piaget (1985) developed it into the equilibration model describing inner self-regulation (Roy & Howe, 1990).

Cognitive conflict is a perceptual state in which one notices the discrepancy between one’s cognitive structure and the environment (external information), or among the different
components (e.g., the conceptions, beliefs, substructures and so on) of 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 various researchers. For instance, Smedslund (1961) used the word *equilibration* as Piaget (1985) defined it. He argued that equilibration may be similar to Festinger’s cognitive dissonance or Heider’s balance mechanisms. Hewson and Hewson (1984) used the term *conceptual conflict* because they believe that it is profitable to consider learning from an epistemological point of view, and that “conceptual conflict” reflects this point of view more adequately than does “cognitive conflict.”

In psychology research, many researchers have tried to answer the question, “How does cognitive conflict affect the learning process?” 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 refers to the 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 the perception of 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 the learner to attempt to resolve it by seeking new information or by trying to reorganize the knowledge he or she already has.

Among recent motivation theorists, Keller (1984)’s Attention, Relevance, Confidence, and Satisfaction (ARCS) model refers to the relation between cognitive conflict and motivation. Keller (1987) argued that attention, as one of elements of motivation, is aroused when students experience cognitive conflict (his terms, *incongruity* and *conflict*). Biggs (1990) argued that inquiry methods of teaching should either draw on existing interests or present students with baffling demonstrations or paradoxes to arouse their motivation. The baffling demonstrations or paradoxes are similar to the anomalous data that lead students to experience cognitive conflict. Biggs said that if students’ interest can be aroused, deep learning is likely to result.

Based on epistemology, Posner, Strike, Hewson, and Gertzog (1982) assumed that students will not change alternative theories unless they experience cognitive conflict that challenges 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.

Models of conceptual change are based on the critical elements of prior knowledge and cognitive conflict (Cobern’s words, *conceptual conflict*) (Cobern, 1995). Since the 1970s, science researchers have found that most students begin to learn science contents with preconceptions that differ from scientific conceptions (Driver, Guesne, & Tiberghien, 1985; Kwon & Oh, 1988; Kwon & Lee, 1993; Pfundt & Duit, 1994). Because of these preconceptions, the students may resist change. Several researchers have insisted that it is not enough for science instruction simply to inform students of scientific conceptions. In addition, students need to be convinced that the scientific conceptions are more intelligible, plausible, and fruitful than their own conceptions (Posner et al., 1982).
Since the 1980s, using cognitive conflict as a teaching strategy has been popular in science education. A considerable number of researchers have argued that cognitive conflict has an important role in conceptual change (Druyan, 1997; Hashweh, 1986; Hewson & Hewson, 1984; Kwon, 1989, 1997; Niaz, 1995; Lee, 1998; Posner et al., 1982; Stavy & Berkovitz, 1980; Thorley & Treagust, 1987).

However, there are still questions about the effect of cognitive conflict. For example, there are many different types of cognitive conflict: visual conflict, kinesthetic conflict, social conflict between peers and between children and adults (Druyan, 1997, 2001), individual conflict, and peer conflict (Chan, Burtis, & Bereiter, 1997). The researchers developed these types of cognitive conflict and investigated the effects of such cognitive conflict on students’ learning. However, they did not assess whether the students really experienced cognitive conflict in their research. The researchers just supposed that the students might experience cognitive conflict because they had designed different types of situations that might seem to be contradictory information to students. Thus, there is the possibility of a gap existing between what the researchers expected students to experience and what the students really experienced. Thus, this is a limitation of their research to determine the effects of cognitive conflict on student learning.

Other researchers (Dekkers & Thijs, 1998; Dreyfus, Jungwirth, & Eliovitch, 1990; Elizabeth & Galloway, 1996; Guzzetti & Glass, 1993; Strike & Posner, 1992) argued that cognitive conflict strategies do not consistently lead to conceptual change. They pointed out that even though students’ ideas are confronted with contradictory information through instruction, students frequently do not recognize the conflict and that sometimes the contradictory information can be threatening to students who do not have enough knowledge for resolution of the conflict.

Vosniadou and Ioannides (1998) observed that this dispute about the effect of cognitive conflict in learning science is not resolved: “Is cognitive conflict a good strategy to produce conceptual change?” In order to answer these questions we need further research on the development of knowledge about the physical world and about the learning science” (p. 1214).

It is important to give serious attention to the issue of the effectiveness of cognitive conflict in learning, for several reasons. First, as Johnson and Johnson (1979) mentioned, learning situations are filled with conflicts among students, between teacher and students, and between what a student presently understands and new information being learned. Such conflicts are inevitable. Johnson and Johnson observed that conflicts have the potential for producing both highly constructive and highly destructive outcomes, depending on how they are managed.

