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An Intervention Study Using Cognitive Conflict to Foster Conceptual Change

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The study involved evaluating the efficacy of a conceptual change instructional programme involving cognitive conflict in (1) facilitating form 2 (grade 8) students' understanding of algebra concepts, and (2) assessing changes in students' attitudes towards learning mathematics, in a mixed quantitative-qualitative research design. The results showed that there was significant improvement in students' achievement in mathematics and students' attitude towards inquiry of mathematics lessons. Enjoyment remained high even though enjoyment of mathematics lessons showed no change. Changes in students' understanding (from unintelligible to intelligible, intelligible to plausible, plausible to fruitful) illustrated the extent of changes in their conceptions. Finally, recommendations for future research are proposed.

***Keywords**:* Cognitive conflict; Conceptual change; Misconceptions; Algebra; Secondary Mathematics

Introduction

The aim of mathematics education is surely to promote understanding and the success of all students, yet it seems to be a fact that whilst a few students are successful in mathematics, a much greater number find mathematics difficult. However hard teachers may try, there are students who begin to struggle and who will need appropriate help to be able to pursue mathematics further. The objective of any mathematics curriculum includes fostering favourable feelings towards mathematics as well as imparting cognitive knowledge. Yet, the general belief and common saying among secondary school students that only exceptionally brilliant students can successfully learn mathematics leaves much to be desired. Such a belief has not only affected students' attitude towards mathematics but also their cognitive achievement or understanding in the subject. Many researchers are unanimous in the submission that secondary school students often show negative attitude towards mathematics (Mullis, Martin, Gonzalez, & Chrostowski, 2004), and that such negative attitudes often result in lack of interest in the subject, which consequently results in poor cognitive outcomes in mathematics assessment (Ma & Kishor, 1997). As a result, researchers in mathematics education have emphasised and recommended the use of diverse methods of teaching mathematics (Ansari, 2004) to promote learning with understanding and as a means of promoting positive attitudes towards.

Teachers usually expect that students who come into their mathematics lessons will develop new concepts and understandings. Many teachers assume that for new learning to occur all they have to do is impart new information and if students are paying attention and are motivated, they will learn what has been taught or will construct new knowledge as a result (Sewell, 2002). On the contrary, students do not come into the classroom in *blank slates* (Resnick, 1983). Often by the time children start school they already possess a huge knowledge bank of their own explanations for the way the world exists.

The purpose of this article is to evaluate the efficacy of a conceptual change instructional program involving cognitive conflict. The hypothetical assertion of this research is that the implementation of diagnostic teaching strategy will challenge alternative conceptions, enhance students' attitudes and perceptions of the mathematics learning, and facilitate conceptual change and achievement in algebra. To this end, we present published literature that discusses the use of a cognitive conflict instructional strategy that might help the student reconstruct their knowledge (Behr & Harel, 1990; Swan, 2005). The next section presents the theoretical background of conceptual change using a cognitive conflict teaching methodology to facilitate more effective student construction of new knowledge and findings of the research. Finally, conclusions are given, and future works are recommended.

Theoretical Framework and Literature Review

Conceptual Change and Conflict Teaching

Bringing successful teaching approaches to stimulate conceptual change in normal classrooms has been a major challenge not only for teachers but also for researchers (Lee & Byun, 2011; Treagust & Duit, 2008). Conceptual change is essential for meaningful learning with students learning most effectively by constructing their own knowledge through the modification of their conceptual framework. Learning may involve changing a person's conceptions in addition to adding new knowledge to what is already there. Researchers have identified the characteristics of desirable conceptual change. Different authors have offered various terminologies for conceptual change. For example, Hewson (1981) uses the terms conceptual capture and conceptual exchange to characterise changes in the overall content of a conception. Posner, Strike, Hewson and Gertzog (1982) characterise these changes as assimilation and accommodation, which are also called weak knowledge restructuring or strong knowledge restructuring to indicate the degree to which students holds a preconception. White and Gunstone (1989) described conceptual change as a principle or belief change – a change in metaphysical belief. The initiating factor for conceptual change is disequilibrium, dissatisfaction, or cognitive conflict.

