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Conceptual Change via Contrasting Everyday and Scientifically Idealized Contexts

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ABSTRACT

This article presents a theoretical model for conceptual change that relates cognitive conflict and the role of context. The model assumes that students derive alternative conceptions from everyday contexts while scientific concepts presume an idealized context, and hence, that the source of cognitive conflict results from the difference between the two contexts. Test results and analysis of the model are presented by applying it in a class studying the inertial motion of bodies. The subjects are 37 seventh grade boys.

Key words: misconception, conceptual change, context, mechanics

I. Introduction

While many authors (Stavy & Berkowitz, 1980; Gilbert & Watts, 1983: Champagne *et al*, 1985; Hewson, 1981: Hewson & Hewson, 1983; Dykstra *et al*, 1992; Caravita, 1994; Fensham *et al*, 1994) have stressed the importance of cognitive conflict in conceptual change, others, for which references are given in the following section, have suggested theoretical models for conceptual change that include cognitive conflict. However, those models are only partially satisfactory for practical usage in classrooms, and some need empirical verification.

Several researchers have reported that context is an important element to consider in understanding science learning (White, 1988; Song & Black, 1992; Choi & Song, 1996). But the role that the contexts plays is not yet well explained. Furthermore, the relationship between cognitive conflict and context matters has not been investigated in detail.

In this paper, we suggest (i) a new model of conceptual change that does relate the roles of context and cognitive conflict, and (ii) a strategy for conceptual change based on that

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model. We then report the empirical results from the application of the model to students who studied the law of inertial motion.

Ⅱ. Theoretical discussion

1. Models of conceptual change

Students try to understand natural phenomena and other peoples' thoughts on the basis of conceptions they have personally acquired. If these personal conceptions do not coincide with any foreign phenomena or with others' thoughts, they may feel conflict in their minds. Hence, recently many researchers have been interested in the role of cognitive conflict in conceptual change (Driver, 1985; Fensham *et al.*, 1994; Scott *et al.*, 1992; Strike & Posner, 1982).

The interest in cognitive conflict in science education might be divided into two categories: the conflict between the students' alternative conceptions and natural phenomena, and the conflict between the alternative conceptions and scientific concepts. Piaget's interest and was in the former, what constructivist researchers currently discuss is the latter.

Hashweh (1986) suggested a model of cognitive conflicts that is shown in figure 1.

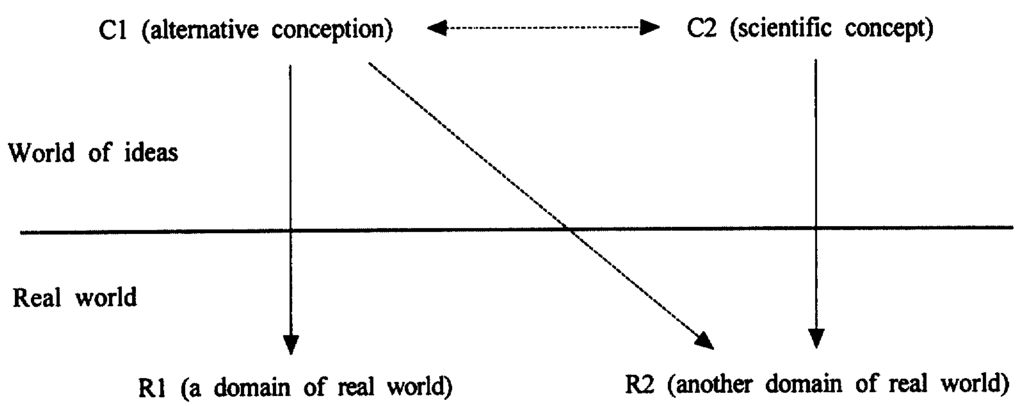

Fig. 1. Structure of cognitive conflicts (by Hashweh, 1986)
(→: coincidence, -->: conflict)

Hashweh pointed out that Piaget stressed only the conflicts between the concept C1 and a particular domain of real world R2, and suggested that the conflicts between C1 and C2 are also important in conceptual change. He continued that the further sequential presentation of R3, R4..., which are well explained by C2, but not by C1, would make cognitive conflicts in students' minds and cause them to change their alternative conceptions.

Kwon (1989) in Korea identified another type of conflict in Hashweh's model, namely the conflict between C2 and R1, in Figure 1. He suggested several strategies for conceptual change according to the identified cognitive conflicts such as extensive, revolutionary, and exchanging types. In another paper, he pointed out that this type of conflict or the effects of the strategies had never been tested empirically (Kwon, 1992).