Second, a major criticism of most cognitive models of change is that they identify cognitive but not affective factors involved in learning (Sinatra & Dole, 1998). Recently, multidimensional views (including interest, motivation, and social activities) have been considered in conceptual change research (Hynd, 1998; Pintrich, Marx, & Boyle, 1993; Strike & Posner, 1992; Tyson, Venville, Harrison, & Treagust, 1997). According to these views, students’ knowledge development in science is different from knowledge development in the scientific community of scientists. For example, a student often does not change his or her previous knowledge even though he or she is confronted with anomalous data. Sometimes, affective reasons are more important than logical/cognitive reasons in students’ learning. Therefore, we also need to apply the multidimensional views to the study of the cognitive conflict in conceptual change. That is, we should consider cognitive conflict beyond the old, cold, view of conceptual change and try to understand it from the new perspectives.

However, in the associated literature, there is still little certainty in answering the basic questions “What is cognitive conflict?” “How do we know if cognitive conflict is actually generated?” and “How can we measure it?” Thus, for an adequate explanation of the effect of
cognitive conflict on conceptual change learning, the existence and the levels of cognitive conflict need to be measurable.

In 1983, Zimmerman and Blom (1983) assessed cognitive conflict (their words, *internal cognitive conflict*) focusing on two topics: degree of uncertainty and response latency. First, following Berlyne’s (1970) analysis methods, they considered cognitive conflict to be a matter of relieving subject uncertainty related to logical necessity. Thus, degree of uncertainty was considered an indicator of the level of cognitive conflict in their study.

They chose response latency as the second measure of cognitive conflict based on another traditional measure used by cognitive psychologists. Zimmerman and Blom (1983, p. 22) proposed that when cognitive conflict occurred, it would sometimes be evidenced by hesitation, looking back and forth, and signs of uneasiness and tension. Thus, they said a child’s resistance to conceptually advanced implications of training experiences and the resulting alternation between advanced and more immature modes of thought will be manifested in response delays. The traditional measure used by cognitive psychologists to assess such delays is response latency. Response latency was therefore chosen as a second (non-self report) measure of the internal conflict in the present study.

In recent research, Lee (1998) rated the levels of cognitive conflict of 30 students in a Korean high school through individual interviews. He presented anomalous situations in mechanics and electricity to students. The researcher and two other panel members rated the levels of cognitive conflict of the students, using a predeveloped rating scale, by replaying the videotaped individual interviews. The levels of cognitive conflict were double-checked by asking students to rate their own cognitive conflict levels. In this research, Lee showed the possibility of quantification of the level of cognitive conflict.

However, the interview method is time-consuming and difficult to apply to a large number of subjects. In addition, this method needs trained interviewers to ensure consistent scoring. To overcome these difficulties, it is necessary to develop a simpler but more valid and reliable instrument for classroom testing.

Therefore, we need a paper and pencil test appropriate for students who are learning science to measuring their cognitive conflict. The purpose of this study was to develop and validate an instrument that would measure students’ cognitive conflict levels in a secondary school science class.

Cognitive Conflict Process Model

The cognitive conflict process model was developed to explain the cognitive conflict that occurs when a student is confronted with an anomalous situation that is incompatible with his or her preconception in learning science (Lee & Kwon, 2001). This model has three stages: preliminary, conflict, and resolution (Figure 1).

The preliminary stage represents a process in which a student who has belief in a preexisting conception accepts an anomalous situation (e.g., experimental results obtained by a teacher) as genuine. If students did not have strong confidence in a well-formulated preconception or if they considered the anomalous situation as a deception, they would not experience cognitive conflict. Thus, the preliminary stage is the stage before cognitive conflict. In this model, the cognitive conflict process occurs when a learner (a) recognizes an anomalous situation, (b) expresses interest or anxiety about resolving the cognitive conflict, and (c) engages in cognitive reappraisal of the situation. For instance, when learners recognize that a situation is incongruous with their conceptions, they should be interested in or anxious about this situation. Components such as recognition, interest, and anxiety are related to the uncertainty that Berlyne measured as an
indication of cognitive conflict. After experiencing this stage, or simultaneous with it, learners would reappraise the cognitive conflict situation to resolve or dismiss it. At this moment, students may exhibit response latency. The reappraisal of the cognitive conflict situation is the cause of response latency.

In Movshovitz-Hadar and Hadass (1990), we found some examples of the cognitive conflict process:

1. A student recognized an anomaly and felt interest and anxiety simultaneously (in a state of cognitive conflict): "It [the result of the demonstration] is kind of a shock, it's fun... no... it's... mind stretching."
2. A student felt anxiety, but after reassessing his cognitive conflicts, he escaped the 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 her cognitive conflict situation by giving up solving the problem: "I was helpless. I could not wait to hear the solution."

