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Cognitive conflict and situational interest as factors influencing conceptual change

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In this study, we investigated the relationships among cognitive conflict and situational interest induced by a discrepant event, attention and effort allocated to learning, and conceptual change in learning the concept of density. Subjects were 183 seventh graders from six middle schools in Seoul, Korea. A preconception test, a test of responses to a discrepant event, and a questionnaire of situational interest were administered as pretests. Computer-assisted instruction was then provided to the students as a conceptual change intervention. Questionnaires regarding attention and effort, and a conception test were administered as posttests. The conception test was administered once more as a retention test four weeks later. The results of path analysis indicated that both cognitive conflict and situational interest induced by a discrepant event respectively had an indirect effect on students' conceptual understanding, which were mediated by attention and effort allocated to concept learning. Situational interest, however, was found to exert a stronger influence on conceptual change than cognitive conflict. It was also found that attention, either directly or indirectly through effort, influenced students' conceptual understanding.

Keywords: attention, cognitive conflict, conceptual change, discrepant event, effort, situational interest

Introduction

Over the immediate past decades, conceptual change has become one of the most crucial domains of research in science education. The conceptual change model suggested by Posner, Strike, Hewson, and Gertzog (1982) may be the most influential theory of conceptual change that has continued to be widely cited and has served as a theoretical framework for numerous studies. The model describes learning as an interaction between new and existing conceptions and suggests the four conditions (dissatisfaction, intelligibility, plausibility, and fruitfulness) necessary for conceptual change. Many studies on conceptual change have focused on specifically designed strategies employing a cognitive conflict approach on the basis of the model. A cognitive conflict strategy emphasises destabilising students' confidence in their existing conceptions through contradictory experiences such as discrepant events and then enabling students to replace their inaccurate preconceptions with scientifically accepted conceptions (Chan, Burtis, & Bereiter, 1997; Limón, 2001; Pintrich, 1999). Contradictory information has been usually presented through texts, hands-on activities, experiments, simulations, and/or the opposing views of peers during group discussion. Although the cognitive conflict strategy, accompanied by discrepant

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events, has been one of the most frequently investigated strategies and frequently yielded positive effects (Guzzetti, Snyder, Glass, & Gamas, 1993), some researchers have raised questions about the effect of discrepant events. It has been reported that merely presenting discrepant events to students does not consistently lead to cognitive conflict (Chan et al., 1997; Chinn & Brewer, 1998; Lin, 2007; Mason, 2001; Shepardson & Moje, 1999; Tirosh, Stavy, & Cohen, 1998; Tsai, 2000). Furthermore, it has been argued that cognitive conflict strategies do not necessarily induce conceptual change (Dekkers & Thijs, 1998; Elizabeth & Galloway, 1996; Limón, 2001; Sinatra & Pintrich, 2003; Strike & Posner, 1992; Vosniadou, 1999). Kang, Scharmann, and Noh (2004), for example, reported that when presented with a discrepant event about density, many Korean seventh graders denied its validity, interpreted it differently within the frameworks of their existing conceptions, or considered it as irrelevant to their existing conceptions, consistent with the results of Chinn and Brewer (1998). The correlation between cognitive conflict and conceptual change was also found to be rather weak, and the explanatory power (R^2) less than 6% (Kang, Scharmann, Noh, & Koh, 2005). These results indicate that cognitive conflict alone might not be as powerful in promoting conceptual change as might be expected.

The traditional model of conceptual change tended to focus on cognitive aspects in learning (Duit & Treagust, 2003; Sinatra, 2005). However, Pintrich, Marx, and Boyle (1993) suggested that motivational constructs should be the potential mediators of the conceptual change process. Sinatra and Pintrich (2003) also argued that conceptual change depends on not only cognitive factors such as the recognition of conflict, but also affective, metacognitive, and/or motivational factors. The non-cognitive constructs discussed in the literature include interest, discomfort, attention, metacognition, effort, self-efficacy, epistemological beliefs, goal orientation, and so on. Even though the results may be influenced by various contexts such as tasks, ages of subjects, and teaching strategies, these studies suggested that the students of higher interest, higher discomfort, higher self-efficacy, more sophisticated epistemological beliefs, and more deliberate goal orientation toward learning and understanding be more likely to engage in concept learning actively and positively and change their preconceptions. However, many of these suggestions tend to be based on qualitative studies, not to be based on empirical results, and/or not to consider various variables comprehensively (e.g., Pintrich & Sinatra, 2003; Sinatra, 2005). In addition, few studies have empirically investigated the effect and role of discrepant events in cognitive and non-cognitive aspects together (Kang et al., 2004; Kang et al., 2005; Pintrich & Sinatra, 2003). Therefore, quantitative studies on a conceptual change process are needed to generalise some suggestions.

For the purpose of studying the conceptual change process induced by a discrepant event, there is a need to focus on the constructs related to students' more immediate and specific learning processes (e.g., interest, discomfort, attention, metacognition, and effort) rather than those related to their more general individual characteristics (e.g., self-efficacy, epistemological beliefs, and goal orientation). Among the constructs concerning students' learning processes, metacognition, which means 'awareness of one's thinking, active monitoring of cognitive processes, regulation of cognitive processes, and application of heuristics to organise problem solving' (Hennessey, 2003, p. 107), is not suitable for young students because it is relatively late-developed, often not developed until adolescence. It is also difficult to propose causal relations between metacognition and the other variables, because it includes not just the control and regulation of cognition but also those of motivation, affect, and beliefs, and, therefore influences the total processes of conceptual change (Pintrich & Sinatra, 2003). In addition, studies discussing the influence of discomfort upon conceptual change have not been much reported, but also most of them are descriptive.

Interest seems to be a potential factor that is directly related to the use of discrepant events, because some aspects of interest are expected to be triggered when students experience contradictory information and their existing conceptions are challenged (Ainley, 2006; Hidi, 2001; Lee et al., 2003). Since the psychological state of interest is 'characterized by focused attention, increased cognitive and affective functioning, and persistent effort' (Ainley, Hidi, & Berndorff, 2002, p. 545), attention and effort may be also potential mediators to conceptual change. In this study investigating the conceptual change process in learning the concept of density (induced by a discrepant event), therefore, we focused on not only cognitive conflict but also three non-cognitive variables: situational interest, attention, and effort. Each of these variables has been suggested as important in conceptual change, and is reviewed below.