Kim (1991) noted that if students do not feel any cognitive conflict for the given phenomena or thoughts that are not coincident with their personal concepts, the conflict model cannot be easily applicable for explaining the conceptual change in these cases. For this reason, he used the analogy of the paradigm theory by Kuhn (1961) to explain the process of conceptual change. In Kim's model (See Figure 2), each of the two contrasted conceptions C1 and C2 can explain the given phenomena as if two rival paradigms do in scientific research. No distinction is made among phenomena as in Hashweh's or Kwon's model. Kim suggested that by contrasting the quality of the explanations of each conception for the given phenomena, students could actively determine which is proper and hence change their personal conceptions into the scientific ones.

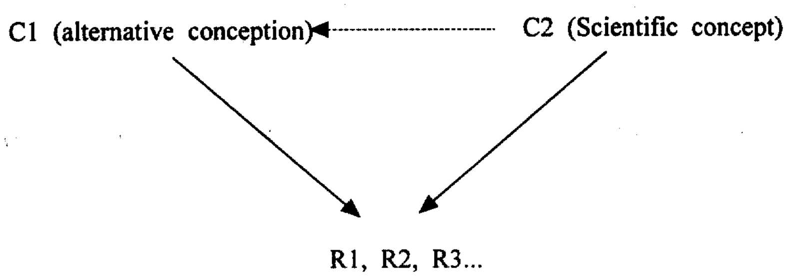

Fig. 2. A representation of Kim's model for cognitive conflicts
(→: coincidence, -->: conflict)

Kwon (1992) replied to Kim that this model is merely a type of the conflicts between C1 and C2 in his model. However, while Hashweh-Kwon's model regards the coincidence between phenomena and concepts, this feature is not in Kim's model; it is hard to see that Kim's model is, in fact, merely a sub-model in this way. Then, which of the models can explain conceptual change better? No clear answer has been given to this question, although each has been applied to physical phenomena as follows.

If we apply Hashweh-Kwon's model to the falling motion of bodies, we can expect that the C1-R2 conflict in students' mind can arise as long as they believe that the heavier body falls faster when, for example, a wooden and an iron ball are falling. Likewise, the C2-R1 conflict can arise in the case of dropping a book together with a sheet of paper if they believe the scientific concept to be correct. In the case of sliding a body on a frictional table, however, it seems as if Kim's model is more applicable, for there exists only one conflict between the student's personal concept C1 that force is consumed in sliding, and scientific concept C2 that friction diminishes the speed of the body for the given phenomenon. Hence it can be said that these models are only partially adequate, and we need a more sophisticated model for explaining the cognitive conflicts of students, especially for these physical phenomena.

2. A modified model of cognitive conflict

Although most scientific concepts are constructed by scientists on the basis of empirical facts in everyday context, each of them always assumes a certain idealized context of its own. That is, a phenomenon that a scientific concept implies can be realized in that idealized context only. However, it seems to students that their personal conceptions may explain the everyday phenomena better than the scientific concepts can do, for those alternative conceptions were acquired in the everyday context. From this, we deduce that the difference in the bases of contexts between the students' and the scientists' ideas should be the key for understanding the source of arising the cognitive conflicts of students in learning science. So we can revise the Hashweh-Kwon's model by considering this contexts matter.

In physical phenomena, we can specify the phenomena R2 that is conflicting to the students' alternative conceptions C1 in Hashweh-Kwon's model as the phenomena in the idealized context, for instance, in which neither gravitation nor friction exist. Then the corresponding scientific concept C2, which is applicable in explaining the phenomena in the idealized context, would conflict with R1 in everyday context in which various constraints such as gravitation and friction exist. From this differentiation of phenomena according to their related contexts, we suggest a revised cognitive conflict model as shown in figure 3. In that, we also identify three types of cognitive conflict as in the Hashweh-Kwon's model, but the two contexts, everyday and idealized, are the criteria for classifying the concepts and related phenomena.

For example, the phenomenon that the falling speed of bodies is independent of weight might be well observed in the idealized context such as in a vacuum. But, in everyday context, weight affects the falling speed of bodies since there exists air resistance. So the concept C1 or C2 in itself can explain only their own examples, but not the counter-examples. The identified three types of conflicts are as follows: R2 is not explained well by C1, R1 is not explained by C2, and C1 is contrary to C2.