Figure 1. Cognitive conflict process model.
The cognitive conflict process model supposes that four components of cognitive conflict comprise the psychological constructs of cognitive conflict: recognition of an anomalous situation, interest, anxiety, and cognitive reappraisal. We can understand why cognitive conflict has the potential for producing either highly constructive or highly destructive outcomes in terms of these components of cognitive conflict.

For example, if a student does not recognize the anomaly or ignores it, or if he does not like to be in a conflict state, the cognitive conflict in this situation might be negligible. If a student feels frustrated or threatened instead of becoming interested, her cognitive conflict might be destructive. Constructive cognitive conflict can be aroused when a student recognizes an 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 experiences a negative feeling (such as frustration or feeling threatened) instead of interest, or if she does not like to be in a conflict state, the cognitive conflict in this situation might be a negligible experience or even a destructive one. In the resolution stage, a learner will try to resolve cognitive conflict in any way possible. The results of resolution of this conflict will be expressed as an external response behavior. Response behaviors include those behaviors suggested by Chinn and Brewer (1998): ignoring, rejection, uncertainty, exclusion, abeyance, reinterpretation, peripheral theory change, and theory change.

The cognitive conflict process model contains two assumptions. First, students’ diverse characteristics and learning environment factors will affect the cognitive conflict process. A number of studies support this assumption. For instance, Lee (2000) found that students’ learning motivation, learning strategies, and levels of preconceptions affected students’ cognitive conflict in learning physics. Recently Limón (2001) found that 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).

Second, the components of the cognitive conflict will strongly affect the response behavior. Kwon, Lee, Park, Kim, and Lee (2000) investigated the relation between students’ cognitive

Table 1

<table>
<thead>
<tr>
<th>Variables related to the learner</th>
<th>Prior knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Motivation and interests</td>
</tr>
<tr>
<td></td>
<td>Epistemologic beliefs (about learning and teaching and about the subject matter to be learned)</td>
</tr>
<tr>
<td></td>
<td>Values and attitudes toward learning</td>
</tr>
<tr>
<td></td>
<td>Learning strategies and cognitive engagement in the learning tasks</td>
</tr>
<tr>
<td></td>
<td>Reasoning abilities</td>
</tr>
<tr>
<td></td>
<td>Role of peers</td>
</tr>
<tr>
<td></td>
<td>Teacher–learner relationships</td>
</tr>
<tr>
<td>Variables related to the social context in which learning takes place</td>
<td>Domain-specific subject matter knowledge</td>
</tr>
<tr>
<td>Variables related to the teacher</td>
<td>Motivation and interests</td>
</tr>
<tr>
<td></td>
<td>Epistemologic beliefs about learning and teaching and about the subject matter taught</td>
</tr>
<tr>
<td></td>
<td>Values and attitudes toward learning and teaching</td>
</tr>
<tr>
<td></td>
<td>Teaching strategies</td>
</tr>
<tr>
<td></td>
<td>Level of training to be a teacher</td>
</tr>
</tbody>
</table>
conflict and their response behavior in learning high school physics. In their study, they found that anxiety among the components of cognitive conflict had both positive and negative effects on response behavior.

In our recent research (Kwon, Park, Kim, Lee, & Lee, 2000), we investigated the relationship between cognitive conflict and students' response types. From students' interviews in this research, we identified some examples of the cognitive conflict process. The participants were four 10th-grade students from a high school in Korea. At the beginning of this study, we developed demonstration kits and preconception tests on mechanics and electric circuit concepts. Before the interview, the four students were pretested on these concepts. Each student was interviewed individually. Based on the results of the students' preconception tests, we presented demonstrations that would be anomalous situations to each student. We asked them to express their thoughts and feelings about those situations. After this, we gave them cards (Figure 2) that expressed the main constructs of cognitive conflict: recognition of anomaly, reappraisal of the cognitive conflict situation (hesitation in response), interest, and anxiety. We asked them to find cards that represented their thoughts and feelings and to arrange the cards according to the time order in which they thought and felt these things in the cognitive conflict situation.

Following excerpt is 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, turning his head and thinking for a while.]
Interviewer: Could you describe your feelings or thoughts now?
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 have made four cards which depict some sorts of feelings and thoughts about this situation. Please arrange these cards to reflect the thoughts and feelings you experienced as time went by.
Student 1: [Arranges the cards.]

- **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 feel 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.

*Figure 2. Four cards.*
Interviewer: Do you have any other feelings or thoughts about the result except these [which were represented in the cards]?
Student 1: No.
Interviewer: Do you think the result of this demonstration is right?
Student 1: Yes, because it is an experimental result.
Interviewer: Could you explain the result?
Student 1: I do not know. I saw this result for the first time. [Talking aloud.] Is it related to the principle of a lever?