Situational Interest

Although interest is generally described as an interactive relation between the individual and certain aspects of one's environments (Krapp, 1999), researchers have conceptualised it in various ways. Many researchers have distinguished individual interest from situational interest (Ainley, 2006; Hidi, 2000, 2001; Schraw & Lehman, 2001). Individual interest is characterized by an intrinsic desire to understand a particular topic that persists over time, whereas situational interest is assumed to be transitory, environmentally activated, and context-specific. Situational interest is changeable and can be partially controlled by teachers through task design and teaching strategies, and can often precede and promote the development of individual interest. Therefore, situational interest has been considered to possess a stronger potential in enhancing learning than individual interest (Bergin, 1995; Hidi & Anderson, 1992; Schraw, Flowerday, & Lehman, 2001). Previous studies (Ainley, 2006; Hidi, 2001; Hidi & Harackiewicz, 2000; Schraw & Lehman, 2001) have reported that higher situational interest was related to enhanced learning. Situational interest, for example, influenced students' engagement with the learning task and/or willingness to persist at the task (e.g., attention, effort, and persistence) and their acquisition of knowledge (Ainley et al., 2002; Krapp, 1999; Nieswandt, 2007; Schraw, 1997; Schraw, Bruning, & Svoboda, 1995).

Interest also plays an important role in conceptual change (Hynd, 2003; Hynd, Holschuh, & Nist, 2000; Lee et al., 2003; Mason & Boscolo, 2004; Pintrich, 1999). Recently, Andre and Windschitl (2003) reported that individual interest, directly or through prior experience and knowledge in subject matter, influenced conceptual change. However, an empirical study on the effect of situational interest upon conceptual change was not conducted in their study. Situational interest was, nonetheless, suggested as a factor for further study. It was also reported that students showed more curiosity or interest when they encountered an inconsistent experience because it was novel or unexpected (Frick, 1992; Yarlas & Gelman, 1998). In this regard, Lee et al. (2003) considered situational interest stimulated by a discrepant event as a construct of cognitive conflict in developing an instrument for measuring cognitive conflict. Their rationale was based on the finding that Korean high school students were interested in discrepant events from problems associated with the use of a pulley and the workings of electric bulbs, which caused the students to doubt, to be surprised, or to think the results strange. Therefore, situational interest might be considered as a plausible construct that would be stimulated by discrepant events and a potential mediator that would influence conceptual change.

Attention

Learning may be positively related to the attention which students pay to a learning task. Previous studies (Ainley et al., 2002; Anderson, 1982) have reported that students achieved better when they allocated more attention to learning tasks or materials. A positive influence of attention on learning is reflected not only by longer attention duration but also by higher intensity and more cognitive effort (Hidi, 1995). Limón (2003) also suggested that students should focus their attention on learning tasks in order to facilitate their conceptual change. Attending to a task which is inconsistent with one's existing explanation should promote a volitional act such as checking one's existing conception and recognising what needs to be changed. In addition, attention has been reported to be stimulated when students experience cognitive conflict (Keller, 1987a; Lee, 2000) and situational interest (Hidi, 2001; Hidi & Harackiewicz, 2000; Schraw & Lehman, 2001). Therefore, it is reasonable to consider attention as a factor that might influence conceptual change.

Effort

Another aspect that might be important in effective conceptual change is effort. Effort invested in a learning task has been found to be an essential component for students' academic success. According to Weiner's attribution theory (Weiner, 1980), the students who ascribe effort as the cause of academic success or failure, are likely to expend more persistence and effort during learning, and thus attain higher achievement. For example, cross-cultural studies revealed that the students of East Asia such as China, Japan, and Taiwan, tended to place more emphasis on effort as the most important factor of their academic performance than did US students, thus resulting in higher academic achievement (Chen & Stevenson, 1995; Evans, Schweingruber, & Stevenson, 2002; Hess & Azuma, 1991). Some researchers (Bloom, 1976; Carroll, 1985; Fisher, 1996) also suggested that academic achievement in a specific domain is a direct function of time on task or active learning time. Positive influences of effort and/or learning time on academic achievement have been reported in mathematics (Huang & O'Neil, 1997; Malpass, O'Neil, & Hocevar, 1999; Singh, Granville, & Dika, 2002; Wang, 1997), statistics (Awang-Hashim, O'Neil, & Hocevar, 2002), and science (Singh et al., 2002).

Conceptual change requires students to make considerable and deliberate efforts and to be highly engaged in the task (Sinatra & Pintrich, 2003). Although the amount of effort students invest is expected to be greater in the discrepant event provided and the task that immediately follows due to its novelty, complexity or unexpectedness (Salomon, 1983), cognitive conflict and deep engagement are often found to be insufficient to induce conceptual change. A strong restructuring of individual conception is indeed a difficult task to accomplish for secondary school students. In this regard, Limón (2003) explicitly described three prerequisites for conceptual change; 'awareness of the need to change and identify what needs to be changed, willingness to change, and the ability to self-regulate the change process' (p. 165, parentheses removed by present authors). The restructuring process is internal to students and under volitional control, which also characterizes the attribute of effort according to Weiner's attribution theory (Weiner, 1980). In fact, state effort, when allocated to concept learning, was reported to be the only significant predictor on students' conceptual change when examining the relationships among self-regulation strategies (planning, self-monitoring, cognitive strategy, and effort), the degree of cognitive conflict, and conceptual change in learning density (Kang, Shin, & Noh, 2002). In addition, effort may be related to the other variables used in this study. According to Keller's theory of motivation, performance, and instructional influence (Keller, 1979), effort is likely to be influenced by attention as one element of motivation. Interest was also reported to influence students' emotional engagement and engagement in deeper processing (Schraw, 1998).

In summary, non-cognitive factors such as situational interest induced by a discrepant event, and attention and effort allocated to concept learning might be related to the process of conceptual change. However, few studies have been conducted which investigate the path models of conceptual change including these non-cognitive variables. As a result, the mechanism by which non-cognitive variables influence conceptual change using a discrepant event is not well known. In this study, therefore, we sought to propose a causal model of cognitive conflict and situational interest induced by a discrepant event, and attention and effort allocated to concept learning, in relation to students' conceptual understanding and the retention of the conception. Based on relevant previous literature, we constructed a compelling theoretical model in which cognitive conflict and/or situational interest induced by a discrepant event are likely to influence conceptual understanding and the retention of the conception directly as well as indirectly through attention and effort allocated to concept learning. Our model thus deals with the relative contribution of cognitive and non-cognitive variables related to conceptual change process. Figure 1 illustrates the elements of the theoretical path model and the potential subsequent hypothetical relationships. Our model consists of a left to right-flowing diagram. The connection with curved double-headed arrow represents a correlation, while that with single-headed arrow proposes a hypothesized causal relationship. For example, four arrows from CC in Figure 1 represent that cognitive conflict is hypothesised to influence the variables AT, EF, CU, and RC, [as stated in hypotheses (2) and (4)].