By specifying the criterion for distinguishing the phenomena R1 and R2, our model would be more helpful in explaining and devising strategies for conceptual change in science learning. This context criterion tells us how to collect phenomena if we want to help

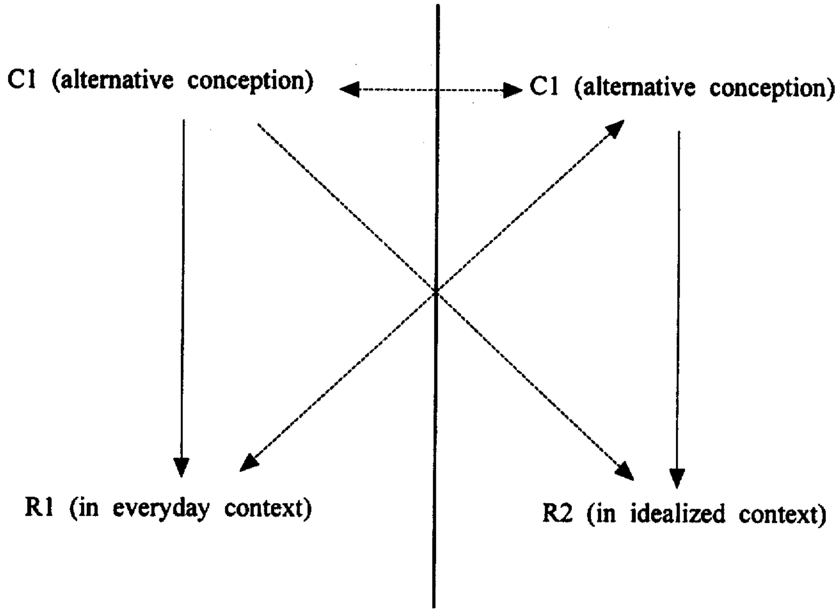

Fig. 3. Modified model of cognitive conflicts
(→: coincidence, -->: conflict)

students change their alternative conceptions into the scientific one. In the case of sliding bodies on a frictional table, Kim's model says that there exists only one type of conflict - conflict between C1 and C2 for the given phenomena. However, these phenomena belong to the everyday context. If we introduce an idealized context in which no friction exists, we can show them phenomena that sliding bodies would not become slower and stop. Hence we can again identify three types of conflicts in that example. So we think that our model should also be more effective than Kim's model.

3. A Strategy for conceptual change: 'structured contrastive activity'

Strike & Posner (1982) argued that making students dissatisfied with their own conceptions is an important starting point for conceptual change. If students find that their alternative conceptions fail to explain the given phenomena, they may feel cognitive conflict, and become dissatisfied with their own conceptions. Hence, at the first stage, we need to concentrate on how to present students with conflicting phenomena that are discrepant to their personal conceptions.

According to the model given above, the alternative conception C1 well explains the phenomena R1 in everyday context, but not R2 in an idealized context. The scientific concept C2 explains R2 well, but not R1. This makes cognitive conflicts between conceptions and phenomena. This is the first stage of the strategy for conceptual change that we suggest, that is, the stage of recognizing cognitive conflicts.

In this stage, we present two contrasting phenomena R1 and R2 as discussed in the revised model. Each of them can be explained by C1 (or C2) but not by C2 (or C1). As Hashweh (1986) mentioned, students have the tendency of biased thinking to be persistant in their beliefs. So the counter-example cannot change their personal conceptions. They consider the anomaly as a special case or as an exception to the rule. Rather, they revise their ideas in an ad hoc manner or add more variables to existing ones to preserve them. Dreyfus *et al.* (1990), and Trumper's (1997) reports show us the same results. These are similar to what Lakatos argued (1970). He argued that scientist change the protective belt by suggesting some auxiliary hypotheses to keep the nucleus of their thoughts safe. From these, we think that the students would suggest some auxiliary hypotheses A1, and hence try to explain R2. So another auxiliary hypotheses A2 by teachers that explains R1 should be introduced to resolve the conflicts between C2 and R1. Then every conflict between a concept and its counter-example would be resolved.