After watching a demonstration that presented a new situation, the student recognized that the demonstration was an anomalous result. He felt futility but showed curiosity and a desire to know the reason. Until the end of the interview, he tried to resolve his cognitive conflict. Thus, we could see that Student 1’s experience of cognitive conflict was similar to the process proposed in the cognitive conflict process model.

Research Procedures

Identification of Measurement Components of Cognitive Conflict

Based on the cognitive conflict process model, we identified the measurement components of cognitive conflict as (a) recognition of an anomalous situation, (b) interest, (c) anxiety, and (d) cognitive reappraisal of the situation. Table 2 shows the operational definitions of each measurement component of cognitive conflict.

In the conflict stage, a student would recognize that his conceptions are inconsistent with the result of the experiment, causing him to doubt, be surprised, and think it strange. Then, the psychological state of the student will exhibit interest or anxiety. A student interested in this situation would show responses such as heightened interest, curiosity, and focused attention. However, a student anxious about this situation would show such responses as confusion, discomfort, and a feeling of oppression. In addition, a student would reappraise his state to decide whether to suspend the state, think a little longer, or seek a more reasonable base. This cognitive reappraisal is related to response latency in decision making and is one of the components that define cognitive conflict.

Table 2

| Operational definitions of measurement components of cognitive conflict |
|-----------------------------|---------------------------------|
| Stage                      | Components                      | Operational Definition                                      |
| Cognitive conflict stage   | Recognition of contradiction    | Recognizing one’s conceptions are not consistent with the results of the experiment/discourse/textbook, etc. (doubt, surprise, strangeness) |
|                            | Interest                        | Being interested in the anomalous situation (interest, curiosity, attention) |
|                            | Anxiety                         | Being anxious about the anomalous situation (confusion, agony, depression) |
|                            | Cognitive reappraisal of situation | Reappraising the anomalous situation; the cognitive conflict and the problem (suspend attention, think a little longer, seek more reasonable base) |
Item Selection

At the beginning of our research, we collected many examples of signs of cognitive conflict by analyzing the previous literature (Berlyne, 1960, 1970; Miller, 1944; Movshovitz-Hadar & Hadass, 1990; Smedslund, 1961; Zimmerman & Blom, 1983) and protocols of the previous research (Lee, 1990, 1998). We made these examples into statements that could be used in a questionnaire and selected some among them according to the following rules: Does one statement represent one subtest component? Are there clear discriminating differences among the statements? Is the vocabulary in the statements appropriate?

For instance, we incorporated the words interest, curious, and attention in separate statements of interest to discriminate among statements more clearly. Likewise, we selected 12 items that could test cognitive conflict (with 3 items for each measurement component of cognitive conflict).

There are many kinds of cognitive conflict according to the situations in which it occurs. When we started to develop the test items, we considered primarily the cognitive conflict that arises from inconsistency between students’ preconceptions and the results of a demonstration or experiment. Thus, this consideration (i.e., demonstration or experiment situation) was reflected in all statements of the test items: For instance, “we saw the results of the demonstration.”

In addition to these cognitive conflict test items, we developed six items to measure students’ degree of confidence in their preconceptions and in the genuineness of the anomalous situation because these are preliminary components in the cognitive conflict process.

Pilot Testing

We conducted three pilot tests to revise the test items according to the validity and reliability results of each pilot test. On the third pilot test, we obtained quite a satisfactory result in terms of validity and reliability. Table 3 shows the results for each pilot test.

In the first pilot test, six experts majoring in science education assessed content validity. A total of 152 high school students (10th grade), who lived in a medium-size city in Korea, participated in the test and were asked to state their reasons for each answer in the blank space provided below each test item. The purposes of this step were to examine whether the students understood the questions as intended and to identify biased responses through the students’

<table>
<thead>
<tr>
<th>Pilot Tests</th>
<th>First</th>
<th>Second</th>
<th>Third</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>152 high school students; 10th grade</td>
<td>88 high school students; 10th grade</td>
<td>279 high school students; 10th–11th grades</td>
</tr>
<tr>
<td>Methods</td>
<td>- Content validity</td>
<td>- Content validity</td>
<td>- Content validity</td>
</tr>
<tr>
<td></td>
<td>- Construct validity</td>
<td>- Construct validity</td>
<td>- Construct validity</td>
</tr>
<tr>
<td></td>
<td>- Interview</td>
<td>- Interview</td>
<td>- Interview</td>
</tr>
<tr>
<td></td>
<td>- Individual response analysis</td>
<td>- Reliability</td>
<td>- Reliability</td>
</tr>
<tr>
<td></td>
<td>- Reliability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revision and development</td>
<td>- Refinement of the questions (making the questions clear, checking the nuances of the statements, etc.)</td>
<td>- Remove space left for reason for choice</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Refinement of questions (making questions clear, checking nuances of statements, etc.)</td>
<td></td>
</tr>
</tbody>
</table>
answers. In addition, 15 students were interviewed to explore and clarify the students’ responses. Students’ responses were analyzed to assess their understanding of each question. The analysis revealed that some students had a biased interpretation of or misunderstood certain questions.