(1) Cognitive conflict induced by a discrepant event is positively related to situational interest stimulated by the discrepant event.

(2) Cognitive conflict directly influences conceptual understanding and the retention of the conception.

(3) Situational interest directly influences conceptual understanding and the retention of the conception.

(4) Attention and effort mediate the relationship between cognitive conflict and conceptual understanding and/or the retention of the conception.

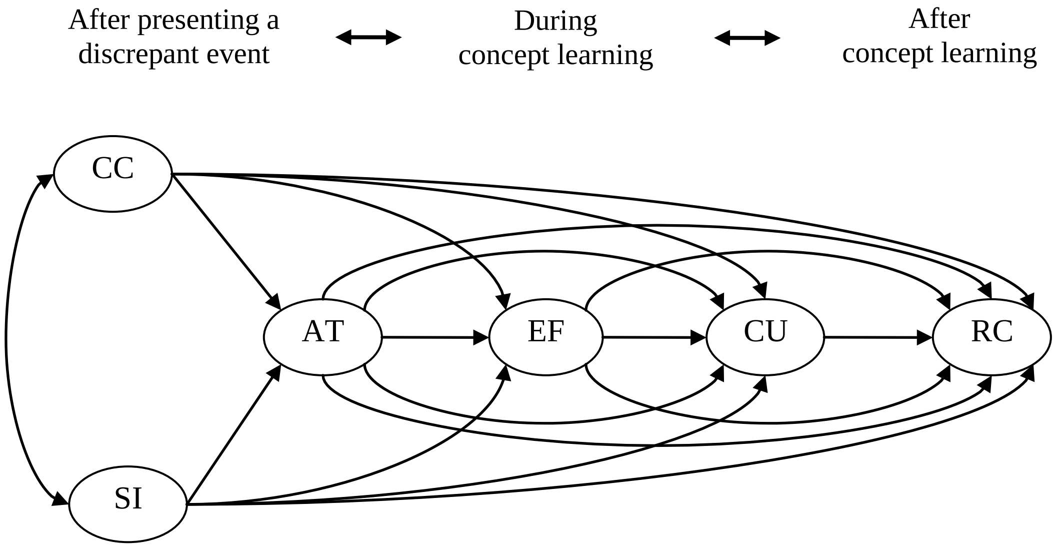
(5) Attention and effort mediate the relationship between situational interest and conceptual understanding and/or the retention of the conception.

(6) Effort also mediates the relationship between attention and conceptual understanding and/or the retention of the conception.

Research Methods

Participants

This study was carried out with 483 seventh graders in Korea. Since only the subjects who possessed the target misconception were included in the analyses, we could not control the variables such as students' gender, achievement, and so on. The randomness of sampling in this study, however, may not be so critical compared to other studies testing causal models. Nevertheless, we tried to get as typical a sample as possible. All participants were selected from six public middle schools in Seoul, a metropolitan city in Korea. The schools are located in middle-class suburban communities, and their achievements are perceived to be near average in Seoul. Two to ten classes from the schools were randomly selected. All the schools possessed a multimedia centre equipped with enough personal computers to conduct this study. According to the seventh National Science Curriculum of Korea, the concept of density should be taught at eighth grade. Therefore, none of the students had been formally taught the concept.



CC = cognitive conflict, SI = situational interest, AT = attention, EF = effort, CU = conceptual understanding, RC = retention of the conception.

Figure 1. Hypothetical path model predicting the influences of cognitive conflict, situational interest, attention, and effort on conceptual understanding and the retention of the conception

Procedures

In order to identify students in possession of a target misconception, a preconception test was administered. The test of responses to a discrepant event (TRDE) for examining their cognitive reactions to a discrepant event was then conducted. The target misconception was an undifferentiated weight-density concept (Smith, Carey, & Wiser 1985), in which students unite components from the concepts of weight and density. The undifferentiated concept was selected, because it is one of the most prevailing misconceptions among middle school students (Noh, Kang, Kim, Chae, & Noh, 1997; Smith et al., 1985). Appropriate conceptual change instruction was also reported to lead students to understand the density concept with observable discrepant events (e.g., Noh et al., 1997; Smith, Snir, & Grosslight, 1992).

After students had completed the TRDE, situational interest from their experiences with the discrepant event was measured. The students were then assigned to work individually on a CAI programme as a conceptual change intervention, in order to exclude the possibility of interpersonal interactions (Kang et al., 2004). The CAI programme concerning density was devised to correspond to the concept introduction and application stages of constructivist learning models, while the administration of the TRDE played the role of the exploration stage. At the CAI program, students were first presented with an animation showing that weight is not a criterion for solving a “sink or float” problem. The density, which is defined as the mass per unit volume, was then introduced as an alternative criterion. Students were provided with another animation showing the procedure for obtaining densities of both wood and iron and presenting the usefulness of density as the criterion for sink or float predictions. All explanations were only at a macroscopic level in order to understand the distinction between weight and density. At the end of the CAI program, students were provided with some application problems and received feedback when necessary. At the CAI program, a virtual teacher provided students with all the contents and materials. However, the teachers who helped this study only managed the classrooms during their individual learning with the CAI programme. The administration of both the TRDE and the CAI corresponds to one class period of normal instruction in terms of the activities and content. Although it may be too short, most science textbooks under the seventh National Science Curriculum of Korea cover the basic aspects of the density concept in one class period. A previous study also reported that a conceptual change instruction of one class period was reasonably successful at least in learning the basic density concept (Noh et al., 1997).

Students' conception(s) and the degrees of attention and effort allocated during learning were measured one day after the instructional protocol. Finally, a delayed conception test was administered four weeks later.

From an original pool of 483, the subjects included in the analyses were 183 students (101 boys and 82 girls). First, 287 students were excluded because they did not possess the target misconception (as assessed by the preconception test). Another 10 students were eliminated because they gave a 'disagree' response with the initial explanation in the TRDE. Finally, three students were ineligible because they did not complete all the tests.