Various pedagogies have been developed to facilitate more effective student construction of new knowledge in order to achieve significant conceptual gain in a given subject (Krause, Kelly, Baker, & Kurpius-Robinson, 2010). Many of these use cognitive conflict as a means of facilitating a change in students' conceptions (Kang, Scharmann, Kang, & Noh, 2010; Swan, 2005) and argue that cognitive conflict is considered a premise for conceptual change (Treagust & Duit, 2008). From the literature, application of cognitive conflict strategies for achieving conceptual change can be characterised by the following four key elements: making students aware of their existing concepts before instructional intervention, confronting them with contradictory information, using conflict teaching (contradictory information or anomalous data) to replace prior concepts with scientifically accepted ones, and measuring the resulting conceptual change. A cognitive conflict strategy emphasises destabilising students' confidence in their existing conceptions through contradictory experiences such as giving a counter example or two conflicting examples, where the student's familiar method of solving the problem fails and then enabling students to replace their inaccurate preconceptions with scientifically accepted conceptions (Kang et al., 2010).

Cognitive conflict is an individual's awareness of contradictory pieces of information affecting a notion in that individual's cognitive structure. Cognitive conflict occurs when an individual cannot apply his/her existing concepts to solve a problem, and thus is confronted with a situation that motivates the learning of new concepts. This results in a state of disequilibrium and it is essential to the occurrence of the acquisition and modification of cognitive structures (Sela & Zaslavsky, 2007). Relating to its character, researchers point to situations where cognitive conflict could cause difficulties, problems, and even dangers to the learning process. For example, if the conflict is excessive, it could lead to withdrawal, anxiety or frustration. Some researchers claim that it can break down the learners' current internal structures. Being aware of these two contrasting sides of conflict strategy, we were challenged and motivated to assess whether the conceptual change instructional intervention involving cognitive conflict will enhance or inhibit learning.

Students' Attitudes towards Learning Mathematics

Students' liking or interest in mathematics has a pronounced effect on the amount of work attempted, the effort expended, and the learning that is acquired. The attitude of students towards what they learn has been of continuing interest to teachers. Given the relatively negative view that many people have of mathematics it seems reasonable to assume that mathematics teachers, in particular, are very much concerned with such attitudes. This concern with student attitudes towards mathematics has led educators to develop instructional techniques and creating positive learning environment leading to greater motivation to learn and more positive attitudes towards the subject.

The research literature, however, has failed to provide consistent findings regarding the relationship between attitude towards mathematics and achievement in mathematics. Despite the inconsistencies of research findings, mathematics educators have traditionally taken the relationship between attitude towards mathematics and achievement in mathematics as their major concern because the attitudes we possess towards mathematics affect how we approach, persist, and succeed at the subject. Students who come to enjoy and value mathematics increase their achievement, persistence, and confidence with the subject. Students also engage in and enjoy mathematics more if they expect to be successful, and generally avoid the subject when they perceive their ability to do mathematics as poor. Attitudes were also found to be shaped in great part by the learning environments one experience (Graham & Fennel, 2001), and teachers who understand their students' attitudes are better able to create learning environments conducive to positive attitudes and better achievement (Middleton, 1995).

As a result, the researchers of this study became interested in determining whether the intervention strategy of conflict teaching within a cooperative learning environment could produce a positive attitudinal change in students and if these changes could in turn affect mathematics achievement. This study focuses on students' difficulties, conceptions and attitudes towards learning algebra in the framework of conceptual change.

Research Methods

This study attempted to determine the difficulties and misconceptions that Form 2 (Grade 8) students have with algebra and, investigated whether conflict teaching could have a positive effect on their attitudes and achievement in mathematics. Furthermore, an attempt was also made to determine whether there is any evidence of students' conceptual change following the teaching intervention. In order to gain information on the relevance of these areas, the research questions that guided the study were:

1. Was there any evidence of students' conceptual change in algebra concepts following the teaching intervention that used the conflict teaching strategy?
2. Were there learning gains in understanding algebra concepts evident after six weeks of intervention?
3. Were students' attitudes towards algebra enhanced after six weeks of intervention?