For example, among the items of interest, different students understood the original statement “I would like to see the results again” in different ways in the first pilot test. That is, the original item was understood by some students to include two different measurement components of cognitive conflict: interest and reappraisal. Some students understood the original sentence as “I am interested in seeing the results again.” On the other hand, other students understood the original sentence as “I want to reappraise the results.” Thus, the original item “I would like to see the results again” was changed to “The results of the experiment were interesting to watch.”

Among the items associated with anxiety, the statement “I feel oppressed” was changed to “I feel depressed” because we found in the interviews that depressed was a more appropriate word to explain anxiety in the state of cognitive conflict. Some students said, “I did not feel oppressed. I just felt depressed.” They thought oppressed was too strong a term and commented that their feeling did not reach this level. Through this kind of process, problematic questions were restated to make them more clear and present the correct nuances.

In the second pilot test, 10 experts majoring in science education assessed content validity. A total of 83 high school students (10th grade), who lived in a medium-size city in Korea, participated in the test. A factor analysis of the responses was carried out, and the reliability of the test was assessed by calculating Cronbach alpha. After the second pilot test, we removed the blank space because it was determined in the interviews that most students understood the questions as intended.

One month after the second pilot test, we conducted the final test. We selected 279 high school students (10th and 11th grades) representing both genders (148 male, 131 female) and three different areas (98 from one metropolis, 80 from one medium-size city, 101 from one small town) for this study. We analyzed the validity and reliability of this final test. The SPSS statistics program was used to calculate the correlations and factor analyses for the three pilot tests. The results are discussed in the Results section below.

**Final Test Items**

Through the pilot tests, we developed the final test items for measuring cognitive conflict. The final items are presented in Tables 4 and 5. All items were on a 5-point Likert scale (0 = “not at all true,” 4 = “very true”). Table 4 shows the 12 test items of the cognitive conflict levels test. We refer to this test instrument as the Cognitive Conflict Levels test (CCLT).

In addition to the CCLT, we developed test items to measure students’ confidence in their preconceptions and their belief in the genuineness of the demonstration after they had watched it. Table 5 shows these test items.

**Test Procedures**

Before we started the pilot tests, we devised a test procedure to measure the levels of students’ cognitive conflict in learning science (Table 6). First, we distributed a packet of three tests and asked the students to complete the test of students’ preconceptions and the strength of their belief in them (Test I) without discussing their answers with other students. We asked the students not to go on to the next page after finishing Test I. After a brief introduction, we presented a demonstration to the students. The students were asked to complete both Test II and the CCLT after the demonstration. In these procedures, we tested the students’ belief in the genuineness of the
demonstration result (Test II) and their cognitive conflict levels (CCLT). It took the participants about 20 minutes to finish the entire test procedure.

**Demonstrations**

For the demonstration, two different problem situations were developed: one was a pulley problem and the other was electric bulbs in parallel. These items have simple structures in terms of physics concepts and contexts (in mechanics and Electromagnetism (E & M), respectively). Previous research (Dupin & Johsua, 1987; Gunstone, 1986; Watts & Zylbersztajn, 1981) has shown that secondary school students have their own ideas about these items. Thus, we selected these items because we believed it would be easy for secondary school students to express their ideas about these items with proper confidence, regardless of their ages, and abilities.

**Problem 1 (Pulley).** There is a pulley with a tennis ball and a block of wood on each side. Figure 3 shows the apparatus. The ball is at the same level as the block. Then the block is pulled down so that it is lower than the ball and it is held at this position. The students were asked to describe the expected motion when the block is released (Gunstone, 1986; Watts & Zylbersztajn, 1981).

We demonstrated the same situation with the result immediately after the students wrote their answers to the problem.

**Table 4**

<table>
<thead>
<tr>
<th>Measurement Components</th>
<th>Test Items</th>
</tr>
</thead>
</table>
| Recognition of contradiction | 1. When I saw the result, I had doubts about the reasons.  
2. When I saw the result, I was surprised by it.  
3. The difference between the result and my expectation made me feel strange. |
| Interest | 4. The result of the demonstration is interesting.  
5. Since I saw the result, I have been curious about it.  
6. The result of the demonstration attracts my attention. |
| Anxiety | 7. The result of the demonstration confuses me.  
8. Since I cannot solve the problem, I am uncomfortable.  
9. Since I cannot understand the reason for the result, I feel depressed. |
| Cognitive reappraisal of situation | 10. I would like to ascertain further whether my idea is incorrect.  
11. I need to think about the reason for the result a little longer.  
12. I need to find a proper base for explaining the result. |