Instruments

Preconception test

A preconception test was administered to exclude students who did not possess the target misconception. In this test regarding a 'sink or float' problem (Kang et al., 2004), students were asked to answer a question and to explain reasons for their answers. The question was as follows: When two balls of the same size were dropped into the water, a small black ball weighing 100 g floated whereas a small gray ball weighing 500 g sank. Here is a 1,000 g large black ball made of same material as the small black ball. Does it sink or float when it is dropped into the water?

Test of responses to a discrepant event

The TRDE was used to examine students' cognitive responses to a discrepant event. The TRDE consists of three phases; initial explanation, discrepant event, and students' rating (Kang et al., 2004). In the initial explanation phase, students read a text passage in which a man, on the basis of the target misconception, predicts the result of the 'sink or float' problem that was in the preconception test. Immediately after students had read it, they were asked to write whether they believed this initial explanation or not, for a check of initial belief. After that, students read another text passage concerning the result (i.e. a discrepant event) of an experiment that contradicted the initial explanation but was consistent with an accurate scientific one. Students evaluated both the initial explanation and the discrepant event in the rating phase. First, students rated the believability of the discrepant event on a scale of 1 (believe) to 3 (do not believe). Second, students rated the extent of consistency between the initial explanation and the discrepant event on a scale of 1 (consistent) to 3 (inconsistent). Finally, students reported whether their beliefs had changed after having experienced the discrepant event. Students were also asked to explain their reasons for each rating.

Questionnaires of non-cognitive variables

A few instruments to measure situational interest have been developed (e.g., Chen, Darst, & Pangrazi, 2001; Gungor, Eryilmaz, & Fakioglu, 2007; Nieswandt, 2007). However, these may not be suitable for this study to measure students' situational interest induced by a particular situation such as a discrepant event, because they tend to measure interest in a specific topic and/or subject for rather a long term period. Items deemed unsuitable were statements such as 'I actually look forward to going to [my] physics course this semester.' (Gungor et al., 2007), and 'My chemistry class is the most important thing [to] me.' (Nieswandt, 2007). In addition, some questionnaires had low reliability and validity because they consisted of too few items (Chen et al., 2001; Gungor et al., 2007; Mason & Boscolo, 2004). In general, however, curiosity has been studied as a method to measure an interest in many situations including learning (Buckley, Hasen, & Ainley, 2004), and some researchers (e.g., Ainley et al., 2002; Litman & Jimerson, 2004) have indeed used the measurements of curiosity as a feeling of interest in learning. Therefore, we selected the Melbourne Curiosity Inventory (MCI; Naylor, 1981) as an assessment tool to measure interest. The MCI was validated through a factor analysis. It consists of two forms—the C-Trait form and the C-State form. The C-Trait refers to individual differences in the capacity to experience curiosity, while the C-State refers to individual differences in response to a particular curiosity arousing situation (i.e. a discrepant event in this study). Therefore, we used the C-State form of the MCI to measure students' situational interest stimulated by the discrepant event, which has twenty items written to conform to a five-point Likert scale. Naylor (1981) reported that the internal consistency reliability coefficients of the C-State form of the MCI ranged from 0.87 to 0.92. We slightly modified the wording of all items by adding the term 'experiment' or 'experimental results' to each of them. Two examples of the items are as follows: I feel interested in the experiment, and I feel puzzled by reading the results of the experiment. The internal consistency reliability coefficient was 0.93 for the scores obtained in this study.

In order to identify students' level of attention paid to a learning task (i.e. the CAI programme in this study), the attention subscale of the Instructional Materials Motivation Survey (IMMS; Keller, 1993) was used. The IMMS was originally designed to be a situational measure of students' motivational reactions to instructional materials in accordance with Keller's ARCS model of learning motivation (Keller, 1987a, b). It consists of four subscales; attention, relevance, confidence, and satisfaction. The attention subscale consisting of twelve items asked students to respond to the questions regarding how they allocate their attention to a learning task (i.e. the CAI programme in this study), ranging from 1 (strongly disagree) to 5 (strongly agree). In order to measure students' attention paid to learning with the CAI programme, we slightly modified the wording of all items by adding the term 'in learning with the CAI programme'. Keller (1993) reported the internal consistency reliability coefficient of the attention subscale to be 0.89. A Cronbach's coefficient of 0.90 was obtained in this study.

The level of effort that students invested in a learning task was measured by a questionnaire of effort, which was adapted from the state effort scale developed by Malpass (1994). It was reported that all six items on a five-point Likert scale were loaded on the same factor in a confirmatory factor analysis and the Cronbach's alpha reliability coefficients were over 0.76 (Malpass et al., 1999; Wang, 1997). Effort in this scale means the extent to which students work hard on a task, and the state effort scale asks students to respond to the questions regarding how they invest their effort in solving problems included in an exam or test. In order to measure students' effort invested in learning with the CAI programme, we modified the wording of all items by replacing the term 'exam' or 'test' with 'learning with the CAI programme'. The Cronbach's alpha reliability coefficient was obtained to be 0.87.

Three independent science educators fluent in English validated the translation of the items of the three questionnaires from English into Korean. Furthermore, we interviewed several students after pilot tests to verify whether students understood the meanings of items correctly. A few minor problems were detected in responses from students and the inappropriate wordings of items were revised with the help of middle school teachers.

Conception test

Students' conceptual change may not be always a radical process but a partial and/or stepwise one. Therefore, students' conceptual change in this study was examined by the conception test used in a previous study in which each item measures the degree of conceptual change on a three-point scale (Kang et al., 2004). It consists of four items, each of which is written in a multiple choice format with an accompanying open-ended section to collect information about students' rationales for their choices. An example of the items is as follows: When a small candle was dropped into the water, it floated. Does a big and large candle sink or float if it were dropped into the water? (a picture of the situation) a. It floats. b. It sinks. c. It neither floats nor sinks. It stays in the middle of water. d. I don't know because the information is not enough. Explain your reason for the choice in detail.

Two raters independently scored a subset of randomly selected students' answers on a three-point scale: no and irrelevant responses, 0; partial understanding, 1; and sound understanding, 2. Discrepancies between the raters were then discussed and resolved. After above 95% intercoder agreement was obtained, one rater scored all the answers and the other independently checked the scoring. Cronbach's internal consistency reliability coefficient for the conception and delayed conception tests in this study were 0.79 and 0.65, respectively.

