Development of an Instrument for Evaluating Anxiety Caused by Cognitive Conflict

Yeounsoo Kim and Lei Bao

Department of Physics, The Ohio State University, 174W. 18th Avenue, Columbus, OH 43201, USA

Abstract. Physics learning situations often involve many cognitive conflicts between a student's present understandings and new information being learned. Cognitive conflict is known as an important factor in conceptual change. Therefore, it is important to help physics teachers and students develop skills and knowledge for more effective conflict management. However there is no readily available method to monitor the existence and features of cognitive conflicts that students may encounter during their learning. We focus the study on student anxiety caused by cognitive conflict so that we can improve student motivation. This study is targeted to develop an easy-to-use instrument that can be implemented in the classrooms to monitor student anxiety in cognitive conflict situations and the effects on student motivation. In this paper, we will discuss the structure of this instrument and show results from using this tool in our Physics by Inquiry class.

INTRODUCTION

Students' conceptual changes have been a dominant area of research in science education for more than two decades. Many researchers of constructivism in science education have argued that cognitive conflict is an important factor in conceptual change even though there are still questions about its positive and negative effects on science learning [1-6].

During learning, cognitive conflicts among ideas or opinions are inevitable. Courses such as Physic by Inquiry (PBI) [7] are especially designed to help students construct knowledge from seeing and resolving conflicts among peer students, among students and instructors, and between a student's present understandings and new information being learned. When conflicts occur, methods for effective management of such conflicts are crucial to learning. Depending on how conflicts are managed, they can lead to constructive or destructive outcomes.

However, there is no readily available method by which to identify the types of constructive or destructive cognitive conflict that students may reveal in their learning. Therefore we need to develop an easy-to-use instrument that can be implemented in classrooms to monitor the status of students' cognitive conflict and the effects on students' motivations in learning.

THE STRUCTURE OF THE INSTRUMENT

Based on a review of research on cognitive conflict [2-6] and our previous studies [8,9], we have designed and tested an instrument to monitor students' status of their anxiety caused by cognitive conflict. It is called the in-class Conflict and Anxiety Recognition Evaluation (iCARE). Table 1 shows the structure.

The iCARE is comprised of four parts: situation (types of cognitive conflict) [10], experience (factors of cognitive conflict) [5], measurement of anxiety, and types of anxiety [8, 9]. The full version of iCARE can be obtained from www.modelanalysis net/ICARE/.

The first part was designed to identify the specific situations that cause a cognitive conflict. During a class, a student may encounter situations that caused differences (a) between student's preconceptions and a result of demonstration or experiment, (b) between a student's opinions and those of others in the group, (c) between a student's opinions and those of the instructor.

Table 1. The Structure of the iCARE.

Category	Factor
1. Situations (Types of conflict)	Individual conflict
	- Idea & Result
	- Idea & Idea
	Social conflict
	- Student & Student
	- Student & Teacher
2. Experiences (Factors of conflict)	Surprised
	Interested
	Trying to pay attention
3. Measurement of anxiety	Confused
	Uncomfortable
	Upset
4. Types of anxiety	Low anxiety
	High anxiety

Table 2. Types of anxiety caused by cognitive conflict

Level	Type	Example
Low	Multiple prediction	"Before the experiment, I predicted multiple possible outcomes. From the experiment, I have seen one of my predictions proved.
	Revision of current theory	"I was confident that by reevaluating my previous beliefs, I would be able to find an explanation without others' help."
	Dependence on others	"Without my effort, I only accepted what instructors or my classmates had said."
	Using past experience	"I made my predictions for this experiment by thinking about my past experience."
High	Confidence in preconception	"Before the experiment, I was highly confident in my previous understandings of the subject."
	Reviewing additional variables	"After I saw the experiment's outcome, I tried to explain it by considering things that I might have ignored as I was making the predictions."
	Lack of confidence	"But right now I don't think I have learned enough physics to build a good explanation yet."
	Conflict with past experience	"On this experiment, the results are inconsistent with what I expected based on my experience"

The measurement of the different situations that cause the conflicts is important since they may have different effects on cognitive development [10].

The second part identifies the experiences that students may have in cognitive conflict situations. Lee et al. [6] developed the cognitive conflict process model to explain the cognitive conflict. In this model the cognitive conflict occurs when a learner (a) recognizes an anomalous situation (e.g., "The differences surprised me."), (b) expresses interest (e.g., "The differences increased my interest in the topic.") or anxiety about resolving the cognitive conflict, and (c) engages in cognitive reappraisal of the situation (e.g., "The differences made me want to pay more attention to the topics and spend more time to work on it."). In second part, we give students the above example sentences and ask them to identify their experiences in conflict situation.