**Table 5**

<table>
<thead>
<tr>
<th>Measurement Components</th>
<th>Test Items</th>
</tr>
</thead>
</table>
| Test I (belief in preconception) | 1. I observed the picture carefully and understood the sentence.  
2. I think my choice is right.  
3. I have a reason for my choice. |
| Test II (belief in genuineness of demonstration result) | 1. I observed the demonstration carefully.  
2. The equipment used for the demonstration has defects.  
3. If I do the demonstration again, I will get the same results. |
Problem 2 (Electric Bulbs in Parallel). Figure 4 shows two circuits of electric bulbs in parallel. There are two electric bulbs lit up in parallel in the left figure. In the right figure, the switch is turned off so that only one bulb is lit up. The problem is to ask students to predict which bulb (A or B) will be brighter after the switch is turned off in the right figure (Dupin & Johsua, 1987).

We used electric bulbs (30 W, 220 V) and a Styrofoam board (60 × 70 cm) for the demonstration.

Results

Validity of the Instrument

Content validity was assessed by 6 experts (2 professors and 4 graduate students). They used a 5-stage Likert scale to judge the validity of each item. Content validity coefficients among the experts ranged from .85 to .97, and the mean value was .93.

Correlations among the answers for the subtest items and the total of the answers were analyzed and interpreted based on guidelines for interpretation of the strength of the correlation coefficients (Ravid, 1994, p. 134). Table 7 reports the correlation result for the pulley problem situation. The correlation between the subtest items and the total score varied from .54 to .79, indicating a moderate to moderately high degree of association. Also, there was a considerably stronger correlation among subtest items in the same construct than between those subtests items and subtest items of other constructs. The correlation among the subtest items in the same construct varied from .47 to .83. Thus, we can see that the 12 subtest items represent four different constructs of cognitive conflict.

In the correlation result for the electric bulbs in parallel, the correlation between the subtest items and the total score varied from .54 to .76, indicating a moderate to moderately high degree of

![Figure 3. Pulley problem.](image-url)
association. The correlation among subtest items in the same construct was a moderately stronger correlation, varying from .40 to .79, compared with the correlation between the subtest items of other constructs.

Thus, from the two correlation results applied to two problem situations, we found that the 12 subtest items represented four constructs of cognitive conflict.

**Factor Analysis**

The scores of the 12 subtest items in the CCLT were subjected to a factor analysis, commencing with analysis of the principal components and extent of communality, and then to computation of a rotated factor matrix by assigning four factors. Table 8 shows the results of the factor analysis of the CCLT in the pulley problem situation. The analysis found that 3 subtests of interest were loaded on the first factor, 3 subtests of recognition on the second factor, 3 subtests of reappraisal on the third factor, and 3 subtests of anxiety on the fourth factor. These four factors completely coincided with the four measurement components proposed as the constructs of cognitive conflict and explained 77.73% of the total variance. A comparatively high degree of association, ranging from .63 to .86, was indicated. On the other hand, the degree of association between each subtest in other components ranged from −.04 to .44.

In the other situation (electric bulbs in parallel), the 12 subtests in the CCLT were subjected to a factor analysis again, commencing with analysis of the principal components and extent of communality, and then computation of a rotated factor matrix by assigning four factors. The results of this factor analysis in the electric bulb in parallel problem were similar to these in Table 8. The outcome was that 3 interest subtests were loaded on the first factor, the second factor included the 3 reappraisal subtests, the third factor included the 3 anxiety subtests, and the fourth factor included the 3 recognition subtests. These four factors completely coincided with the four measurement components that were presupposed to be the constructs of cognitive conflict. Similar to the results in the pulley situation, these results explained 72.31% of the total variance, indicating a comparatively high degree of association (ranging from .62 to .87). On the other hand, the degree of association between each subtest in other components ranged from −.04 to .48.

**Reliability of the Instrument**

Reliability of the cognitive conflict test items of the CCLT was assessed by calculating the internal consistency values using Cronbach alpha. Table 9 shows the values determined for each subtest as well as for the total test.