Scoring of cognitive conflict

Because students' cognitive conflict induced by a discrepant event can be at various levels, the degree of cognitive conflict in this study was scored on a four-point scale developed in a previous study (Kang et al., 2004) to quantify conflict from a cognitive perspective. First, students' responses in the TRDE were classified into seven types; rejection, reinterpretation, exclusion, uncertainty, peripheral belief change, belief decrease, and belief change. In classifying the students' written responses, three criteria were used: believability of a discrepant event, inconsistency between a discrepant event and students' existing conceptions, and belief change after experiencing a discrepant event. Belief change does not mean that students change their initial conceptions to scientific one(s), but that students feel dissatisfaction with their existing conceptions and completely give them up. A typical example of students' responses classified as belief change was that they gave up their initial answers because the results contradicting their existing conceptions were presented based on an experiment. Some even attempted weak restructuring to reach other wrong answers, which exhibited their willingness to change their initial conceptions in addition to giving up their initial conceptions. After 90% of the intercoder agreement was obtained, one rater classified all the responses again while the other rater independently checked the classification.

Cognitive conflict was operationalised as the degree of dissatisfaction that a student exhibits with one's existing conception after being presented with a discrepant event. Seven response types were collapsed into four levels, and the following rating scale was used in order to facilitate a manipulation of the data. Rejection, reinterpretation, and exclusion were rated as '0', to mean no provocation of change in students' beliefs in their existing conceptions. Responses classified as 'uncertainty', corresponded to no confidence in the validity of a discrepant event as well as belief in an existing conception, were rated as '1'. Peripheral belief change and belief decrease, which indicate dissatisfaction with an existing conception at least to some extent, were rated as

'2'. Belief change was rated as '3', because this means an entire dissatisfaction with the existing conception.

Path Analysis

By means of structural equation modeling (Kline, 2005) employing the AMOS 4.0 programme (Arbuckle & Wothke, 1999), we attempted to test a causal model (Figure 1). In this path analysis, we used maximum likelihood estimation after using bootstrapping to estimate robust standard errors and to evaluate different estimation methods (Efron, 1982). Cognitive conflict and situational interest were entered as exogenous variables predicting attention, effort, conceptual understanding, and the retention of the conception. Attention and effort, in turn, were used as predictors of conceptual understanding and the retention of the conception. All possible paths were included at first and then statistically non-significant ($p > 0.05$) paths were eliminated from the model.

In evaluating the fit of the model, multiple indices of fit were used by following recommendations from other researchers (Hu & Bentler, 1999; Kline, 2005). In this study, the chi-square test was complemented by the use of the Goodness-of-Fit Index (GFI), the Adjusted Goodness-of-Fit Index (AGFI), the Normed Fit Index (NFI), the Comparative Fit Index (CFI), and the Root Mean Square Error of Approximation (RMSEA). The chi-square test assesses the magnitude of the discrepancy between sample covariance matrices and fitted covariance matrices. However, there are some problems in relying solely on the chi-square test as a fit statistic. It is not only sensitive to the degree of correlation but also affected by sample size. Fit indices, therefore, were conducted to confirm the authenticity of the chi-square test result.

Fit indices have been developed to verify and enhance confidence in the results obtained from chi-square tests. Fit indices can be classified into absolute and incremental fit indices (Hu & Bentler, 1999). Absolute fit indices assess how well a researcher's model reproduces the sample covariance matrices. Absolute fit indices used in this study are the GFI, the AGFI, and the RMSEA. In contrast, incremental fit indices assess the relative improvement in the fit of a researcher's model compared with a baseline model which assumes all the observed variables are uncorrelated. Incremental fit indices used are the NFI and the CFI. The indication of good fit from various indices increases the confidence in a model because each index evaluates the fit of a model using a slightly different method (Hu & Bentler, 1995, 1999). If the result of the chi-square test is not statistically significant, a model could be considered to have a good fit. It would also be an indication of a good fit that the values of the GFI, the AGFI, the NFI, and the CFI are higher than 0.90 which is the recommended critical value. The RMSEA value of about 0.05 or less could also be considered to indicate a good fit (Browne & Cudeck, 1993). The fits for the model of this study were as follows; χ^2 (12, n = 183) = 9.00, p = 0.342, GFI = 0.984, AGFI = 0.958, NFI = 0.979, CFI = 0.998, and RMSEA = 0.026. All indices indicated a good fit to the data.

Results

Means and standard deviations for the scores of the tests and the questionnaires used in this study are summarised in Table 1. The maximum TRDE score is three. Mean score of the students who took the TRDE was 1.45 with a 1.29 standard deviation. In addition, mean score of the questionnaire of situational interest was 61.20 (a full mark, 100 points). Mean scores of the questionnaires of both attention and effort were about two-thirds of full marks. These results indicated that many Korean seventh graders participating in this study experienced some

Table 1. Means and standard deviations for the scores of the tests and the questionnaires

Instrument (maximum score possible)	Mean	SD
Test of responses to a discrepant event (3)	1.45	1.29
Questionnaire of situational interest (100)	61.20	14.82
Questionnaire of attention (60)	40.25	9.35
Questionnaire of effort (30)	20.45	4.64
Conception test (8)	4.42	2.47
Delayed conception test (8)	4.28	2.27

cognitive conflict and situational interest provoked from the use of the discrepant event, and allocated reasonable amounts of attention and effort to the concept learning through the CAI programme. Mean score (4.42) of the conception test was a little higher than that (4.28) of the delayed conception test, and both scores were above half of a full mark. The results indicated that some students understood and partly retained the conception of density.

Pearson correlation coefficients among the scores of the tests and the questionnaires are summarised in Table 2. The TRDE scores were significantly correlated with the questionnaire scores of attention and effort at the 0.01 level, whereas the questionnaire scores of situational interest were significantly correlated with the scores of the conception test and the delayed conception test as well as with the questionnaire scores of attention and effort ($p < 0.01$). The questionnaire scores of attention and effort were significantly correlated with each other as well as with the scores of the conception and delayed conception tests ($p < 0.01$). However, the

Table 2. Correlation coefficients among the scores of the tests and the questionnaires

Instrument	TRDE	SI	AT	EF	Conception test
Test of responses to a discrepant event (TRDE)	-				
Questionnaire of situational interest (SI)	0.124	-			
Questionnaire of attention (AT)	0.218**	0.666**	-		
Questionnaire of effort (EF)	0.191**	0.539**	0.734**	-	
Conception test	0.090	0.306**	0.416**	0.408**	-
Delayed conception test	0.130	0.304**	0.408**	0.356**	0.715**

** $p < 0.01$.

correlation coefficient (r = 0.124) between the TRDE scores and the questionnaire scores of situational interest was not statistically significant.

