THE EFFECT OF USING STEPANS' MODEL OF CONCEPTUAL CHANGE ON THE MODIFICATION OF ALTARNATIVE MATHEMATICAL CONCEPTS AND THE ABILITY OF SOLVING MATHEMATICAL PROBLEMS OF NINTH GRADE STUDENTS IN JORDAN

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Abstract

The present study investigates the effect of using Stepans' model of conceptual change on students' modification of alternative mathematical concepts and on their ability of solving mathematical problems. The investigation was conducted by using ninth graders in two different sections in a secondary school in Amman. This study dealt with intact groups, but the treatments were randomly assigned to the classes so that the conceptual change group (CCG) contains one section and the non-conceptual change group (NCCG) contains the other section. An analysis of covariance (ANCOVA) showed that the CCG outperformed the NCCG in terms of students' modification of alternative mathematical concepts and their ability of solving mathematical problems. Classroom implications and suggestions for further research are included.

Keywords: Misconceptions, Students' modification of alternative mathematical concepts, Mathematical problems, Stepans' conceptual change model

Introduction

A Conceptual Change Strategy is a widely known teaching strategy in the field of different subject areas (Tirosh & Tsamir; Ozdemir & Clark, 2007; Duilt, Treagust, & Widodo, 2008; Vamakoussi, Vosniadou, & Van Dooren , 2013; Vosniadou; 2013; Vosniadou & Kampylis; 2013). This strategy is derived from the constructivist philosophy. In this regard, Constructivism postulates that learners are active participants in building their knowledge and resolving their own misconceptions. Since learners will not become active by accident, but by design, constructivism sees the role of the teacher as not only to present new information, help learners correct their misconceptions, and demonstrate skills, but also to organize classroom environment and content in a way that helps learners construct their own knowledge and resolve their own misconceptions (Ernest, 1998; Vosniadou & Vamvakoussi, 2006; Blake & Pope, 2008; Caker, 2008; Caroline Learning, 2011; Summit & Rickards, 2013; Vamakoussi, et al., 2013).

The advocacy of constructivism has its origin in the Piagetian and Vygotsky's studies on how learners construct their knowledge. With respect to Piaget, these studies helped him to develop his ideas of assimilation, equilibrium and accommodation (Bettencourt, 2009). Assimilation is the process by which taking data from the environment occurs in a form of mental structure rather than in a mechanistic sense. A discrepancy arises when the learner can not assimilate a new experience into his or her pre-existing experiences. In this case, a kind of disequilibration occurs. Equilibrium occurs when this discrepancy is resolved. Accommodation is the process by which the existing experiences are modified to fit the assimilated experiences. Accommodation always leads to the emergence of new structures (Furth, 1970). On the other hand, Vygotsky’s studies focused on the social context of learning. He believes in the importance of cooperative learning and teacher's support in helping learners understand things they cannot understand on their own. Therefore, Vygotsky recommends that teachers must encourage learners to work in cooperative groups while thinking about their tasks in order to construct meaning with others. In his theory, Vygotsky uses some concepts like the "zone of proximal development" and "scaffolding". The zone of proximal development represents the difference between a learner's actual development and the level of potential development. Scaffolding represents the support that the teacher provides learners with to help them solve problems which are beyond their current abilities (Ernest, 1998; Blake & Pope, 2008; Caker, 2008; Linn & Burbules, 2009; Wheatley, 2009; Caroline Learning, 2011).

Although constructivism provides a useful framework for the conceptual change learning, it does not stipulate a particular conceptual change model. It only provides guidelines for good teaching by describing both learners' and teachers' roles. For example, constructivism recommends teachers to create learning environment that look at learners' misconceptions as a rich source of information about learners' thinking rather than learners' errors that must be corrected. This learning environment involves an active negotiation among learners that helps learners in exchanging their existing misconceptions by the new, correct ones (Simon, 1995; Ernest, 1998; Anderson,, Reder & Simon, 2000; Lowery, 2002; Cakir, 2008; Bettencourt, 2009; Wheatley, 2009).