Both qualitative and quantitative data were used. The purpose for the use of both types of data arose out of concern by the researchers that the use of only quantitative data would not give a clear enough picture of students' conceptual change and attitudes about mathematics. Furthermore, the researchers felt that face-to-face interviews would be the most beneficial method for gathering these data. Quantitative data can provide some information about student conceptual understanding, likes and dislikes, but it cannot report on the extent to which student conceptions meet the three conditions of intelligibility, plausibility and fruitfulness as described by Hewson and Hewson (1992) as being the status of a person's conception (Treagust, Harrison, & Venville, 1996) and why one has formed these views. In addition, using both quantitative and qualitative data allowed the researchers to use the strengths of each method while compensating for the weaknesses (Bryman, 1988, 1992). Therefore, both quantitative and qualitative data were deemed necessary to gain a clearer perspective of the questions being asked. First, in order to determine how well students performed on the pre/post-tests on algebra diagnostic test and attitudes toward mathematics, quantitative data were collected in order to obtain responses to the variables and the relationships that existed among them. The second part of the present study attempted to gain insight into students' difficulties and misconceptions and set out to examine whether conceptual change took place (Treagust et al., 1996). Interviews designed by the researcher, revolving around the thoughts and understandings of mathematics, and in particular about algebra, were used for this purpose.

Participants and Instruments

The study was conducted at a suburban public school in Sabah, East Malaysia. 78 Form 2 students of mixed academic abilities from two heterogeneous classes participated in the study. Each class consisted of 39 students each of high achieving and below-average achieving students. The first author was teaching mathematics for five 40-minute teaching periods a week in the two classes during the 2009 school year over a duration of six weeks. The participants were administered the Algebra Diagnostic Test consisting of 24 items and the Test of Mathematics-Related Attitudes (TOMRA). The Algebra Diagnostic Test was adapted from Blessing's (2004) Algebraic Thinking Content Knowledge Test for Students while the TOMRA is a modified version of the Test of Science-Related Attitudes (TOSRA, Blessing, 2004; Fraser, 1981). Because of the close connection between mathematics and science, the

TOSRA was adapted to a mathematics context as the Test of Mathematics-Related Attitudes (TOMRA). It has been used to investigate the effectiveness of innovative mathematics programs (Spinner & Fraser, 2005). Therefore the TOMRA was deemed useful in this study for investigating the attitudes of students towards mathematics, and for exploring possible associations between attitudes towards mathematics and achievement in mathematics. Since the achievement of favourable attitudes is an important outcome of this study, the TOMRA was used to monitor student progress toward achieving attitudinal aims. Besides, the TOMRA could be used for measuring the status of individual students or for providing information about the changes in student attitudes after the teaching intervention. In order to assess students' attitudes towards mathematics in this study, two scales were used: *Enjoyment of mathematics lessons* and *Attitude to mathematical inquiry*. Each scale contained 10 questions; half of the items (that is, *Enjoyment of mathematics lessons* as odd-numbered statements) were designated as positive, and another half of the items (that is, *Attitude to mathematics inquiry* as even-numbered statements) were designated negative. Participants responded using a five-point Likert scale ranging from 'strongly agree' to 'strongly disagree'. Positive items are scored by allotting 5 for 'strongly agree' and 1 for 'strongly disagree' responses. Negative items are scored by allotting 1 for 'strongly agree' and 5 for 'strongly disagree' responses.

The Intervention

A typical diagnostic teaching lesson implemented throughout the six weeks duration of the teaching experiment as recommended by Perso (1991) used the following procedures:

1. Introductory task – students were initially confronted with a problem containing a rich exploratory situation which contained a conceptual obstacle (misconception) identified earlier through an analysis of the common errors on algebra diagnostic test given prior to the teaching experiment and from literature reviewed. Students individually came up with an answer and wrote down their individual responses. Students used their most relevant mental model to approach the problem; their answer reflected that model.
2. Each students set out their mental models by explaining how they arrived at their particular answers. Public differences began to arouse dissonance; heightened dissonance and some resolution as students

tried to persuade each other and reach group agreement or working towards consensus as this provoked greater involvement in a less threatening manner and then maintained a greater involvement when discussion involved the whole class. Results were again recorded. At the same time, the teacher monitored the discussion and, recorded the students' misconceptions.

