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The Role of the Synectics Model in Enhancing Students' Understanding of Geometrical Concepts

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Achievement of our students in geometry is attributable to several reasons. The researcher's personal experience in the field and review of related literature revealed that one of the major reasons for low achievement is low understanding of geometry concepts. So a study was conducted to explore the effect of the Synectics model of teaching on the conceptual understanding of the geometry of a cohort of grade eight students. The methodology employed was a form of quasi-experimental study known as Nonequivalent Control group design. The sample was comprised of two intact control groups, (N=35) and experimental, (N=33). Two schools were selected among high schools of district Haripur where the researcher sought permission to conduct the study. The instrument employed to assess development was a self-developed achievement test based on the geometry portion (Fundamentals of Geometry) in the eighth class mathematics textbook. Items were developed according to the knowledge, application and synthesis levels of Bloom's taxonomy. The results of the study revealed that after analogy integrated lessons students were able to: (i) redefine and recall the concept in a new way using their own words; (ii) relate learnt knowledge to their daily lives; (iii) apply learnt knowledge in daily lives; and, (iv) synthesize the concept in a better way. This clearly indicates that use of analogy enhanced students' understanding of geometrical concepts and their higher order learning skills in geometry.

Introduction

The achievement of students in secondary school mathematics is often very low not only in Pakistan but also across the globe due to several complex reasons. These include issues pertaining to teachers' poor knowledge and foundation in mathematics, the unsatisfactory pedagogical competence of mathematics teachers, and poor perception of mathematical knowledge (Amirali & Halai, 2010). Prevailing methods for teaching mathematics are not compatible with on ground realities and demands of everyday life (Bibi, 2009). Instructional strategies used by our teachers are often unintelligible for the students (Confrey, 1990). This creates an environment for teaching and learning mathematics that is not too conducive and confusing for students who often become disengaged from the learning the discipline perceiving it as a boring subject (Bibi, 2009; Yadav, 1992). Knowing simple alternative methods to deal with areas of potential difficulty enhances creative teaching practices; unfortunately, most teachers are unaware of this factor they do not adopt different techniques for solving the same problems (Singha, Goswami, & Bharali, 2012). Inadequate design of instruction is one of the major problems of mathematics education (Carnine, Jitendra, & Silbet, 1997). There is often a gap between the level of teacher language and explanations provided and the level of extant student understanding; this appears to be especially true in the case of geometry (Luneta, 2015). All these problems result in the poor performance of students and the consequent poor results for the majority of students. Even if they are successful in passing the Secondary School Certificate (SSC) examination, they frequently remain disconnected from the subject (Government of Pakistan, 2009).

In order to improve the situation, our teachers need to be made aware of common difficulties that hinder quality Mathematics education. Our teachers must be skilled in using a wide variety of strategies, techniques and activities to help build prerequisite knowledge and strengthen connections between what students already know about a concept and what more they need to know. This may involve discussion, story-telling, role-playing, the use of visual illustrations, encouraging pattern seeking, using examples from real life, and the use of analogies, metaphors and explanations (McLaren, 2010).

The government of Pakistan is emphasizing in-service training of math teachers with due attention being paid to developing conceptual understanding (GoP, 2009). Several measures such as refresher courses, reforming the examination system, reforming curricula, developing low and no cost audio-visual aids have been adopted to enhance the quality of education. But all such efforts have failed due to one reason or another, the central one being that remains ideas on paper. In actual practice students' performance in mathematics is below expected levels for several reasons including the incompatibility of textbooks with students' cognitive levels of development, students' low cognitive levels, the predominance of memory-based learning, the nature of the examination system, and the incapability on the part of teachers to use innovative methods of teaching.