Later, educators in different fields of subject areas especially in the field of science and mathematics education have started using these constructivist guidelines to build and implement working conceptual change models in classrooms. For example, in 1994, Stepans developed a constructivist-working model entitled the Conceptual Change Model (CCM). This model consists of the following six steps. The first step aims at helping learners become aware of their own thinking in order to help them commit to a problem or challenge and make predictions to an outcome before starting any activity. The second step aims at helping learners expose their beliefs and share ideas with classmates before testing these ideas. The third step aims at helping learners confront their existing ideas by testing them in small groups. The fourth step aims at helping learners benefit from class discussions to accommodate the new concept and resolve any existing conflicts. The fifth step aims at helping learners extend the concept by making connections between the concept they have learned in class and other related concepts and ideas. Finally, the sixth step aims at helping learners go beyond the concept through pursuing new ideas related to the concept they have learned in class (Stepans, 1994; 2011).

According to Stepans, this model is a research-based model that can be used by many researchers and teachers. Also, this working model calls for constructing a cooperative-learning environment that uses multiple sources of data in a way that encourages learners to confront their existing preconceptions, work toward accommodating the new concept and develop metacognitive skills (Stepans, 2011).

Furthermore, Stepans and his colleagues wrote a book entitled "Teaching for K-12 Mathematical Understanding Using the Conceptual Model". Authors of this book argue that using Stepans model in mathematics classrooms is aligned with the NCTM standards. This book includes 112 lesson plans that use Stepans' Conceptual Change Model in resolving students' mathematical misconceptions and developing students' metacognitive mathematical skills (Stepans, Schimidt, Welsh, Reins, & Saigo, 2005).

Review of Related Literature

A careful look at the research literature shows that studies about conceptual change strategies can be grouped according to two major themes. Some researchers such as Toka & Askar (2002), Cetin (2003), Vamvakoissi & Vosniadou (2004), Harber (2005), Baser (2006), Prediger (2007), Beerenwinkel, Parchmavn, & Crasel (2011), Koparan , Yodiz, & Kogee

(2011), Gurefe, Yarrar, Pazarbasi & Es (2014) focus attention on the effectiveness of the conceptual change environment on students' modification of their alternative concepts and on their understanding of subject matters. The other group of researchers such as Lowery (2002), Ivers (2006), Rolka, Rosken & Liljedah1 (2007), Zepra, Kajander, & Barneveld (2009), Kabaca, Karadag & Aktumen (2011) give a particular attention has to studying the effectiveness of using conceptual change strategies during teacher-education programs.

In Jordan, Al-Nemri (2011) studied the impact of using Stepans' model of conceptual change on the modifications of alternative biological concepts and the acquisition of science skills among 7th grade students. Overall findings showed a difference in students' modifications of alternative biological concepts and in the acquisition of science skills in favor of Stepans' model group.

The current study investigates the effect of using Stepans' model of conceptual change on students' modification of alternative mathematical concepts and on their ability of solving mathematical problems. Instructors of mathematics at all grades and levels, mathematics education researchers, and publishers of mathematics textbooks could benefit from this study.

Rationale and Importance of the Study

Looking carefully through the conceptual change strategies and their applications in classrooms indicate that most researchers who used conceptual change strategies are teachers and model builders at the same time. They extend their methodology to classroom environment by conducting classroom teaching experiments. They employed a different methodology called "teaching-experiment methodology" and they based their research on the foundation of subjectivist paradigm (Simon, 1995; Mackenzie, & Kmipe, 2006; Tobin & Tippins, 2009). One of the strengths of this methodology is that it takes place in a classroom setting. Thus participants of their studies are less sensitive to the introduction of the treatment. However, these research studies rarely focused on the comparison between conceptual and non-conceptual change strategies. Therefore, further investigation is needed to examine the differences between teaching and learning mathematics based on the conceptual and non-concptual change strategies.