3. Class discussion – students were organised in groups of two or four, each group leader or spokesperson presented the group's opinions to the rest of the class, one at a time. This helped to ensure that if a whole group had accepted an erroneous conclusion it can be exposed and countered. Wrong responses could be challenged by other groups or the teacher. The teacher acted in a way as to make the situation unthreatening, while at the same time not providing any positive or negative feedback. The teacher facilitated discussion not indicating who was correct initially but offered checking methods if necessary that might allow students to work out who is right while at the same time providing further provocation or conflicting ideas where necessary in order to ensure the exposure of all misconceptions. Students reached agreement on the correct model, with varying degrees of teacher support: the conflict was resolved and dissonance abated. There was a need to make sure students at least know which answer was right.
4. Reflective class discussion – students can discuss how errors were made and which misconceptions they were likely to be based on. The teacher can 'sum up' the ideas presented although this is not necessary (the teacher should be continuously aware that the aim is that students resolve conflict on their own based on their own perceptions).
5. Consolidation – a new problem explored. Students were given an opportunity to consolidate new mental model. Students were presented with further questions in the form of written work, which can now be attempted in order to consolidate the newly acquired understanding. Exercises contain built-in feedback of correctness whenever possible, so that students can know immediately if they have made an error.

A typical conflict teaching lesson began with an introductory task where students were confronted with a problem containing a conceptual obstacle by asking them to solve a problem and discussing how they solve it. The cognitive conflict was generated by giving a counter example, or two conflicting examples, where the student's familiar method of solving the problems fails. The environment after the conflict varied, but it was necessary to provide students with an alternative conception that they could understand. This was usually done with a sharing of ideas about why a method failed or defending why one method is superior to another.

Exemplar lesson. The *think of a letter* activity was taken from Perso (1991). The aim of the activity was to address the misconceptions that the order of operations is unimportant, working in mathematics is always from left-to-right and parentheses don't mean anything in which students had to write down what the teacher was doing exactly using signs, symbols and brackets:

Teacher	Carey
"Think of a letter,	y
Add four	y + 4
Multiply by 2	y + 4 x 2
Add five	y + 4 x 2 + 5
The answer is 19	y + 4 x 2 + 5 = 19
The letter you thought of must be 3."	

When Carey checked this by putting '3' back into the equation in place of 'y' she got 16 as her answer. Was her equation wrong? If you think that it was, write down what you think it should have looked like and give a reason.

Following the teaching intervention, all the students were given the similar post-tests. Nine students were purposefully selected to participate in an interview at the conclusion of the study in an attempt to provide deeper insight to their responses to the quantitative data collected during the study.

The Test Administration

The test was administered twice, one as a pre-test before the teaching intervention and another as a post-test after the 6-week teaching experiment This was done in order to minimise the students merely remembering from their previous instruction; it was intended that the instrument would test the students' understanding of algebra. Students were given 40 minutes in which to complete the test, but more time was given if the teacher felt it was necessary. The extended time was allowed since the test had not been designed to see how quickly the students could complete the test but how much they understood the concepts being tested. The students were instructed to take their time and to consider their choice of answer carefully, rather than rushing to finish the test. They were also advised to avoid random guessing. The researcher marked all papers. Individual responses by each student for every question on the test paper were recorded on the spreadsheet.

Results

The analyses indicated that the conceptual change instructional strategy involving cognitive conflict had a positive effect on facilitating students' conceptual understanding, achievement and attitudes towards mathematics. The results showed (see Table 1) that there was significant improvement in students' achievement in mathematics [(Pre-test: M = 13.06, SD = 3.54), (Post-test: M = 14.91, SD = 3.94); t = 9.27, $p<.05$, effect size=.49]. In order to estimate the degree of differences in addition to statistical significance, the effect size was determined as recommended by Thompson (1998) and Cohen (1988). The effect size for the *Algebra diagnostic test* pre-test and post-test was .49 suggesting a moderately educationally significant difference between the pre-test and post-test scores for the test. An effect size of .49 as shown for the pre and post test means that the score of the average person in the post-test group is 0.49 standard deviations above the average student in the pre-test group indicating that the mean of the post-test (treated) group is at the 69th percentile of the pre-test (untreated) group (For more details please refer to Cohen (1988) for an interpretation of Cohen's *d* as the average percentile standing of the average treated participant relative to the average untreated participant).