The third part measures the anxiety caused by cognitive conflicts. We used three items based on the Cognitive Conflict Level Test [5]. The items are as follows. (a) "The result of this experiment confused me." (b) "Since I can't resolve the differences, I am uncomfortable." (c) "I am upset because I cannot understand the reason for the result." All items were on a 5-point Likert scale (1= "not at all true", 5= "very true"). If the total scores are less than 9, the student is considered to have a low level of anxiety, and higher total scores were labeled as a high level of anxiety [9].

The forth part identifies the types of anxiety related to student behavior in cognitive conflict situations. Based on our previous research, we suggest eight types of anxiety according to the level of anxiety, which are shown in Table 2. According to Kim [8] and Cho, Kim, and Kwon [9], among these types, 'confidence in preconception' of high anxiety and 'revision of current theory' of low anxiety promote the learning of conceptual change. In general, students who have 'confidence in preconception' can distinguish between their preconceptions and the scientifically consistent models. Students in the category of 'revision of current theory' can often suggest explanatory hypotheses as a trial to correct preconceptions in order to recognize and resolve conflicting situations. The students in the remaining six categories need more external interaction with instructors.

RESEARCH CONTEXT

This data collection was conducted during one quarter of the PBI course at The Ohio State University. This 10-week course covers the topics on electric circuits. Thirty students were enrolled in this class.

The PBI course is a group-learning environment that implements an elicit-confront-resolve model of learning. In the learning process, there are many situations in which students may encounter conflicts. Accompanying the inquiry method is a system of formative assessment and feedback through

Table 3. Topic of section and iCARE used

Section	Topic	iCARE
1	Single-bulb circuits	1st
2	A model for electric current	1st
3	Extending the model for electric current	1st
4	Series and parallel networks	2nd
5	Kirchhoff's first rule	2nd
6	Equivalent resistance	2nd
7	Multiple batteries	2nd
8	Kirchhoff's second law	2nd
10	Ohm's law	2nd

checkpoints, questions of the day, pretests, homework, exams, and journal entries.

The iCARE was given to students as the post-evaluation to each section (except for section 9 which was not evaluated due to scheduling problems). Table 3 lists the sections to which we used iCARE as the post-evaluation. From section 1 to section 3, we used first version of iCARE focused on anxiety. From section 4, an improved version was used that includes measurement for identifying the type of conflict and experiences in conflict situations.

The structure shown in Table 1 reflects the second version. On average, students took about 5 minutes to complete the evaluation in class right after they finished the work of one section. This can help students report with 'fresher' experience about their learning during the section.

RESULTS

From the data, we have identified a number of interesting results.

First, most of the students (average 93.3%) experienced cognitive conflict in every section. However, the situations that cause conflicts are different. Figure 1 shows the percentage of the situations against total reported situations by each section. Among the possible situations, the difference between the student's preconception (or prediction) (C1) and the result of an experiment (R) remains the highest in all sections (from section 4 to section 10). In Figure 1, C2 means the student's preconception of a different experiment, G means another group member's opinion, and T represents the teacher's opinion. The pattern C1:R represents a conflict between a student's preconception and the result of an experiment.

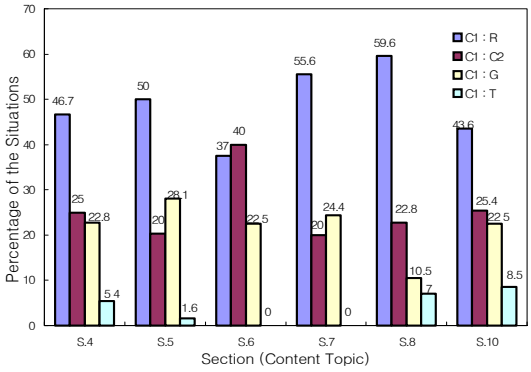

Figure 1. Percentage of the Situations by Each Section.

In addition, students also demonstrate a variety of reactions to the conflicts; students can be 'surprised', 'interested', and 'trying to pay more attention' to the topic. Figure 2 indicates the percentage of different types of experiences against total reported experiences by each section. It shows that from section 5 to section 10 the reaction of 'interested' decreases, and the reaction of 'trying to pay more attention' to the topic increases. The reason could be related to the increasing difficulty of the content.

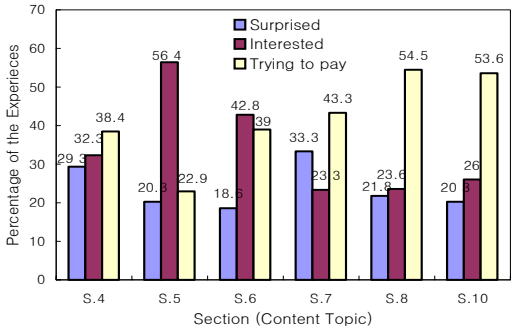

Figure 2. Percentage of Students by Experience.

Second, we found that students can have different levels of anxiety over different sections (content topics).