Purposes of the Study

The present study investigates the effect of using Stepans' model of conceptual change on students' modification of mathematical concepts and on their ability in solving mathematical problems. In particular, the study has the following two research questions:

1)What is the effect of using Stepams' model of conceptual change on the modification of alternative mathematical concepts for 9th grade students?

2) What is the effect of using Stepans' model of conceptual change on problem solving ability for 9th grade students?

Definitions of Terms Used in the Study

1) Alternative Mathematical Concepts: Incorrect mathematical concepts that learners have as a result of inadequate teaching or informal learning from everyday experiences. These alternative concepts always impede learners from understanding of mathematical concepts or developing deep understanding of mathematical thinking skills.

2) The Modification of Alternative Concepts: A process by which the learner exchanges his\her existing misconceptions by correct concepts. In the current study, the first instrument was used to measure students' modification of alternative mathematical concepts.

3) Mathematical Problems: Nonroutine problems that are related to a specific mathematical content. Those problems are more difficult to solve than routine mathematical exercises and their solutions are not known in advance by learners. In the current study, the second instrument was used to measure students' problem solving ability.

Methodology

The Sampling Strategy

The current study was implemented on 9th grade students in two different sections in a secondary school in Amman (the capital city of Jordan). In this case, it is impractical to use the random assignment procedure of students from a population to the conceptual change group (CCG) and the non-conceptual change group (NCCG), so this study dealt with intact classes. However, the treatments were randomly assigned to the classes so that the CCG could contain one section and the NCCG could contain the other section. The sample size was 60 students (30 students in CCG and 30 students in the NCCG). The teachers and students of the two sections volunteered to participate in the study.

Statistical Treatment

To create a conceptual change environment for the CCG, Stepans' conceptual change model was used. Classroom activities that cover the unit of analytical geometry for ninth grade students were developed based on the six-steps of Stepans' model. Also, before starting the treatment, a ten-hour workshop was held between the first researcher and the teacher in the CCG class. During this workshop, the researcher discussed the goals of the research and the strategy of using Stepans' conceptual change model. On the other hand, the learning environment in the NCCG is a typical session in which students study the mathematical concepts in a regular learning environment where teacher talk is the major teaching strategy used.

Instruction took place for a period of four weeks and classroom observations were conducted by the first researcher to confirm that both groups spent approximately the same amount of time on the teaching of the analytical-geometry unit and the CCG did not have additional time for the teaching of the same unit. Also, for the CCG, observations were made to confirm that the teaching and learning strategy is based on Stepans' conceptual change model.

Data Sources and Credibility Issues

In this study, two major instruments were developed in the unit of analytical geometry. The first instrument is a mathematical concept test and the second instrument is a problem solving test. The first instrument is a test of twenty five multiple choices items and the second instrument is a test of eight essay non-routine problems . These two instruments were administered before starting the treatment and used as covariate variables for research questions1 and 2 respectively. Then, they were administered at the end of the treatment and used as dependent variables to measure students' modification of alternative mathematical concepts and students' problem solving abilities respectively.

Eight expert judges in the field of mathematics and mathematics education were kindly requested to examine the content validity of these two instruments. Therefore, these instruments were considered content valid as they were designed to measure students' modification of alternative mathematical concepts (the first instrument) and students' problem solving abilities (the second instrument). Moreover, Cronbach alpha coefficient was used to estimate the internal reliability of these two instruments. The values of Cronbach alpha coefficient were found to be 0.87 and 0.79 for these two instruments respectively. These values were considered quite high for this type of instruments.

An analysis of covariance (ANCOVA) was implemented to analyze data. Since intact groups were used, ANCOVA can be used to adjust the pre-existing differences between the two groups. Intact groups were chosen because of the impracticality of randomly assigning students to the CCG and the NCCG.