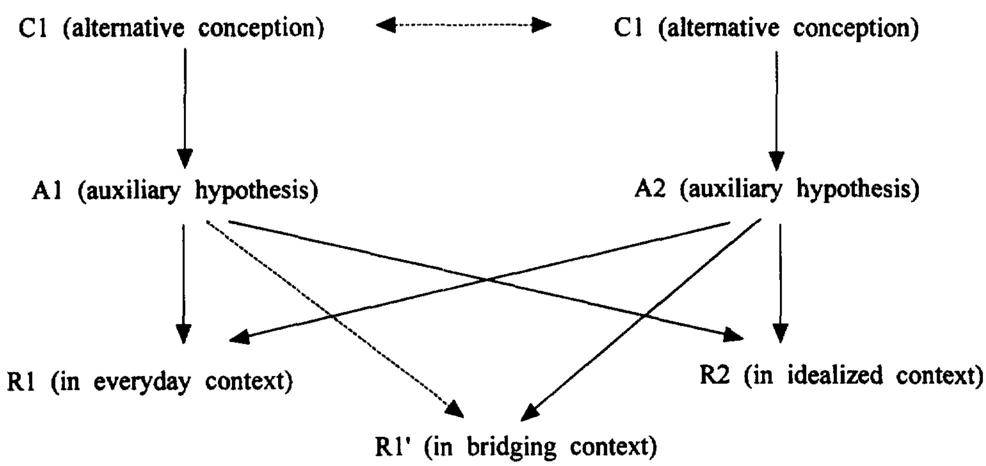

Fig. 4. Auxiliary Hypotheses to resolve C-R conflicts
(→: coincidence, -->: conflict)

However, these resolutions even strengthen the conflict between the concepts C1 and C2 in students' minds, because each concept acquires its own reasonability for explaining both phenomena with the help of the auxiliary hypothesis, even though they are still contradictory to each other (See figure 4). (An example of C1, C2, A1 and A2 can be seen in Appendix 1).

In this stage, we can expect that students will no longer hold their personal conceptions as true even though they still do not accept the contrasting scientific concept C2. We named the procedure in this stage 'contrastive discussion'. In case the students cannot perform the discussion enough for themselves, it can be presented more strongly in the form of role-play or as a drama written by teachers.

Since the auxiliary hypotheses cause the strengthening of the conflict, the students will have a strong desire to determine which one is correct or better. However, in a classroom situation, one might agree that A1 would be much stronger than A2 in explaining the difference between the two contexts. In many cases, students would not have experienced the phenomena in the scientifically idealized context. So it is necessary to show them such phenomena in that context via available resources in the school or classroom setting. Since these phenomena might seem to be strange or curious to students, we believe they can create a lot of helpful episodes, which White (1988) stressed to be important in science learning. This is a distinctive stage. We named it the 'idealized context observation' stage.

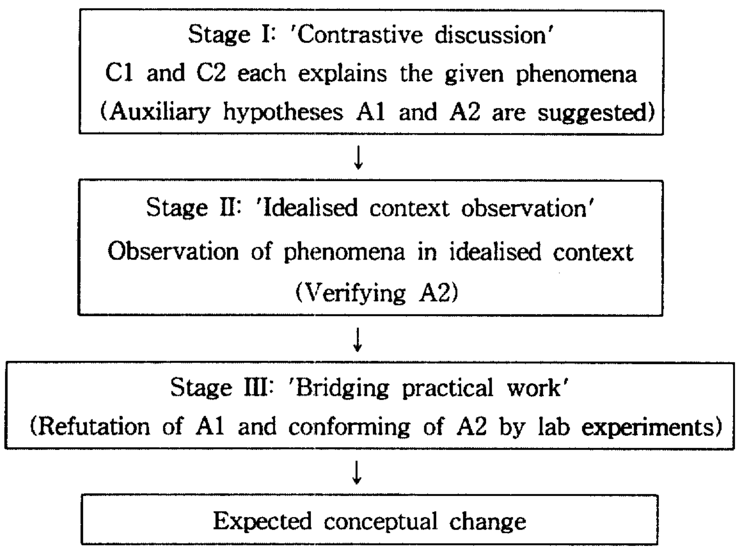

Fig. 5. Structured contrastive activity

In the final stage, the students are given opportunities to test the validity of A1 and A2 through practical lab activities. We expect that they might well, in this way, find the restrictions in their previous ideas and change their concepts. In this stage, the role of experiment is similar to that of a critical experiment in a scientist's activities. The use of this strategy, we believe, gives a distinctive meaning and role to practical work in school science. Even though the laboratory is not an idealized context but an everyday context, it always aims to extrapolate phenomena to the idealized context by controlling all possible miscellaneous factors. By this, we think that the role of practical work in the laboratory is to bridge the two contexts. We name the final stage 'bridging practical works'. Figure 5 summarises the overall stages of the strategy, which we call 'structured contrastive activity'.