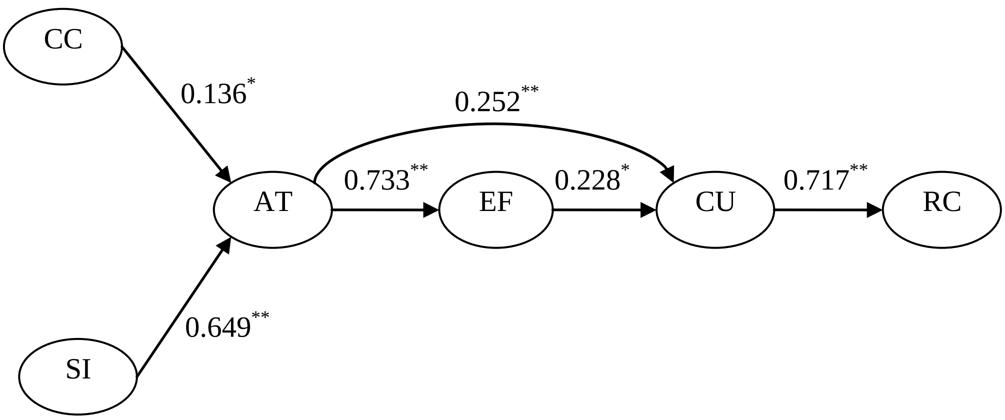
In order to further investigate the predicted relationships among the variables used in this study, we attempted to test a causal model (Figure 1) by means of structural equation modeling (Kline, 2005) employing the AMOS 4.0 programme (Arbuckle & Wothke, 1999). The results of the path analysis are summarised in Table 3 and the resulting path model is shown in Figure 2. Parameter estimates in Figure 2 indicated that both cognitive conflict and situational interest did not directly influence conceptual understanding and the retention of conception. Attention and effort were found to mediate the relationship of cognitive conflict and situational interest with conceptual understanding. However, the path coefficient ($\beta = 0.649$) between situational interest and attention was noticeably larger than that ($\beta = 0.136$) between cognitive conflict and attention. Attention had positive path coefficients on effort and conceptual understanding ($\beta = 0.733$ and $\beta = 0.252$, respectively). Effort had a positive path coefficient ($\beta = 0.228$) on conceptual understanding. Conceptual understanding was the only direct predictor of the retention of the conception ($\beta = 0.717$).

Table 3. Results of the path analysis

Variable			Standardised parameter	Bootstrap SE
Independent		Dependent		
			Path coefficient	
CC	→	AT	0.136^{*}	0.055
SI	→	AT	0.649^{**}	0.042
AT	→	EF	0.733^{**}	0.048
EF	→	CU	0.228^{*}	0.079
AT	→	CU	0.252^{**}	0.092
CU	→	RC	0.717^{**}	0.041
			Squared multiple correlation	
AT			0.467^{*}	0.053
EF			0.540^{*}	0.069
CU			0.207^{*}	0.060
RC			0.516^{*}	0.059

$^{*}p < 0.05$, $^{**}p < 0.01$

CC = cognitive conflict, SI = situational interest, AT = attention, EF = effort,
CU = conceptual understanding, RC = retention of the conception.



* $p < 0.05$, ** $p < 0.01$.

Figure 2. Resulting path model for the influences of cognitive conflict, situational interest, attention, and effort on conceptual understanding and the retention of the conception

Discussion

Although cognitive conflict has been hypothesised as a precondition for conceptual change by many science educators and cognitive developmental psychologists, the application of cognitive conflict, provoked from the use of discrepant events, does not work to the extent it is expected (Chan et al., 1997). There are still many questions about the effect of a discrepant event and the role of cognitive conflict (Baddock & Bucat, 2008). One reason for these doubts might stem from the limitation that ‘classical’ conceptual change approaches have mainly focused on cognitive factors while ignoring non-cognitive factors such as affective and motivational ones (Duit & Treagust, 2003; Sinatra, 2005). Therefore, it is important to consider the roles of non-cognitive factors inhibited in some cognitive processes and/or mediated during conceptual change (Pintrich, 1999). Although many potential constructs have been discussed in the literature, the mechanism for conceptual change is not yet understood. Moreover, most studies discussing the affective and motivational factors that may influence conceptual change are descriptive. In this study, we quantitatively investigated the roles of cognitive conflict and situational interest by testing a causal model that examines the relationship among outcome performance on a test of conceptual change, cognitive conflict, situational interest, attention, and effort.

In the present study, mean scores (4.42 and 4.28) of the conception test and the delayed conception test were a little above half of a full mark (8 points). About 18% and 13% of the students gained full marks respectively. These results indicated that some students understood and partly retained the conception of density. The ranges of both scores were 0-8, and the standard deviations were relatively high (2.47 and 2.27) to indicate wide spread scores. Mean scores near half of a full mark with relatively high standard deviations obtained in this study are suitable for quantitative analyses, although the learning task may be somewhat difficult for some students. Comparing students’ performance on each item of the conception test, the students performed better on the item (mean 1.33) asking them to compare the densities in a “sink or float” situation than those (means 1.02 and 1.21) asking them to predict whether some given materials sink or float. The item (mean .86) in which the students performed most poorly was when they were asked to compare the densities of the two parts of a broken material. These performances may be interpreted to be due to the degree of the novelty of the problems. That is, the students performed better in less novel problem compared with the content of the CAI programme.

The correlation coefficients of the TRDE scores with the scores of the conception test and delayed conception test ($r = 0.090$ and $r = 0.130$, respectively) indicating the degree of conceptual change were found to be weak and statistically non-significant (Table 2). In a previous study (Kang et al., 2005), a weak correlation ($r = 0.237$) between the TRDE scores and the conception test scores was also obtained, and cognitive conflict was not a statistically significant predictor of conceptual understanding. The results of the path analysis in this study indicated that cognitive conflict induced by a discrepant event had only an indirect effect on conceptual change (Figure 2). The path coefficient ($\beta = 0.136$) between cognitive conflict and attention was small but significant. These results indicated that the students who had experienced more cognitive conflict tended to be more attentive during concept learning, which in turn led them to exert more effort in concept learning and to achieve better conceptual understanding.