When we consider that in exploratory research a modest reliability of .50 to .60 is acceptable (Ravid, 1994, p. 252), the final instrument showed moderate reliability in the subtest (Cronbach α: .69 ~ .87) and in the total test (Cronbach α: .86 ~ .91).
<table>
<thead>
<tr>
<th></th>
<th>An1</th>
<th>An2</th>
<th>An3</th>
<th>Real</th>
<th>Rea1</th>
<th>Rea2</th>
<th>Rea3</th>
<th>Re1</th>
<th>Re2</th>
<th>Re3</th>
<th>In1</th>
<th>In2</th>
<th>In3</th>
</tr>
</thead>
<tbody>
<tr>
<td>An1</td>
<td>—</td>
<td>.48**</td>
<td>.47**</td>
<td>.31**</td>
<td>.25**</td>
<td>.29**</td>
<td>.25**</td>
<td>.29**</td>
<td>.37**</td>
<td>.13*</td>
<td>.24**</td>
<td>.28**</td>
<td></td>
</tr>
<tr>
<td>An2</td>
<td>—</td>
<td>—</td>
<td>.60**</td>
<td>.45**</td>
<td>.40**</td>
<td>.39**</td>
<td>.41**</td>
<td>.32**</td>
<td>.46**</td>
<td>.19**</td>
<td>.33**</td>
<td>.36**</td>
<td></td>
</tr>
<tr>
<td>An3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>.53**</td>
<td>.49**</td>
<td>.45**</td>
<td>.53**</td>
<td>.45**</td>
<td>.54**</td>
<td>.27**</td>
<td>.54**</td>
<td>.51**</td>
<td></td>
</tr>
<tr>
<td>Rea1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>.64**</td>
<td>.57**</td>
<td>.53**</td>
<td>.48**</td>
<td>.47*</td>
<td>.42**</td>
<td>.45**</td>
<td>.47**</td>
<td></td>
</tr>
<tr>
<td>Rea2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>.77**</td>
<td></td>
<td>.47**</td>
<td>.41**</td>
<td>.41**</td>
<td>.44**</td>
<td>.59**</td>
<td>.62**</td>
<td></td>
</tr>
<tr>
<td>Rea3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>.42**</td>
<td>.31**</td>
<td>.29**</td>
<td>.44**</td>
<td>.44**</td>
<td>.55**</td>
<td>.59**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Re1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>.76**</td>
<td>.58**</td>
<td></td>
<td>.44**</td>
<td>.51**</td>
<td>.53**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Re2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
<td>.60**</td>
<td></td>
<td>.55**</td>
<td>.55**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Re3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
<td>.31**</td>
<td>.45**</td>
<td>.44**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
<td>.63**</td>
<td>.62**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
<td>.83**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>.54**</td>
<td>.65**</td>
<td>.76**</td>
<td>.74**</td>
<td>.75**</td>
<td>.71**</td>
<td>.75**</td>
<td>.73**</td>
<td>.69**</td>
<td>.63**</td>
<td>.77**</td>
<td>.79**</td>
<td></td>
</tr>
</tbody>
</table>

*Note. Re = recognition, In = interest, An = anxiety, Rea = reappraisal.

*p < .05, **p < .01.*
Conclusions and Educational Implications

In this study, results indicate that the CCLT instrument is a valid and reliable instrument for measuring secondary students’ cognitive conflict in science class. After the process of development and revision of the first two pilot tests, all the items of the CCLT appeared to be functioning to discriminate among various levels of cognitive conflict. As predicted by the cognitive conflict process model, a moderate level of correlation was found in identifying the components of cognitive conflict: recognition of anomalous situation, interest, anxiety, and cognitive reappraisal of the cognitive conflict situation. Factor analysis supported the expectation that there were four factors in the CCLT and these factors completely coincided with the four components that were presupposed to be constructs of cognitive conflict. The validity of the CCLT was also supported by the results of the construct validity test by 6 experts (2 professors and 4 graduate students who were majoring in science education). The content validity coefficients among the experts ranged from .85 to .97, and the mean value was .93. The reliability coefficients of the CCLT were over .69 in the subtest items and .86 in the total test, respectively. Therefore, these results support the expectation that the CCLT is a reliable instrument for measuring students’ levels of cognitive conflict in a paper and pencil test.

Chinn and Brewer (1998) said, “When teachers attempt to use anomalous data to foster conceptual change, they may fail because students have several different ways to respond to the data other than theory change. A teacher could use the framework of alternative responses to try to

Table 8
Rotated component matrix (pulley problem)