Ⅲ. Experimental test

1. Research procedure

1) Research questions

The research question is to check if the suggested strategy for conceptual change is validated by the practical data. This main question is divided into the following three sub-questions.

a. Do auxiliary hypotheses that first appeared in the 'contrastive discussion' stage reinforce the cognitive conflict between the two contrasting concepts C1 (representing students' alternative conceptions) and C2 (corresponding scientific concepts)?
b. Does the 'idealised context observation' provide students with the motivation for conceptual change? Do the students recognize that the scientific concept is plausible?
c. Does the 'bridging practical work' help students change their alternative conceptions by recognising that these conceptions have many restrictions?

2) The subjects

The subjects were 37 seventh grade boys in a junior high school class in Korea. They have had no lessons on the topic of inertial motion during their elementary school years. Judging from their scores of previous examinations, their abilities were not homogeneous. In Korea, talented and low ability students commonly co-exist with other normal students in classes.

3) Procedure of lessons and data gathering

The whole procedure of the lesson followed the general stages of figure 5 (see Figure 6). It has three stages and four tests (one pre-test and three post-pests at end of each stage). The lesson was carried out by one of the authors. It took 5 weeks with 4 hours in a week to finish the whole procedure of the lesson.

The theme of the lesson was to understand the Galileo-Newtonian conceptions about force and motion, and to learn the concept of inertia. The representative alternative conception about the motion of bodies that every sliding body on a plane comes to rest for its force is exhausted was challenged during the lesson. Detailed procedure is as follows. In the pre-test, the students had to answer which of the two persons A (representing pre-

Pre-test on the alternative conceptions of inertia

(pre-Galilean and Galilean ideas were presented,

and students were required to choose one and state their reasons)

↓

Stage Ⅰ : contrastive discussion in a drama style dialogue

(Auxiliary hypotheses A1 and A2 are suggested

in the dialogue by the discussants)

↓

Post-test Ⅰ

↓

Stage Ⅱ : idealised context observation

(Verifying C2 by the video watching on the motions in the Sky lab space shuttle)

↓

Post-test Ⅱ

↓

Stage Ⅲ : bridging practical work

(experiments about the motion of objects on various surfaces)

↓

Post-test Ⅲ

Fig. 6. Procedure of lessons and data gathering

Galilean view) and B (representing Galileo-Newtonian view) appearing in the exemplary dialogue was closer to their personal ideas, and give reasons for their choices.

Next, two volunteer students in the class performed an extended debate between A and B of the exemplary dialogue in the pre-test, as the 'contrastive discussion', in a form of drama prepared by the authors (see Appendix 1). In this drama, a argues that the book stops because it loses its moving force. B argues that a certain resistance hinders the book from maintaining its motion. The dialogue is open ended, and the opinions of A and B are treated as equally as possible. One of the authors had written the content of the dialogue in the drama. The well-known historical debate about the concept of inertia makes up the main story of the dialogue. But some of the lines in the dialogue were made from the previous investigations on the alternative conceptions to make the dialogue sound familiar to the students. While performing the drama, the student audience in the class are not merely passive listeners. They take the role of jurors in the debate. After finishing the drama, they should write their own opinions about which one is correct as if writing a verdict in a trial. Later, these answers were analysed in comparison to the answers of the pre-test.

The following is a dialogue of two boys A and B. After reading that carefully, answer the following questions.

A: Lets see what happen if I push the book on the table. By the time the book leaves my hand, it stops. So we can know that if there is no force on the book, the book would stop at last.

B: I don't agree with you. The book would continue in its motion. But there is a certain resistive force acting on the book. So it could not go further.
Which boy do you agree with?
Write the reasons you think that the other is wrong. How will you persuade him that your idea is better?

Fig. 7. The exemplary dialogue and the question of the pre-test

In the second stage, the 'idealised context observation', the students watched a video on the motions in the Skylab (NASA-AAPT, 1976). Its purpose is to help them observe inertial motion in an idealized context where neither gravity nor friction is apparent. They were expected to see inertial motion in that context. The teacher did not guide them as what to notice in the video. After watching the video, they were again asked if any changes exist in their opinions compared to the previous answers.