Rationale of the Study

One of the major problems stated above is low conceptual understanding in mathematics in general and in geometry in particular, perhaps due to students' perceptions that it is an irrelevant subject disconnected from everyday life. One possible solution to this problem is to use the Synectics model to teach geometrical concepts. Various studies have validated the use of the Synectics model for clarifying concepts and concept development (Gordon, 1961; Evans, 1996; Dastjerdi, 2001; Duin, Hauge, & Thoben, 2009; Kallonis & Sampson, 2011; Chandrasekaran, 2014), and for developing understanding of new concepts (Heid, 2008; Sierra-Jones, 2001; Duin, Hauge, & Thoben, 2009; Kallonis & Sampson, 2011; Shabani, 2011; Chandrasekaran, 2014; Girija, 2014; Yousefi, 2014).

The model is relatively unknown and underused in Pakistan and no significant research has been carried out concerning the application of the Synectics model for concept development in geometry. The review of the related literature leads to the conclusion that there is a need to explore the utility of the Synectics model and see how it might be applied to the development of conceptual understanding in geometry. The study will draw the attention of educational researchers in Pakistan to the potential benefits of this interesting model.

Statement of the Problem

The problem under investigation was to analyze the role Synectics model in enhancing students' understanding of concepts of geometry.

Objectives

Following were the objectives of the study.

1. To determine the baseline understanding of selected concepts of the geometry of 8^{th} class students.
2. To determine the effectiveness of the Synectics Model in enhancing students' understanding of selected concepts in geometry.