ANCOVA, which combines regression and analysis of variance, controls the effect of an extraneous variable and explains more of the error variance in the study. The covariates for the study were scores on the pretests, whereas the dependent variables were scores on the posttests. The treatment conditions were monitored by observing both groups to verify that

Stepans' conceptual change model was not used in the NCCG while it was solely used in the CCG.

Results, Discussions of Findings and Conclusions

To answer the first research question: "What is the effect of using Stepams' model of conceptual change on the modification of alternative mathematical concepts for 9th grade students?", a null hypothesis states that there is no difference in the adjusted mean posttest scores on modification of alternative mathematical concepts for 9th grade students in the conceptual group (CCG) and non-conceptual change group (NCCG).

In this case, the pretest given at the beginning of the treatment was used as a covariate, whereas the posttest given at the end of the treatment was used as the dependent variable.

Table (1) gives the counts, means and standard deviations for each group in the pretest and the posttest. This table shows that both groups had medium pretest scores with high variations among scores (The mean score for the CCG was 60.30 with a standard variation of 13.81and the mean score for the NCCG was 57.73 with a standard variation of 13.67). This table also shows that both groups gained more scores in their posttest after the unit of analytical geometry had been taught. But students in the CCG gained higher scores in the posttest than students in the NCCG (The mean score for the CCG became 72.07 with a standard variation of 18.27 and the mean score for the NCCG became 63.53 with a standard variation of 19.33). Table(1) shows also that the adjusted mean score for the CCG is 71.42 and the adjusted mean score for the NCCG is 64.17.

Table (1) Descriptive Statistics For the Pre-and the Posttests

Group	Count	Pre test		Post test		The Adjusted Mean
		Mean	SD	Mean	SD	
NNCG	30	57.73	13.67	63.53	19.33	64.17
CCG	30	60.30	13.81	72.07	18.27	71.42

Note. The maximum possible score =100

In accordance with Table (1), the CCG had a higher mean posttest score than the NCCG. In order to test whether this difference is significant, an analysis of covariance (ANCOVA) was used. Table (2) summarizes the results of ANCOVA for the posttest.

Table (2) The Analysis of Covariance Summary Table

Source	DF	SS	MS	F	P
Covariate	1	2516.17	2516.17	8.001	0.041
Between Groups	1	1752.26	1752.26	2.087	0.003
Within Groups	57	18.52.33	215.13		

*P< 0.05

Based on Table (2), the null hypothesis is rejected at.05 level (F = 2.087, Sign. of P. = .003). This indicates that taking the pretest as a covariate and the posttest as a dependent variable implies that, at the end of this treatment, the CCG outperformed the NCCG on the posttest scores.

To answer the second research question ”What is the effect of using Stepans' model of conceptual change on problem solving ability for 9th grade students?, a null hypothesis states that there is no difference in the adjusted mean posttest scores on problem solving ability for 9th grade students in the conceptual group (CCG) and non-conceptual change group (NCCG).

In this case, the pretest given at the beginning of the treatment was used as a covariate, whereas the posttest given at the end of the treatment was used as the dependent variable.

Table (3) gives the counts, means and standard deviations for each group in the pretest and posttest. This table shows that both groups had very low mean pretest scores with high variations among scores (The mean score for the CCG was 30.30 with a standard variation of 13.81 and the mean score for the NCCG was 27.73 with a standard variation of 13.67). This table also shows that even though both groups still had low posttest scores with high variations among scores, students in the CCG gained more scores in the posttest than students in the NCCG (The mean score for the CCG became 48.10 with a standard variation of 14.49 while the mean score for the NCCG became 33.03 with a standard variation of 14.16). Also, Table 2 shows that the adjusted mean score for the CCG is 34.29 whereas the adjusted mean score for the NCCG is 26.64.