<table>
<thead>
<tr>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest2</td>
<td>.81</td>
<td>.25</td>
<td>.28</td>
<td>.21</td>
</tr>
<tr>
<td>Interest3</td>
<td>.79</td>
<td>.24</td>
<td>.33</td>
<td>.23</td>
</tr>
<tr>
<td>Interest1</td>
<td>.79</td>
<td>.27</td>
<td>.19</td>
<td>-.04</td>
</tr>
<tr>
<td>Recognition2</td>
<td>.41</td>
<td>.81</td>
<td>.08</td>
<td>.13</td>
</tr>
<tr>
<td>Recognition1</td>
<td>.27</td>
<td>.80</td>
<td>.27</td>
<td>.14</td>
</tr>
<tr>
<td>Recognition3</td>
<td>.15</td>
<td>.72</td>
<td>.14</td>
<td>.38</td>
</tr>
<tr>
<td>Reappraisal2</td>
<td>.35</td>
<td>.19</td>
<td>.31</td>
<td>.15</td>
</tr>
<tr>
<td>Reappraisal1</td>
<td>.39</td>
<td>.02</td>
<td>.80</td>
<td>.21</td>
</tr>
<tr>
<td>Reappraisal3</td>
<td>.12</td>
<td>.44</td>
<td>.71</td>
<td>.20</td>
</tr>
<tr>
<td>Anxiety1</td>
<td>.13</td>
<td>.07</td>
<td>.02</td>
<td>.86</td>
</tr>
<tr>
<td>Anxiety2</td>
<td>.01</td>
<td>.26</td>
<td>.33</td>
<td>.72</td>
</tr>
<tr>
<td>Anxiety3</td>
<td>.21</td>
<td>.38</td>
<td>.34</td>
<td>.63</td>
</tr>
</tbody>
</table>

Extraction method: Principal component analysis
Rotation method: Varimax with Kaiser normalization

Table 9
Reliability of the instrument (CCLT)

<table>
<thead>
<tr>
<th>Test Item Problems</th>
<th>Recognition</th>
<th>Interest</th>
<th>Anxiety</th>
<th>Reappraisal</th>
<th>Total Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulley (Cronbach α)</td>
<td>.85</td>
<td>.87</td>
<td>.76</td>
<td>.85</td>
<td>.91</td>
</tr>
<tr>
<td>Electric bulbs in parallel (Cronbach α)</td>
<td>.69</td>
<td>.86</td>
<td>.75</td>
<td>.78</td>
<td>.86</td>
</tr>
</tbody>
</table>
anticipate how students might react to anomalous data” (p. 649). Moreover, it will be helpful for a teacher to understand how students experience anomalous data, how students feel when they experience cognitive conflict, and how those experiences are related to their final responses, which Chinn and Brewer identified as taxonomy. The cognitive conflict process model provides a theoretical explanation of the whole process, from confronting anomalous data to a final response to the data through decision making. With an understanding of this model, by using the CCLT, a teacher can interpret his or her students’ cognitive conflict and be able to make conceptual change more likely.

Like the taxonomy of students’ responses, the results of the CCLT or even particular items of it can provide a resource for classroom discussion about how to interpret anomalous data, how to recognize and manage cognitive conflict, and so forth. This could help students develop a deeper understanding of their learning in science.

We address a number of issues for future research. First, it is important to help students have meaningful learning experiences. Cognitive conflict is a frequent experience of students in their learning inside and outside of class. However, as discussed previously, cognitive conflict has both constructive (meaningful) and destructive potential. Thus, research about the relations between cognitive conflict and the variables that might affect cognitive conflict is significantly needed. We can use the CCLT to understand how to induce meaningful cognitive conflict. Recently, Limón (2001) found that the successful application of cognitive conflict strategy is closely related to the complexity of variables intervening in the context of school learning. Moreover, Limón (2001) introduced a number of variables that might contribute to meaningful cognitive conflict (Table 1). By using the CCLT, we can investigate the relation between cognitive conflict and these variables.

Second, even though there is a limitation to this study (i.e., the instrument was developed and applied using demonstrations of pulley and electric bulb situations from the physics area), the CCLT is composed of general statement-type items, content-free, that can be applied to measure students’ cognitive conflict in any situation, e.g., verbal, imaginary, or hands-on activities in different subject classrooms. Thus, we can use the CCLT to understand students’ cognitive conflict in different educational settings and contexts (lecture, small-group discussion, lab in science, math or history classes, etc.). Recently, some researchers used the CCLT to measure the cognitive conflict levels of Korean students who were confronted with anomalous explanations in reading a science text [Yoo (2000), with 788 middle school students; Kim (2000), with 670 high school students].

Third, establishing the validity of an instrument is an ongoing process. It is incorrect to speak of validity as ever being established in the once-and-for-all sense of the word (Abd-El-Khalick, Lederman, Bell, & Schwartz, 2001). Thus, there is a need for further research focused on validating and refining the CCLT through application of the CCLT to diverse areas.

Finally, we hope that the CCLT can be used in research and practice to measure the levels of students’ cognitive conflict more precisely, and we anticipate that it will contribute to the recent debate about the educational effects of cognitive conflict.

The authors thank Dr. David Treagust and Dr. Michael E. Beeth for their comments on earlier version of this article. They want to express sincere appreciation to the anonymous reviewers for their extremely valuable feedback. This research was supported by a grant from the Brain of Korea 21 Project (Korean Ministry of Education).

References

conceptions of nature of science. Paper presented at the 2001 AETS annual meeting, Costa Mesa, CA.