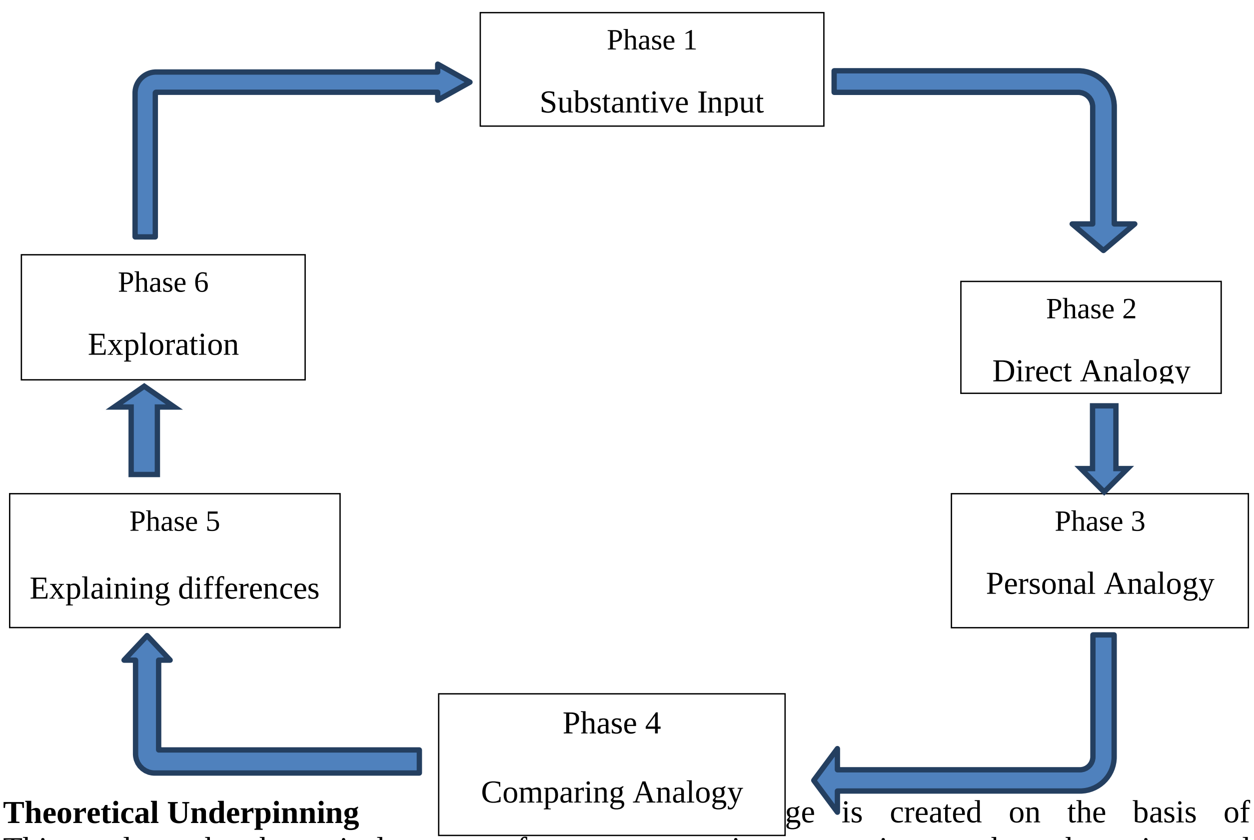
Review of Related Literature

In this study, the Synectics model of teaching was used as an independent variable. This model was developed by William J. J. Gordon and his colleagues in 1961. In the words of Gordon and Poze (1981), Synectics is a creative word coined to mean "amalgamation of different and apparently irrelevant elements". It means the Synectics process is involved in bringing diverse and apparently irrelevant and disparate elements together to develop fresh ideas about a concept. The model invokes a creative process which is premised on the mind's remarkable capacity to discover and unifying themes in seemingly different and disconnected ways (Gordon, 1961; Gunter, Estes and Mintz, 2007), drawing together seemingly irrelevant elements of thought (Weaver & Prince, 1990).

There are primarily three Synectics models: the original Synectics model, the corporate Synectics model, and the K-12 Synectics model (Gunter et. al., 2007). In the present study, the K-12 Synectics model was used. The process of K-12 Synectics model follows two basic activities; making the familiar strange/creating something new and making the strange familiar (Gunter et al., 2007). The activity "making the strange familiar" was used in the current study because, according to Seligmann (2007), it often begins with the teacher's direct guidance. This prevents students from drawing inappropriate analogies that could result in their learning new material incorrectly. In this study, this activity was used. Figurative representation of steps of this activity is given below.

Synectics Process

(Making the Strange Familiar)



Theoretical Underpinning

This study seeks theoretical support from three main theories – experiential learning theory, situated learning and constructivism. Experiential learning theory suggests that ge is created on the basis of previous experiences through active and personal involvement. The main theme of situated learning is that learning is a function of the activity, content and the culture in which it occurs or where it is situated (Lave & Wenger, 1991). Social, active interaction is vital for situated learning to occur. The learner engages in real daily life activities with other learners of similar interests. Individual constructivism asserts that knowledge can be constructed, through active involvement, drawing upon the organized experiences (schema) of what learner already knows or has learnt (Pritchard & Woollard, 2010). During this study, previous experiences of students' everyday lives were used as the opportunity to provide each learner with the opportunity to construct new knowledge on the platform of previous experiences. Learners used analogies from their local lives and developed an understanding of new geometry concepts. Each learner was personally engaged in the knowledge construction process. As all analogies and examples were derived from the everyday local experiences of the learners, they were enthusiastic and motivated and actively involved in the process of developing an understanding of new concepts.