Table 1

Descriptive Statistics and Comparison of Mean Scores, Pre-test and Post-test responses and Gain Scores on the Algebra Diagnostic Test

Descriptive Statistics	N	Pre-test	Post-test	Differences: Gain score	Differences: t-value	Differences: Effect size
Mean	78	13.06	14.91	1.85	9.27*	.49
Standard Deviation	78	3.54	3.96	Sig. level (2-tailed)= .000*		

*p< .05 (there is statistical difference between pre and post-test mean scores)

The frequency of correct responses obtained by 78 students for the pre and post tests (raw scores) for each of the 24 questions were plotted to produce the composite graph shown in Figure 1. Except for questions 8 and 20 (where the number of students answered correctly remained the same, 71 and 16 respectively) and questions 9 and 17 (a drop of 3 and 5 students respectively), this chart reveals a trend of increasing number of students with more questions correct for the post test with the most significant improvement for question numbers (Items) 4, 12, 19, 21, 22, 23 and 24.

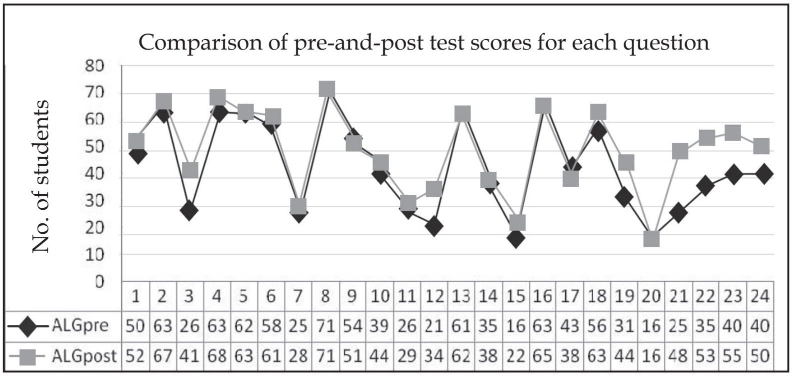
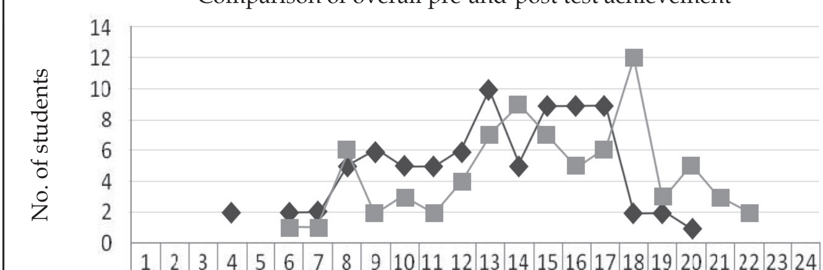


Figure 1. Comparison of pre-and-post test scores for each question.

For the observed scores, students performed better in the post test. As expected, the comparison charts of Figures 2 and 3 reveal an increasing frequency of students getting more questions correct for the post test as compared to pre test. The range for the number of students' pre test score was from 4 to 20 whereas the post test score was from 6 to 22 with significant increase in number of students scoring 18, 19, 20, 21 and 22 questions correct out of a total of 24 questions. For example, the number of students scoring 18 questions correct increased from 2 to 12, an increase of 10 students. The number of students getting 20, 21 and 22 questions correct increased by 4, 3 and 2 respectively after the intervention programme (refer to Figure 2), suggesting that a conceptual change instructional programme involving cognitive conflict was successful in facilitating students' understanding of algebra concepts.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ALGpre				2		2	2	5	6	5	5	6	10	5	9	9	9	2	2	1				
ALGpost						1	1	6	2	3	2	4	7	9	7	5	6	12	3	5	3	2		

Figure 2. Comparison of overall pre-and-post test achievement.