In the final stage, the students carried out some 'bridging practical work'. They had to measure the distance several objects like wood block, eraser, and ice moved on several surfaces, such as the floor of the classroom, wood tables, and plastic board etc., both with and without soapy water on these surfaces. They used a ball-point pen with a spring inside to give equal impulse to the objects. It was also possible to vary the number of springs. After these practical activities, they made their experimental reports, and answered a few inquiry problems (see Appendix 2). Again, they were asked to answer the pre-test question, and these answers were analysed as the post-test .

2. Results

1) Comparison between the pre-test and post-test I (after the contrastive discussion)

The data in table 1 indicate that the frequencies of agreement with the view of A and B in the pre-test are similar. This result differs from other researchers who have found that most students' alternative conceptions are similar to the pre-Galilean scholars.

After listening to the contrastive discussion between A and B, some students changed from A to B or B to A. About 20% of the students, D, who answered that both A and B are correct. These students are already showing the cognitive conflict suggested in our model. In addition, we see that half of them remained in that position from the pre-test.

Table 1. Change of frequency of position between pre-test and post-test I

In Pre-test	In post-test I				Total
	A	B	D	N	
A	10	2	1	0	13
B	5	8	2	0	15
D	1	3	4	0	8
N	0	0	0	1	1
Total	16	13	7	13	7

A: agreeing with pre-Galilean ideas B: agreeing with Galileo-Newtonian ideas
D: agreeing with both A and B N: Not agreeing with either A nor B

To find out if the auxiliary hypotheses appearing in the dialogue of the contrastive discussion affected the change in the position of students' ideas, the answers of post-test I were analysed as follows. Examples of the students' answers indicating the change from B to A were:

"The table hinders the motion of book." --> "Only by applying force to the book, it moves. When the force gets lost, it stops." (student #11)

"B is right. Without the friction, the book will persevere in its motion." --> " Nothing can move without force even though it is so light and frictionless." (student #21)

"B is right. The book is contacting the table. There is friction." --> "Force is always needed to move. Though the table is slippery like an ice plate, it will stop sometime." (student #44).

In these answers, we can find from the words that their ideas were affected by the auxiliary hypothesis A1 (written in italic letters) of the discussant A in the dialogue of Appendix 1. Likewise, answers of the change from A or from D to B also show the same tendency.

The following are the answers of students who changed their ideas from A to B. In this case, the students mention the words in the auxiliary hypothesis A2. From these two examples, we deduce that the auxiliary hypotheses of A or B influenced the students in changing their position.

"A is right. Only living things have force that they can move. The dead cannot move." --> "B says that friction makes stopping. I agree." (student #17)

"Without motive force, it cannot move. But the table gives friction. Both are right." -->

"If the table becomes more slippery, the book will move farther." (student #24)

Contrary to above examples, some students defended their original ideas and refuted the opposite idea with the help of the related auxiliary hypotheses.

"A is right. Though B says that friction hinders moving, nothing can move without force." --> "A bicycle goes better in an inclined plane. But that is because some force still is remained in that plane. In horizontal plane, we have to pedal harder to go farther." (students #13, 18, 26)

" If I take away my hand from the book, it loses force and stops." --> "The pushing force remains in the book until it stops." (students #27, 28, 45).

"Bs opinion is absurd. If B is right, everything will move in any way as they like." --> "B says that the book would persist in moving unless there is any resisting force. That is absurd except for falling motion." (student #20).

These students, by using the auxiliary hypothesis A1, confirmed their original alternative conceptions and refuted the opinion of B. A Similar tendency is found in the following examples. Those students confirm their own ideas and refute the opinion of A with the use of the auxiliary hypothesis C2.

"If I push a ball, it rolls on after pushing. A is not correct. I have read that friction is the cause of stopping." --> "In this dialogue, B says that if the contact plane becomes more slippery, the book moves farther. I agree." (student #1, 9)

"The reason why B is correct is that the book stops by friction." --> "Friction makes things stop. If not, there would be nothing like brakes of a car or bicycle." (student #33)

"B is right. In the place like space where there is no resistance, nothing hinders any body moving permanently." --> "The resistance which B mentions is the friction." (student #32)

In the answers of students who defend their original ideas, we could find the tendency that some are in a more refuting approach to the opposite ideas (for example, students #1, 9, 13, 18, and 26 in above quotations) while others are in a more confirming approach (for example, students # 20, 33). Table 2 shows how the students who maintained their original ideas, A or B, referred to the dialogue.