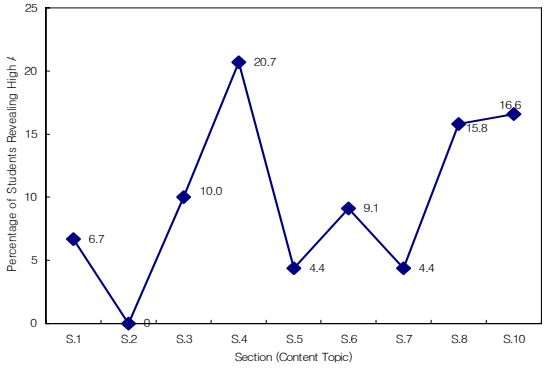

Figure 3. Percentage of Students Revealing High Anxiety by Each Section (excluding Section 9).

Table 4. The t- test results of variance for students' first midterm exam scores by levels of anxiety

	Anxiety level	N	M*	SD	t	p
Exam scores	Low	23	89.04	6.03	2.432	.022**
	High	6	81.16	10.45		

* Maximum score: 100, **: $p < .05$

Figure 3 shows the percentage of students revealing a high level of anxiety by section.

In particular, in section 4 (series and parallel networks), 41% of students experienced cognitive conflicts when working with exercise 4.4 (the experiment that asks students to rank the current through the battery for a list of series and parallel combinations). Students reported that this experiment made the most impression on them.

Further analysis suggests that the students who experienced high anxiety in section 4 also had lower first midterm exam scores than those who experienced low anxiety. The students took the exam a week after doing section 4. The exam consisted of the problems related to series and parallel networks. As shown in Table 4, the t-test results indicate there was a significant difference in the exam scores between the students who experienced high anxiety ($M = 81.16$) and those who experienced low anxiety ($M = 89.04$), $t(27) = 2.432$, $p < .05$. In particular, among the six students exhibiting high anxiety, two students showed the type of 'reviewing additional variables' (see Table 2). Two students revealed the types of 'conflict with past experience' and 'reviewing additional variables'. One student had 'lack of confidence' and 'confidence in preconception'. And the last one had 'reviewing additional variables' and 'confidence in preconception'. These details can provide useful information when implementing strategies to help students resolve conflicting situations.

In this study, instructors follow the typical PBI instruction methods. We didn't try to use additional strategies to help the students who were found to have a high level of anxiety. In our future studies, we will develop and implement new strategies to address students' anxiety based on the measurement from iCARE.

CONCLUSIONS AND IMPLICATIONS

From this study, we have seen interesting results from using the iCARE. The implementation is also practical so that it can serve as a standard tool to evaluate students' status of anxiety in cognitive conflict situations. Such a tool will be a crucial element for further research on strategies to help students resolve cognitive conflicts and control anxiety. In addition, we can use the iCARE to inspect how specific curriculum components affect student learning in terms of triggering cognitive conflicts and causing anxiety. From students' learning behaviors and reactions to conflict situations, we can also obtain additional assessment of students' preparations and learning styles. Further, we can construct a more systematic study in which all these behavior-based results and students' performance data can be correlatively analyzed to yield a better picture of student learning.

ACKNOWLEDGMENTS

We thank all members of the PER group at OSU, especially Florin Bocaneala, and of the PER group at KNUE for their help in conducting this research. This work is supported by Korea Research Foundation Grant (KRF-2003-037- B00102) and by NSF grants #REC-0087788 and #REC-0126070.

REFERENCES

1. G. J. Posner, K. A. Strike, P. W. Hewson and W. A. Gertzog, *Science Education*, **66**, 221-227 (1982).
2. C. Chan, J. Burtis and C. Bereiter, *Cognition and Instruction*, **15**, 1-40 (1997).
3. C. A. Chinn and W. F. Brewer, *Journal of Research in Science Teaching*, **35**, 623-654 (1998).
4. M. Limón, *Learning and Instruction,* **11**, 357–380 (2001).
5. G. Lee, J. Kwon, S. Park, J. Kim, H. Kwon and H. Park, *Journal of Research in Science Teaching*, **40**, 585-603 (2003).
6. Y. Kim and J. Kwon, *Journal of the Korean Association for Research in Science Education*, **24**, 687-708 (2004). (http://www.modelanalysis net/ICARE/)
7. L. C. McDermott and the Physics Education Group at the University of Washington, *Physics by Inquiry*, Vol. Ⅱ. Wiley & Sons, New York, 1995.
8. Y. Kim, Characteristics of Students' Conceptual Change in Physics by Anxiety Types in Cognitive Conflict and Motivation Psychological Factors of Attributions. Unpublished doctoral dissertation, Korea National University of Education (2002).
9. Y. Cho, Y. Kim and J. Kwon, *Journal of the Korean Association for Research in Science Education*, **24**, 574-591 (2004).
10. S. A. Druyan, *International Journal of Behavioral Development*, **25**, 226-236 (2001).