A graphical representation of the comparison of overall pre-and-post test achievement is shown in Figure 3.

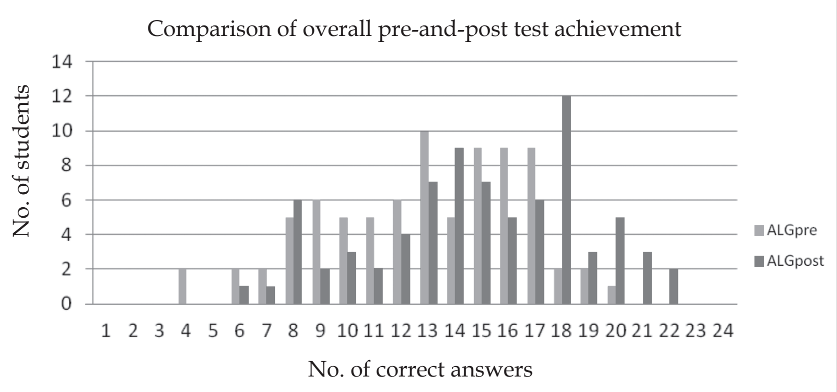


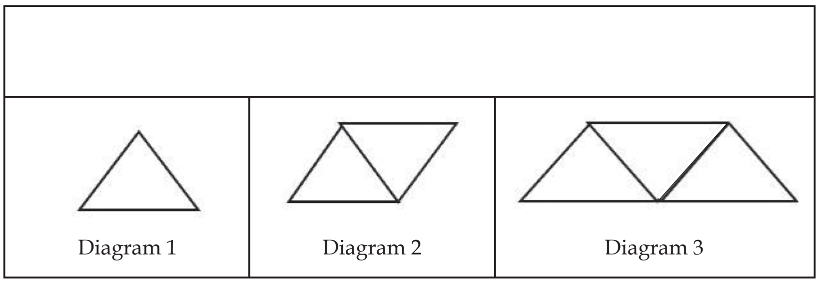
Figure 3. Comparison of overall pre and post-test achievement.

In summary, Figures 2 and 3 display the comparison of overall distribution of pre-and-post test student achievement as a function of number of correct answers. There is a general increase in the number of students getting 18 to 22 out of 24 questions correct indicating significant gain in achievement of post test scores.

However, there were evidences (in test items, student interviews or class observations) of the difficulty that students encountered as they engage in generalising a pattern algebraically. In the process of the production of a general rule to express a relationship, students are found to be using an iterative (additive) rule instead of the multiple-rule and had great difficulty in generating a symbolic expression for the general term of a geometric-numeric pattern as illustrated in the following task (see Figure 4):

(1) Make a table for the number of toothpicks for several triangular figures and find out how many toothpicks are in diagram 10 and diagram 25?

(2) Find a direct formula that expresses the total number of toothpicks for diagram *n* (in terms of the triangular figure). Explain how you arrive at the formula.



(Adapted from Radford, 2006)

Figure 4. Toothpick pattern.

Most students (about 92%) did not have much trouble calculating the number of toothpicks in the concrete diagram 10. They did so by counting the number of toothpicks, diagram after diagram up to diagram 10 and then proceeded to use their addition strategy laboriously up to diagram 25. The following is an excerpt from an interview (two students) when asked by the researcher how they arrived at the formula:

Teacher: So how do you establish the formula?

Student 1: It's always n + 2. It's like diagram 4 + 2 equals diagram 5.

Student 2: You do 2 times the box plus 1. [*Student 2* referred to the triangle as a box.]

Teacher: How did you come up with $2 \times n + 1$? Why do you add '1' to $2 \times n$?

Student 2: Ahm, you know diagram number, like diagram 10. You times 10 by 2 equals 20 and then you add 1 equals 21 and you get the number of toothpicks. Cos' when you count it, you only count 1 extra [at the beginning] and then you kinda ... keep adding two extra sides. Yea it works! (At this point S1 interjected).