Here we find that students who agree with B used more refuting approaches than those with A. This can be explained as follows. The students who selected B might have felt that this position was controversial with respect to popular alternative conceptions A, so they showed more refuting manners to the others. They actively tried to find contradictions in the auxiliary hypothesis of A. That is what we expected for students after the contrastive discussion.

Table 2. Referring approaches of students who maintained original ideas

	A	B
Confirm	7	1
Refute	3	7
Total	10	8

This result also explains why, contrary to our expectations, so many students selected B in the pre-test. Of the 15 who selected B in pre-test, eight students mentioned friction, and seven mentioned certain resistance, gravitational force, or air as the reasons for selection. We cannot find any evidence if they already knew about the concept of friction before our lesson. But judging from their use of refutations, we might guess that they recognised the position B to be more valid than A already in the pre-test.

The answers of the students persisting with D are analysed. In these answers, we could find that they accept the two auxiliary hypotheses A1 and A2. Even though they did not express their conflict explicitly, we believe it was present.

"Pushing makes the book move. But the friction gives stopping." --> "Force is needed to move. Though the friction exists, the book stops by loosing its force. Both are right." (student #8)

"Both are right. The book stops in a horizontal plane, but not in a inclined one." --> "Ski or skate goes better. So B is right. However, they finally stop. So A is also right." (student #30)

In summary, from these various responses to the auxiliary hypotheses, we conclude that they affected the students ideas significantly. The auxiliary hypotheses made some students change, and others confirm their beliefs. We think that, after the contrastive discussions, conflict between the phenomena and students' ideas does not exist, but it does exist between the two contrasting ideas, A and B. Hence, we conclude that the contrastive discussion reinforced the cognitive conflict between the two rival concepts expected in our model.

2) Change after the idealised context observation

Table 3 shows how many positions changed after watching the video. According to our model, the role of video watching is to enable the students to see how the phenomena in an idealised context is different from everyday context, and that the auxiliary hypothesis C2 holds true in this context. We expected that most of the students who thought A, or both A and B, to be correct would now feel that B is more correct.

Table 3. Change of frequency of position between post-test I and post-test II

In Post-test I	In post-test II				Total
	A	B	D	N	
A	6	8	1	1	16
B	1	11	1	0	13
D	0	4	2	1	7
N	1	0	0	0	1
Total	8	23	4	2	37

A: agreeing with pre-Galilean ideas B: agreeing with Galileo-Newtonian ideas
D: agreeing with both A and B N: Not agreeing with either A nor B

As expected, 8 out of 16 of A and 4 out of 7 of D changed to B, while only 2 out of 13 of B changed. 11 of B sustained their original ideas. This result shows considerable difference from that of Table 1. Those who selected B as correct after listening to the contrastive discussion would have confirmed the auxiliary hypothesis C2 as our model intended. They could accept that the motion would not cease in weightless context, while it ceases in everyday context due to friction. We can find these ideas in students' answers as follows.

I think A is right. Because the book cannot move after losing all force. --> I think, a originally, moving body does not stop. It stops by some resistance (student #11).

It is absurd that the book moves forever without any resistance. --> I see things keep moving without stopping in the video (students #20, 35).

Even though it is so light, anything cannot move without force. --> I saw things which did not stop before any resisting causes in the video. B is right (students #21, 37, 41).

3) Change after the bridging practical work

To find out the role of the practical work on the students' view, the frequency before and after the practical work was compared in Table 4.

Contrary to our expectations, 5 out of 23 of B again changed their mind to A. This suggests that the practical work was not as effective in changing concepts as was watching the video. The practical work was more like the everyday context because all the results involved motion that stopped. We think that these five students returned to the alternative conceptions because of their failure in linking the lab context to the idealised context. We can explain this in more detail as follows.

Table 4. Change of frequency of position between post-test II and post-test III

In Post-test II	In post-test III				Total
	A	B	D	N	
A	5	2	0	1	8
B	5	15	2	1	23
D	0	2	2	0	4
N	1	1	0	0	2
Total	11	20	4	2	37

A: agreeing with pre-Galilean ideas B: agreeing with Galileo-Newtonian ideas
D: agreeing with both A and B N: Not agreeing with either A nor B

Table 5. Frequency of students mentioning friction, and their conceptual positions

Mentioned	A-->A	B-->B	A, D-->B	B-->A	others	Total
No	1	2	1	2	2	7
Yes	4	13	3	3	6	29
Total	5	15	4	5	8	37

A: agreeing with pre-Galilean ideas B: agreeing with Galileo-Newtonian ideas
D: agreeing with both A and B

After the practical work, the students were asked to answer which factors affect the persistence of motion. Table 5 presents the frequency of students mentioning friction and their conceptual positions.