This experimental design in a short time of intervention without interpersonal interactions may permit only limited scope for conceptual change to take place as do most studies on cognitive conflict. When compared with those of situational interest, however, these results are consistent with the viewpoints that cognitive conflict does not necessarily result in conceptual change (Baddock & Bucat, 2008; Dekkers & Thijs, 1998; Elizabeth & Galloway, 1996; Kang et al., 2005; Sinatra & Pintrich, 2003; Vosniadou, 1999), and that cognitive conflict would be just one of the important factors to be considered in conceptual change rather than a necessary pre-requisite for it (Duit & Treagust, 2003; Limón, 2001; Sinatra, 2005). Cognitive conflict may activate particular kinds of cognitive activities such as knowledge building that leads to conceptual change (Chan et al., 1997). However, many students tended to patch-up local inconsistencies in a superficial way without reaching conceptual change in situations of cognitive conflict (Vosniadou, 1999). Therefore, productive cognitive processes from cognitive conflict may be most applicable to secondary students who are able to integrate their conceptions with new information. But even for those students, the dissatisfaction with one's own existing conception (operationalised as cognitive conflict in this study) would be a motivator likely to influence conceptual change (Posner et al., 1982; Sinatra, 2005).

The results of this study indicated that situational interest stimulated by a discrepant event also played an important role in conceptual change. The questionnaire scores of situational interest were correlated with the scores of the conception and delayed conception tests as well as the questionnaire scores of attention and effort (Table 2). However, situational interest was found to have only an indirect effect on conceptual change as did cognitive conflict (Figure 2). These results are consistent with the viewpoint that the interest stimulated by a learning task influences students' selective attention, effort, willingness to persist at the learning task, and achievement (Ainley, 2006; Hidi, 2001; Schraw & Lehman, 2001). It is noteworthy, however, that the path coefficient ($\beta = 0.649$) between situational interest and attention was much larger than that ($\beta = 0.136$) between cognitive conflict and attention. That is, the influence of situational interest on attention, which also indirectly influences conceptual change in our path model, was much bigger than those of cognitive conflict (although both cognitive conflict and situational interest influenced attention). This might be regarded as partial evidence for supporting an argument in which affective and motivational factors could be more crucial than cognitive ones in determining whether or not discrepant events would produce conceptual change (Duit & Treagust, 2003; Limón, 2001; Niaz, 2006; Sinatra, 2005; Sinatra & Pintrich, 2003). It is too impetuous, however, to conclude that situational interest is more important than cognitive conflict, because their relative contributions to conceptual change are likely to be influenced by various factors such as students' characteristics, domain specificity, and social context (Ainley et al., 2002; Chen &

Darst, 2002; Duit & Treagust, 2003; Kang et al., 2005; Limón, 2001; Sacco & Bucciarelli, 2008; Sinatra & Pintrich, 2003; Zohar & Aharon-Kravetsky, 2005; Zusho & Pintrich, 2003). For example, Chen and Darst (2002) found that students in lower grades, in comparison with higher grade students, tended to show more situational interest after having experienced the tasks in physical education classes, although the tendency seemed rather limited. Thus, our findings may be caused by the characteristics of the students sampled in this study. However, the large difference between the path coefficients may still suggest the importance of situational interest at least for the lower secondary school students to learn density through a cognitive conflict strategy.

In the study performed by Andre and Windschitl (2003), individual interest in a subject matter, directly as well as indirectly through prior experience, influenced conceptual change in their understanding of circuits. On the other hand, situational interest stimulated by a discrepant event in this study only indirectly through attention influenced conceptual change. Since individual interest is conceptualised as a relatively stable and enduring disposition, they explained their results by stating that 'students should engage in deeper processes of anomalous data when they have a higher degree of interest in the subject matter than when they do not.' (p. 182) based on the models of Chinn and Brewer (1993) and Dole and Sinatra (1998). Situational interest is considered to be more important in attracting students' attention, while individual interest to be more important in holding it (Schiefele, 1992; Schraw et al., 2001). This different nature of situational and individual interests may cause their influences on conceptual change to be different. However, it was suggested that situational and individual interests are not dichotomous phenomena but rather are likely to interact and affect each others' development (Hidi, 2001; Hidi & Harackiewicz, 2000). Therefore, a further study is needed to clarify the effect of both constructs on conceptual change by considering the interaction between the two.

As described earlier, students' attention and effort allocated to the learning task mediated the effects of cognitive conflict and situational interest on conceptual understanding (Figure 2). Both of the direct and indirect effects of attention on students' conceptual change were significant. The total effect of attention was 0.419, and the direct effect of effort was found to be 0.228. These results concerning the roles of students' attention and effort are consistent with those of many previous studies (e.g., Ainley et al., 2002; Singh et al., 2002). For example, Ainley et al. (2002) reported that topic interest influenced text learning through the mediation of affective response and persistence. It has been well-documented that the more students expended attention or effort in learning, the more successful learning outcomes were obtained in various subject domains including mathematics, science, and statistics (Awang-Hashim et al., 2002; Hidi & Harackiewicz, 2000; Huang & O'Neil, 1997; Malpass et al., 1999; Schraw & Lehman, 2001; Wang, 1997). The effect of effort on conceptual change has been widely described (e.g., Chinn & Brewer, 1993; Dole & Sinatra, 1998; Linnenbrink & Pintrich, 2003). Recently, Kim and Kwon (2004) reported that only the students, among the Korean college students with high levels of cognitive conflict, who attributed success outcomes to effort and described in the interviews that they actually used a self-regulated learning strategy changed their conceptions in learning the mechanics. Meanwhile, the direct effect of attention on conceptual change was significant in this study. This indicated that attention enhanced the process of conceptual change after controlling for effort. This may suggest that a longer duration of more intensive knowledge-processing promotes volitional acts such as checking students' existing conceptions, knowing what needs to be changed, and comparing their conceptions against new information (Chan et al., 1997; Limón, 2003).

Implications for Teaching

Although the relative contributions of cognitive conflict and situational interest to provoke conceptual change may be influenced by some factors such as students' characteristics, the results in this study suggested that situational interest plays a more crucial role than cognitive conflict at least for younger secondary school students, who seem to be more sensitive to situational interest. This finding of the important role of situational interest in conceptual change induced by discrepant event may not be new. However, this study provides some empirical evidences for generalisation. Therefore, we can support more convincingly that science teachers working with younger secondary school students need to pay close attention to the roles of affective and motivational aspects of discrepant events used in conceptual change instruction. When planning and conducting instruction using discrepant events, for example, teachers need to consider not only students' misconceptions but also the sources of situational interest such as novelty and challenge (Chen et al., 2001). That is, the discrepant events should have some information unknown and/or be at a moderate level of difficulty so that students arouse curiosity and continue to engage in activity (Palmer, 2005).