Student 1: But no, that would be the number of the diagrams times 2 plus 1. Because, look, 2 times 2, 4, plus 1, 5. One times ... 1 times 2, 2, plus 1, 3! Yes. That would work!

Student 2: So it's times 2 plus 1, right? And, to calculate the number of toothpicks in diagram number, 25, it's ... diagram 25, so, yes, it's 25 times 2 plus 1. Yeah, 51 toothpicks!

The interview indicated that these two students were not using the standard formula, (2n + 1), in determining a direct formula that expresses the total number of toothpicks for figure n. *Student 1* used the recursive formula (additive rule to express a general term of this triangular pattern activity (i.e., the relationship between the diagram number and the number of toothpicks). However, *Student 2* found the formula 'n × 2 + 1' (where n stands for the diagram number) through a process of generalisation of numerical action in the form of an operation scheme that, according to Radford (2006), remains bound to the numerical level.

Furthermore, results from test Item 14 (What rule can be used to determine the number pattern: 2, 5, 11, 23, 47, …?) showed that a high proportion of the students, about 51% had difficulty in providing the correct rule (2N + 1) to determine the following number pattern: 2, 5, 11, 23, 47, ... This proved to be extremely difficult for the students as only 49% of the students were able to select the correct response to the item. In addition, results from Item 24 (What rule can be used to fill in the blanks in the following number pattern?

INPUT	1	2	3	5	9
OUTPUT	1	4	9	-	-

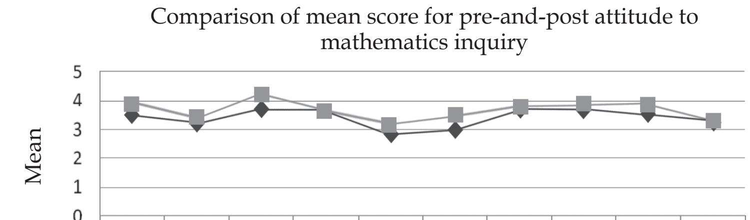
About 36% of the students selected the wrong response to the item (the correct response is INPUT x INPUT).

Table 3
Descriptive Statistics and Comparison of Students' Pre-test and Post-test Responses on TOMRA Scales after Teaching Intervention (n=78)

	Pre-test		Post-test		Differences	
Scale	Mean	SD	Mean	SD	t-value	Effect Size
Inquiry of Math Lesson	3.39	.49	3.65	.58	3.30**	1.09
Enjoyment of Math Lesson	4.03	.73	4.02	.59	0.11	0.02

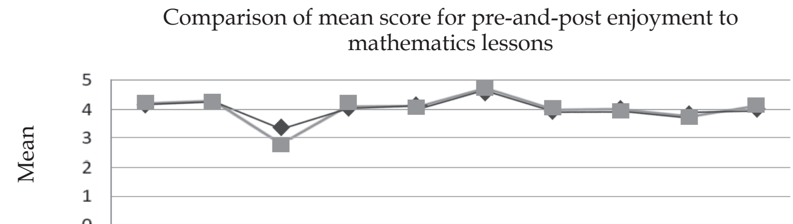
**sig. level (2-tailed) at .001, i.e., p<0.05 (statistically significant)

Further, the students' attitude towards inquiry of mathematics lessons showed significant positive improvement [(Pre-test: M = 3.39, SD = .49), (Post-test: M = 3.65, SD = .58); t = 3.30, p<.05, effect size=1.09]. Enjoyment remained high (mean at 4.02 out of 5) even though the Enjoyment of Mathematics Lesson scale showed no change [(Pre-test: M = 4.03, SD = .73), (Post-test: M = 4.02, SD = .59); t =.11, p>.05, effect size=.02]. The results suggest that the pre-and-post enjoyment of mathematics lessons did not differ. (See Figures 5 and 6)



	1	2	3	4	5	6	7	8	9	10
INQpre	3.49	3.18	3.69	3.64	2.81	2.99	3.73	3.65	3.49	3.28
INQpost	3.86	3.41	4.21	3.65	3.14	3.45	3.78	3.85	3.86	3.33

Figure 5. Comparison of mean score for pre-and-post attitude to mathematics inquiry.