29 out of 37 recognised the role friction played in determining the moving distance. However, four of them still sustained the alternative conception, A; 3 changed to A from B; and 6 showed irrelevant thinking. So 13 of 37 could still not accept the scientific idea in spite of recognising the role of friction in the practical work. So these students could not extrapolate the results that they observed to the case of idealised context. Once again this shows, as other researchers have found, how difficult is the conceptual change to bring about.

Ⅳ. Conclusion and implications

There is evidence from students' answers that our model does have some validity. The role of the bridging practical work, however, was not as predicted. Some students still have maintained their alternative conceptions after the practical work. This again reminds us of the difficulty of promoting students' conceptual change. Revising the content of practical work as a next stage in the research may enable us to demonstrate its role.

Strike and Posner (1982) suggested four conditions for conceptual change: a new concept should be plausible, intelligible, and fruitful, and students should be dissatisfied with their existing concept. This implies two things: there should be a counter-concept to substitute the current alternative conception, and this should be appealing to students as having its own validity (the first three above). Also, without feeling dissatisfaction with current conceptions, conceptual change would not occur. However, Strike and Posner did not suggest how to produce dissatisfaction.

In comparison, our strategy has a detailed way of making pupils dissatisfied with their current alternative conceptions, and giving appealing counter-concepts as well. Our strategy points out that a major dissonance between the alternative conceptions and scientific concepts, especially for mechanical concepts of physics, comes from differences in context. The understanding of a phenomenon is constrained to its particular context. So any conceptions explaining phenomena might seem to be true in the given context, but not in different contexts (Champagne *et al*, 1985). In general, science deals with a context which is more idealised and generalised than our everyday context. For this reason, conceptions generated in an everyday context often do not coincide with the scientific concept. Accordingly, students holding alternative conceptions associated with the everyday context only would not understand the scientific concepts easily. Hence, we think that making pupils consider the idealised context will help them feel dissatisfied with their alternative conceptions. This is the role that the structured contrastive activity plays in our strategy.

In many current teaching strategies for conceptual change, we think that the role of practical work is not so clearly defined. Those strategies claim that helping students experience phenomena is important in conceptual change. Most science curricula also emphasize that experimental activities should be encouraged. But hardly ever can we find that such notions are meaningfully structured into the teaching strategy or curriculum. In our strategy, observation and experiment in the light of two contrasted concepts and contexts are the fundamental activities for conceptual change. The strategy also relates these components of science lessons in a manner consistent with the activities of scientists, in which a theory is suggested based on observed phenomena, and experiments are carried out to find if the theory is valid. Those activities are meaningfully structured in the sequence of processes that make the structured contrastive activity. In this way, we believe that the content and the practical work are not alienated from each other, but well integrated as a whole.

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<Appendix 1>

DIALOGUE IN THE CONTRASTIVE DISCUSSION

A: The book alone cannot move if I do not give force to it. That is, without force no motion exists (: C1).

B: But the book moves some distance after pushing. It means that motion can be possible without force (: C2).

A: Oh! That motion was caused by the pushed force still remaining in the book (: A1).

B: Thats impossible. How could you know it? Can you see it? Is it a kind of object?

A: I am not saying that the force is a kind of object or visible thing. If there is force, the book moves. So we can conclude that there is force while the book moves.

B: That's not a fact. When the book moves, friction exists between the book and the table. This friction keep the book from going. If the surface becomes more slippery, it moves farther (: A2).

A: It is impossible. Though it is slippery, the book stops sometime. So without force, no motion is possible!

<Appendix 2>

WORKSHEET

By pushing the following objects with your ball-point pen, measure the distance on various surfaces.

Inquiry Problems

1. Which object moved farthest on a given surface?
2. On which surface does the given object move farthest?
3. Write more than three methods to make the distance longer?
4. What can be inferred from the above results about the moving distance?
5. Compare the results to what we have watched in the video of the space shuttle.

Questions

1. Why is the moving distance of the given object different as the surface changes?
2. Can you use these results to explain why a heavy and a light body fall simultaneously?