In addition, using a discrepant event does not guarantee students' abandoning previous beliefs and accepting an alternative conception, but facilitates only the early stage of conceptual change, that is, inducing cognitive conflict and situational interest. The influences of cognitive conflict and situational interest on conceptual understanding were also mediated through attention and effort. Therefore, teachers need to encourage students to stimulate their motivation rather than simply to provide students with incompatible experiences. It has been recently suggested that motivating, promoting, and guiding students' intentions could play an important role in leading them to conceptual change (Sinatra, 2005; Sinatra & Pintrich, 2003). In order to successfully promote conceptual change, therefore, teachers should attempt to create and maintain those instructional environments, which foster students' intention such as attention to learning tasks and efforts allocated to learning during conceptual change.

Limitations and Further Research

There are a number of limitations to this study. Due to the purpose of conducting a path analysis with situational interest and cognitive conflict during learning, the design permits only a short period of intervention. This study also requires a large number of students whose intervention is tightly controlled. Therefore, interpersonal interactions among students and teacher were excluded by using a CAI programme. On the other hand, an experienced constructivist teacher may spend more time on this topic despite the natural restrictions of the National Curriculum, and encourage additional students-to-students interactions. The teacher may also endeavour to raise interest in the details of phenomena by considering students' responses. Therefore, the intervention used in this quantitative study does not provide desirable learning conditions for the students to change their existing conceptions, and the results should be interpreted by considering the limitations.

It has been reported that East Asian students tend to attribute achievement outcomes to more effort-based learning and to less innate abilities-based or interest-based learning than those of western countries (Dahlin & Watkins, 2000; Dandy & Nettelbeck, 2000; Evans et al., 2002). Therefore, the mechanism for conceptual change proposed in this study might be modified in other cultural contexts. Moreover, it has been argued that the conceptual change process would be influenced by domain specificity such as the difference in content domain, students' characteristics, and the nature of a learning task (Pintrich & Sinatra, 2003). It was also reported that situational interest was found to vary across different learning tasks (Ainley et al., 2002; Chen et al., 2001). These research results imply that conceptual change processes are likely to be learning task-specific. In order to obtain more in-depth insights of conceptual change process, therefore, replication studies should be conducted with other ethnic groups of students and/or other learning tasks of various science topics.

We investigated the effects of only a few non-cognitive variables which were presumed to play an important role in conceptual change. First, this study only focused on situational interest among various affective and motivational components which might be stimulated by discrepant events. It has been reported that students exhibit emotional reactions such as anger, anxiety or discomfort, and tension when they are confronted by discrepant events (Hynd, 2003; Lee et al., 2003; Limón, 2003; Zimmerman & Blom, 1983). Therefore, the effects of the other psychological responses induced by discrepant events should be further investigated. Second, we focused on the roles of situational interest, attention, and effort during conceptual change. Previous studies (Duit & Treagust, 2003; Sinatra, 2005; Sinatra & Pintrich, 2003; Zohar & Aharon-Kravetsky, 2005) have reported, however, that other variables especially concerning students' individual characteristics such self-efficacy, epistemological beliefs, goal orientation, individual interest, and prior knowledge should also be related to students' conceptual change. Therefore, further studies concerning the roles of these constructs in conceptual change are needed in order to obtain more comprehensive understanding of conceptual change process.

The results of this study implied that, in comparison to cognitive conflict, situational interest is the more important factor induced by discrepant events. It should be investigated, therefore, how to promote students' situational interest effectively when science teachers and educators use discrepant events in conceptual change instruction. It has been suggested that the sources of interest should be considered in order to effectively arouse students' interest (e.g., Bergin, 1999; Hidi, 2001; Hidi & Harackiewicz, 2000; Mitchell, 1993; Schraw et al., 1995; Schraw et al., 2001; Schraw & Lehman, 2001; Wade, Buxton, & Kelly, 1999). Berlyne (1971) suggested novelty, expectation, complexity, conflict, ambiguity, and instability as the important sources of interest. Recently, Chen et al. (2001) suggested novelty, challenge, attention demand, exploration intention of a learning task, and instant enjoyment of learning as the sources of interest. Practical guidelines for selecting and presenting discrepant events in conceptual change instruction need to be developed based on the understanding of the adequate sources of interest provocation in the context of conceptual change using discrepant events.

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Kavramsal değişimi etkileyen faktörler olarak bilişsel uyuşmazlık ve bağlamsal ilgi

Bu çalışmada, yoğunluk kavramını öğrenmede kavramsal değişim, tutarsız durum, dikkat ve öğrenme çabasıyla bağlamsal ilgi ve bilişsel uyuşmazlık arasındaki ilişkiler bu çalışmada incelenmiştir. Katılımcılar Kore Seul'de öğrenim gören 183 yedinci sınıf ortaokul öğrencisidir. Tutarsız bir duruma tepkilerin ölçüldüğü bir ön-kavram testi ve bağlamsal ilgi anketi ön-test olarak uygulanmıştır. Öğrencilere, kavramsal değişim için müdahale aracı olarak, bilgisayar destekli öğretim sağlandı. Dikkate ve çabaya yönelik olarak anketler ve bir kavram testi son-testler olarak uygulandı. Aynı kavram testi, dört hafta sonra izleme testi olarak bir kez daha uygulanmıştır. Tutarsız bir durumla ortaya çıkan hem bilişsel uyuşmazlık hem de kavramsal ilginin, öğrencinin dikkat ve kavramsal öğrenmeye ayırdığı çaba tarafından etkilenen kavramsal anlamasında doğrudan olmayan bir etkiye sahip olduğu sonucuna varılmıştır. Bununla beraber, kavramsal ilginin bilişsel uyuşmazlıktan ziyade kavramsal değişim üzerinde daha etkili olduğu sonucu bulunmuştur. Ayrıca, dikkatin, doğrudan veya dolaylı olarak ortaya koyduğu çabayla öğrencinin kavramsal anlamasını etkilediği sonucuna varılmıştır.

Anahtar Kelimeler: dikkat, kavramsal uyuşmazlık, kavramsal değişim, tutarsız durum, çaba, kavramsal ilgi