Table (3) Descriptive Statistics for the Pre-and the Posttests

Group	Count	Pre test		Post test		The Adjusted Mean
		Mean	SD	Mean	SD	
NCCG	30	27.73	13.67	33.03	14.16	26.64
CCG	30	30.30	13.81	48.10	14.49	34.29

Note. The maximum possible score =100

In accordance with Table (3), the CCG had a higher mean posttest score than the NCCG. In order to test whether this difference is significant, an analysis of covariance (ANCOVA) was conducted. The following Table (4) summarizes the results of ANCOVA for the posttest.

Table (4) The Analysis of Covariance Summary Table

Source	DF	SS	MS	F	P
Covariate	1	5352.59	5352.59	58.81	0.000
Between Groups	1	2356.63	2356.63	25.89	0.000
Within Groups	57	5187.73	91.01		

*P< 0.05

As Table (4) shows, the null hypothesis is rejected at.05 level (F = 25.89, Sign. of P. = .000). This indicates that taking the pretest as a covariate and the posttest as a dependent variable implies that, at the end of this treatment, the CCG outperformed the NCG on the posttest scores.

In Sum, overall results indicate that a significant difference in the adjusted mean posttest scores was found between the two groups in favor of the conceptual change group. The CCG outperformed the NCCG in terms of students' modification of alternative mathematical concepts and of students' problem solving ability.

These results are consistence with the basic tenets of the conceptual change models and with overall findings of other related research studies such as Toka & Askar, (2002), Tirosh & Tsamir (2004), Vosniadou, (2004), Harber, (2005), Vamvakoissi & Prediger (2007), Blake & Pope (2008), Linn & Burbules, (2009), Wheatley (2009), Caroline Learning, (2011), Koparan et al, (2011), Vamakoussi, et al., (2013), Vosniadou; (2013), Vosniadou & Kampylis (2013).

There are at least two possible reasons which are based on Stepans' model of conceptual change and could be given as evidence to support the conclusion made. First, the nature of learning tasks which were organized around the learners' alternative mathematical concepts. These learning tasks help learners exchange these alternative concepts with the correct concepts. Second, the nature of learning environment which was embedded in Stepans' model. This learning environment encourages the teacher to create a learning environment that involves social negotiations among learners which encourage them to confront their existing preconceptions and work toward accommodating the new concept and developing metacognitive skills. As a result, they acquire a deep understanding of the mathematical content and its related mathematical problems.

In conclusion, the conceptual-change learning environment offers learners opportunities to reflect and negotiate mathematical meaning with their classmates which help them become stronger learners in their own, so each learner become much better prepared to exchange his\her alternative mathematical concepts with correct mathematical concepts and solve problems which were beyond his/her current ability.

Classroom Implications and Suggestions for Further Research

From the results of this study and the discussions made so far, many classroom implications and suggestions for further research could be provided. Some of these are as follows:

1) Since intact groups were used, findings of this study may reflect actual classroom practices. Therefore, mathematics teachers and publishers of textbooks at all grade levels are encouraged to create a constructivist-learning environment as described in Stepans's conceptual change model.

2) In the present study, classroom observations were conducted to confirm that the learning environment in the CCG is based on Stepans' conceptual change model and a typical learning environment in the NCCG. These observations revealed that students in the CCG became more engaged in classroom discussions as compared with students in the NCCG. This tentative finding may lead to the conclusion that the instruction in the CCG encourages learners to take more responsibility for their learning as it compares with instruction in the NCCG. However, studying the differences between the CCG and the NCCG group with instruction as a variable was beyond the scope of the present study and could be appropriate for further research.

3) This study dealt with the differences between conceptual and non-conceptual change learning environments in terms of students' modifications of their alternative mathematical concepts and of their ability of solving mathematical problems. But there are other differences that could be investigated among students in both groups such as their critical thinking skills as a metacognitive variable or their motivations toward learning mathematics as an affective variable and they could be appropriate for further research.

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