# Students' Cognitive Conflict and Conceptual Change in a Physics by Inquiry Class

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**Abstract.** With proper context settings, instructors need to guide students to recognize explicitly cognitive conflicts among students' existing understandings and new observations. To study this issue, we have developed an easy-to-use instrument, the in-class Conflict and Anxiety Recognition Evaluation (iCARE), for monitoring the status of students' cognitive conflicts and anxiety in the context of Physics by Inquiry (PBI) classes. Using iCARE, we investigate what types of cognitive conflict is constructive or destructive in conceptual change when college students are confronted with anomalous situations in a PBI class. In this research, we will present our results about the relationship between students' prior knowledge and their conceptual change and the relationship between students' types of cognitive conflicts and their conceptual change.

**Keywords:** Cognitive Conflict, iCARE, Conceptual Change, Physics by Inquiry.
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## INTRODUCTION

Many science education constructivists 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, 2]

Recently, Lee *et al.* [3] developed a cognitive conflict process model to explain cognitive conflict and asserted that cognitive conflict consists of four constructs: recognition of an anomalous situation, interest, anxiety, and cognitive reappraisal of the conflict situation. They found that anxiety has both positive and negative effects on student learning. In addition, studies into feelings of anxiety during academic situations have consistently reported a negative correlation between virtually every aspect of school achievement and a wide range of anxiety measures. [4] However, little is known about how constructive or destructive types of anxiety affect students' conducting step-by-step experiments to resolve cognitive conflicts.

During learning, cognitive conflicts among ideas or opinions are inevitable. This is specially so in courses such as *Physics by Inquiry (PBI)* [5], which are designed to help students construct knowledge from observation of nature and subsequent discussion, which leads to a need to resolve conflicts among peer students, between students and instructors, and between a student's present understanding and new observations. When conflicts occur, methods for effective management of such conflicts are crucial to learning. Cognitive conflicts can lead to constructive or to destructive outcomes, depending on how such conflicts are managed.

Kim and Kwon [6] and recent studies cited in an edited volume by Sinatra and Pintrich [7] emphasize the role of the learner's intention in knowledge change and suggest models of intentional conceptual change. They argue that more research is needed to examine the interaction of contextual and individual factors to better explain how and why some individuals not only realize discrepancies but also take the action necessary to restructure their knowledge while others do not.

Therefore, the purpose of this study is to investigate what types of cognitive conflict are constructive or destructive in conceptual change when college students are confronted with anomalous situations in a PBI class. To achieve this purpose, we examine the relationship between the level of students' prior knowledge and their conceptual change and the relationship between students' types of cognitive conflicts and their conceptual change.

## RESEARCH CONTEXT

This study involved nineteen students learning about electric circuits in one quarter of a three-quarter PBI course sequence at the Ohio State University. The PBI course has a group-learning environment that implements an elicit-confront-resolve model of learning. During the learning process, there are many situations in which students may encounter conflicts.

Four assessments were used to identify students' motivation, characteristics of cognitive conflict, and conceptions of series and parallel networks during the study: the MSLQ (Motivated Strategies for Learning Questionnaire) [8], iCARE (in-class Conflict and Anxiety Recognition Evaluation) [9], a pre- and posttest, and a delayed posttest (a question in a first midterm exam).

We used 9 items from MSLQ that could test students' motivation (with 3 items for each measurement factor of motivation: Intrinsic goal orientation, task value, and self-efficacy). All items were on a 5-point Likert scale (1 = "not at all true", 5 = "very true"). This test was implemented in the course.

iCARE [9] (www.modelanalysis.net/ICARE/) was used to measure the status of students' cognitive conflicts, the resulting levels of anxiety, and students' reactions and behaviors in responding to conflict situations. Most items on the test were derived from instruments developed in previous research that have gone through a systematic validation process. [3, 10, 11] iCARE was given to students as the post-evaluation for each section immediately after they finished the work on the topic as shown in Table 1. In our previous study, students often reported experience cognitive conflicts and high levels of anxiety caused by cognitive conflict during the PBI class. Taking iCARE can help students recognize their learning process.

The pre- and posttests were conducted in identical forms to identify students' conceptions and to help students correct any misconceptions after working through each topic. The delayed posttest was also administered a week later after the posttest of Section 4. It was used to assess individual students' conceptual change. Each test consists of one or a few questions relating to drawing a standard circuit diagram, ranking the brightness of the bulbs in series and parallel networks or when a switch is closed.

For statistical testing, students' responses on the conceptual tests are subjected to a quantifying technique similar to those used by Lumpe and Staver. [12] The statements made by students are coded into one of five possible performance categories. Descriptions of the five categories are as shown in Table 2.