	1	2	3	4	5	6	7	8	9	10
ENJpre	4.18	4.28	3.33	4.04	4.12	4.59	3.91	4	3.85	4.01
ENJpost	4.24	4.29	2.81	4.15	4.1	4.72	4.04	3.94	3.74	4.15

Figure 6. Comparison of mean score for pre-and-post enjoyment to mathematics lessons.

Limitations

The results and conclusions generated in this study refer specifically to the sample groups involved in the study and the short period of six weeks in which this study was conducted. Generalisations of the findings to all secondary students in Malaysia must be considered with caution due to the nature, limited size of the sample and the short time frame. Due to these constraints, the effect of a conceptual change instructional programme involving cognitive conflict on students' understanding, achievement, attitudes and perceptions, and conceptual change cannot be generalised with absolute certainty. Potential effects of the students' learning styles, the attitude of the students towards the learning of mathematics, the classroom climate/environment, as well as the effect of different teachers who taught the students, their teaching and management styles were not explored in this research. Though a small number of Malaysian students were involved in the development and administration of diagnostic teaching intervention, the author is confident that the findings presented here are, nevertheless, relevant to all mathematics teachers of secondary schools in Malaysia.

Conclusion

Findings of the study suggest potentially important implications for the teaching and learning of algebra. The teaching approach used to foster conceptual change in students' mathematics learning involving cognitive conflict can be considered for other similar classrooms to promote conceptual change or learning progression of students. More importantly, cognitive conflict teaching places students in an environment that encourages them to confront their preconceptions and then work toward resolution and conceptual change. It helps students to learn by actively identifying and challenging their existing conceptions and the views of their classmates. In the process, students are encouraged to come up with and explore multiple ways to approach a problem rather than just following strict instructions that may present one way of doing something.

Overall, the conceptual change theory used to frame the study suggests possible effectiveness of conflict teaching in achieving conceptual gain and changes in students' attitudes. It turned out that there was significant improvement in students' achievement and attitudes towards inquiry of mathematics lesson while enjoyment of mathematics lesson remains high though unchanged. The results indicated that there may be potential for improving student learning, attitude, and retention by employing the cognitive conflict approach to learning.

Conceptual change is complex (Taber, 2011), a slow process (Vosniadou, 2008), "where any observed apparent sudden changes are hard-won and simply offer the surface evidence of extended, preconscious processes influenced by many months of classroom experience" (Taber, 2011, p. 13). This brings to mind Taber's (2011) view that this is something that will resonate with many classroom teachers, who experience learning in their students as a gradual, incremental, often tentative evolution of thinking facilitated by carefully scaffold and drip-fed teaching inputs. We are not simply seeking learning of discreet simple facts or techniques, but rather meaningful conceptual change that leads to new ways of understanding aspects of the world. That requires a lot of mental work by the student, with skilful support by the teacher.

The findings add evidence to the existing literature that promoting conceptual change through the use of cognitive conflict is not an automatic process. Rather, first it requires individuals to realise the existence of a meaningful conflict between their own theories and the evidence conflicting with them. Then it requires individuals to become aware of the un-tenability of their conceptions on a given phenomenon and to be willing to change them. The use of cognitive conflict as an instructional strategy has been criticised as often as students either fail to recognise contradictions they are presented with or superficially combine with local inconsistencies without reaching fundamental changes that are necessary (Vosniadou, 2001). As highlighted by Limon (2001) in a recent critical review of the use of cognitive conflict for conceptual change, there are controversial results of its efficacy which can be explained by referring to different factors. Often the significance of the conflict itself is not apparent to students.

Hence, we recommend that further research be done to help teachers to understand how students experience conflict, how students feel when they experience cognitive conflict, and how those experiences are related to their final responses because cognitive conflict has both constructive and destructive potential. Thus, by being able to interpret, recognise and manage cognitive conflict, a teacher can then successfully interpret his/her students' cognitive conflict and be able to make conceptual change more likely or help students to have meaningful learning experiences in secondary school algebra.

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