**Table 1.** Topic of section.

| Section | Topic |
|---|---|
| 1 | Single-bulb circuits |
| 2 | A model for electric current |
| 3 | Extending the model for electric current |
| 4 | Series and parallel networks |

**Table 2**. Evaluation Scheme for Students' Conceptions.

| Score | Degree of understanding (Using interval) | Criteria for scoring |
|---|---|---|
| 0 | No understanding ($0.0 \le NU < 0.5$) | Blank, repeats question, irrelevant response |
| 1 | Specific misconception ($0.5 \le SM < 1.5$) | Scientifically incorrect responses. |
| 2 | Partial understanding with a specific misconception ($1.5 \le PU/SM < 2.5$) | Responses that show understanding of the concept, but that also contain a misconception. |
| 3 | Partial understanding ($2.5 \le PU < 3.5$) | Responses that contain a part of the scientifically accepted concept. |
| 4 | Sound understanding ($3.5 \le SU \le 4.0$) | Responses that contain all parts of the scientifically accepted concept. |

For each pretest and posttest, we obtain an average concept score for each student. To avoid coder bias and to determine whether the coding scheme is reliable, two coders were trained to code students' answers independently and the average scores from the two coders were used as the final score. The consistency between the two graders was established at 90% agreement.

The 19 students were grouped according to two dimensions: (a) amount of conceptual change (none, some, or substantial if their gain in answer score from pretest to posttest was < 25%, 25-50%, and 50% or more, respectively – this percentage is based on at least the category shift from SM to PU); and (b) pretest answer scores (high, medium, or low). The grouping of the students is given in Table 3. The scores of pretest, MSLQ, and anxiety from iCARE were regarded as high, medium, and low if they were, respectively, more than on standard deviation above the class mean, within one standard deviation of the mean, and more than one standard deviation below the mean.

## RESULTS

Statistical tests were conducted to determine the effect of group learning in the PBI class. As shown in Table 4, significant differences between the pretest and the posttest scores of each topic indicate that the group learning in the PBI class was effective in changing students' prior knowledge.

However, as shown in Table 3, further analysis indicates that of the 19 students, 13 students (68%) showed partial understanding (PU) at the posttest, two showed partial understanding with a specific misconception (PU/SM) (Sara and David), and the remaining 4 students (21%) showed sound understanding (SU) (Wilson, Mark, James, and Kerry). Not all the students were able to retain the correct knowledge.

**Table 3.** Grouping of students according to conceptual change and pretest score.

| Pretest | Conceptual Change: No change (<25% Gain) | Some change (25-50% Gain) | Substantial Change ( > 50% Gain) |
|---|---|---|---|
| High score | Wilson* (3.4, 3.8, 3.5) | Mark* (2.8, 3.9, 3.3) | |
| Medium score | | James* (2.3, 3.7, 3.6)<br>Kerry (2.1, 3.8, 3.1)<br>Kalvin (2.0, 3.1, 3.6)<br>Chelsea (2.0, 3.4, 3.5)<br>Jane (1.8, 3.3, 3.4)<br>Marry (1.6, 3.4, 3.1)<br>Keller (1.5, 2.9, －)<br>Tara* (1.4, 2.5, 2.6)<br>Adam (1.3, 3.2, 3.3)<br>Sara* (1.3, 2.4, 2.3)<br>David (0.9, 2.2, －) | Paul* (1.2, 3.3, 2.3)<br>Max (1.0, 3.1, 2.8)<br>Eve (0.9, 3.1, 3.2) |
| Low score | | | Bany* (0.8, 2.8, 2.8)<br>Simon* (0,7, 3.2, 3.6)<br>Tom (0.5, 3.2, －) |

*Note*. All students' names are pseudonyms. Numbers within parentheses indicate students' average scores of the pre-, post-, and delayed posttest, respectively. See Table 1 for the evaluation scheme. The symbol (－) identifies students did not take the delayed posttest. The symbol (*) means the students who were selected for further analysis.

**Table 4.** The pretest and the posttest comparison (n = 19).

| Section | Test | Mean* | SD | t | p |
|---|---|---|---|---|---|
| 1 | Pre | 1.47 | 1.14 | 8.10 | .000** |
| | Post | 3.61 | 0.31 | | |
| 2 | Pre | 1.16 | 0.83 | 7.64 | .000** |
| | Post | 2.63 | 0.89 | | |
| 3 | Pre | 1.76 | 1.01 | 6.56 | .000** |
| | Post | 3.26 | 0.59 | | |
| 4 | Pre | 1.77 | 1.25 | 4.87 | .000** |
| | Post | 3.19 | 0.78 | | |

* Maximum score: 4.00, **: $p < .05$

Paul regressed to his alternative conceptions in the delayed posttest and some vacillated between alternative and scientific conceptions from the posttest to the delayed posttest. This result shows that students' conceptual understanding subsequent to PBI instruction differed widely.

In addition, as shown in Table 5, there was a significant correlation between the pretest scores and the posttest scores ($p < .01$), and between the posttest scores and the delayed posttest scores ($p < .05$). This means that higher scores on the pretest indicate higher scores on the posttest and higher scores on the posttest show higher scores on the delayed posttest.

To gain insight into the process of conceptual change, we selected eight students who showed representative characteristics in the two dimensions as shown in Table 3. Table 6 summarizes the eight students' characteristics of motivation and cognitive conflict derived from MSLQ and iCARE.

As shown in Table 3 and Table 6, Wilson was the only high- scorer in the pretest who showed a high level of motivation to learn in the class and a low level of anxiety caused by conflict when he was confronted with discrepant events in the PBI class. Wilson worked diligently on PBI tasks, completing most of the tasks successfully.

**Table 5**. Pearson Correlations between the pretest, the posttest, and the delayed posttest.

| | Pretest | Posttest | Delayed posttest |
|---|---|---|---|
| Pretest | 1.000 | | |
| Posttest | 0.653** | 1.000 | |
| Delayed posttest | 0.435 | 0.580* | 1.000 |

*Note.* N=19 in the pre and the post, N=16 in the delayed posttest.
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

**Table 6**. The case students' characteristics of motivation and cognitive conflict derived from MSLQ and iCARE.

| Student | Level of motivation | Number of instances of cognitive conflict | Level of anxiety | The type of anxiety reaction |
|---|---|---|---|---|
| Wilson | High | 20 | Low | Attempts to revise current theory |
| Mark | High | 8 | Middle | Attempts to revise current theory |
| James | Middle | 11 | Middle | Attempts to revise current theory |
| Tara | High | 19 | Middle | Multiple predictions |
| Sara | High | 72 | High | Lack of self-confidence<br>Insistence on need for additional variables |
| Paul | High | 17 | Middle | Use of past personal experience |
| Bany | Middle | 21 | Middle | Use of past personal experience |
| Simon | High | 2 | Middle | Attempts to revise current theory |

In iCARE, he reported that he was confident that by reevaluating his previous beliefs, he would be able to find an explanation without others' help when he encountered cognitive conflict situations. This reaction was categorized as "attempts to revise current theory." He showed reasonably comprehensive understanding in all tests. Mark, James, and Simon, who also revealed a high (or middle) level of motivation, a low (or middle) level of anxiety, and the anxiety reaction of "attempts to revise current theory" showed sound understanding in the posttest and the delayed posttest.

On the other hand, as shown in Table 3, Tara, Sara, Paul, and Bany who had a low level of scientific conception in the pretest showed partial understanding with a specific misconception in the delayed posttest. In particular, as shown in Table 6, Sara reported that she experienced cognitive conflict very often (72 instances) during the instructions from Section 1 to Section 4. But, despite having a high level of motivation, she exhibited a high level of anxiety and was not able to resolve the cognitive conflict situations. When she was confronted with the discrepant events, she showed the reactions "lack of self-confidence" and "insistence on need for additional variables." Through iCARE, she contended that "I believe that there must be good reasons that can explain the experiment well. But right now I don't think I have learned enough physics to build a good explanation yet." and "After I saw the outcome of the experiment, I tried to explain it by considering things that I might have ignored as I was making the predictions." In this study, instructors didn't try to use additional strategies to help her when she was found to have a high level of anxiety. This result suggests that, in our future studies, we will develop and implement new teaching strategies to address students' anxiety reaction based on the measurement from iCARE.

Paul and Bany, who had a high and a middle level of motivation, respectively, showed the anxiety reaction of "use of past personal experience" when resolving cognitive conflicts. Tara, who had a high level of motivation, showed the reaction of "multiple predictions" in conflict situations. In order for instructors to help resolve students' cognitive conflict, these characteristics of anxiety reaction should be considered.

## CONCLUSIONS AND IMPLICATIONS

First, this research shows that the level of students' previous knowledge plays an important role in their understanding of scientific conceptions in their PBI class. This indicates that a higher level of previous knowledge can produce a higher level of scientific conception on a posttest.

Second, this result indicates that students who show the reaction of "attempts to revise current theory" with a high level of motivation can gain scientific understanding when encountering cognitive conflict situations in a PBI class. On the other hand, despite having a high (or middle) level of motivation, those who show the reaction of "multiple predictions," "lack of self-confidence," and "use of past personal experience" need to develop strategies to facilitate recognition of cognitive conflicts. Teachers need to encourage students' confidence to help them resolve cognitive conflicts.

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