Review of Previous Researches

Brief review of previous studies reveal that numerous studies validate the use of the Synectics model and analogies as an effective method for developing conceptual understanding (Dilber & Duzgun, 2008; Gay, 2008; Heid, 2008; Calik, Ayas, & Coll, 2009; Duin, Hauge, & Thoben, 2009; Kallonis & Sampson, 2011; Ramos, 2011; Sierra-Jones, 2011; Shabani, 2011; Souza-Hart, 2011; Wichaidit, Dechsri, & Chaivisuthangkuru, 2011; Ugur, Dilber, Senpollat & Duzgun, 2012; Chandrasekaran, 2014; Girija, 2014; Yousefi, 2014; Arifiyanti & Wahyuningish, 2015). Abstract concepts are always difficult for learners, particularly for novices. They are unable to comprehend ambiguous, intangible attributes of such concepts. The use of analogy concretizes the attributes of the concept (Newby & Stepich, 1987; Silkebakken & Camp, 1993), serving as a useful tool for teaching, learning, understanding and comprehension of abstract concepts (Bello & Ali, n.d.; Newby & Stepich, 1987; Biermann, 1988; Thiele & Treagust, 1994; Dunican, 2002; Richland, Holyoak, & Stigler, 2004; Calik & Ayas, 2005; Dilber & Duzgun, 2008; Wichaidit, Dechsri, & Chaivisuthangkuru, 2011; Ugur, Dilber, Senpollat, & Duzgun, 2012; Arifiyanti & Wahyuningish, 2015). Analogies also serve as a bridge between new and the already learnt concepts (Gick & Holyoak, 1983) thus making the concept easier to learn (Halpern, Hansen, & Riefer, 1990; Thiele & Treagust, 1994). Analogy acts as a guide for concept formation (Nersessian, 1998). In particular, it is more valuable in learning the concepts pertaining to capacity (Halpern, Hansen, & Riefer, 1990). Apart from learning new concepts, appropriate use of analogy helps learners to see already learnt concepts in a new way (Middleton, 1991). Students can construct their own understanding of the concept (Stepich, Timothy, & Newby, 1988) or generate new and novel ideas about the concepts (Dahl & Moreau, 2002). Regular and appropriate use of analogy can facilitate concept learning (Thiele & Treagust, 1994; Newby, Ertmer, & Stepich, 1995) through the creation of anomalies in a conceptual framework (Mason, 1996).

Methodology

The design of the study took the form of a quasi-experimental method known as Non-equivalent control group design.

Sample

Two intact groups of Grade 8 students from two boys' high schools in the Haripur (KPK) district were selected. These schools were selected on the basis that the researcher could obtain permission to conduct the study. The selected schools were representative of typical government high schools in terms of facilities, the school environment, socio-economic status of the students, their family background, teachers' qualification and the process of their recruitment and promotion, and the provision of audio-visual (AV) aids.

Instrument

The instrument used in the study was a self-developed achievement test in geometry. Items, based on Bloom's taxonomy were developed in keeping with the application, analysis, synthesis, and evaluation levels of the taxonomy. It contains questions to check (a) factual knowledge of the students, (b) their ability to apply mathematical knowledge by using questions not drawn from the textbook, (c) their ability to connect mathematical knowledge to daily life.

Table 1

Test specification for Fundamentals of Geometry

Topics	Group 1 Knowledge/Understanding	Group 2 Application	Group 3 Analysis /Synthesis/ Evaluation	Total
Parallel Lines	1	2	1	4
Polygon/ Parallelogram	1	2	1	4
Regular Pentagon	2	2	2	6
Regular Hexagon	1	2	2	5
Regular Octagon	2	2	2	6
Total	7	10	8	25

Our purpose was to analyze the role of the Synectics Model in developing higher order skills But to solve questions pitched at the taxonomic levels, knowledge and understanding of these concepts was prerequisite. Therefore some items requiring students to demonstrate their knowledge and understanding were also developed.

Validation of Teaching Method

As the researcher was not expert in using the Synectics model and no such precedent was present in Pakistan, therefore to trial the method, he developed a model lesson in the light of the guidelines given by its developers and presented it in a school, which was not included in the population, in front of a committee of experts from the faculty. In the light of the feedback and guidance of the committee, the researcher improved the model lesson and presented it again in front the committee to strengthen its validation.

Table 2

Comparison of control and experimental groups before treatment

Unit	Level	Total Scores	Group	N	Mean	SD	*t*	df	*p*
Fundamentals of Geometry	Knowledge	21	Control	35	.00	.00			
			Experimental	33	.09	.52	-1.00	32.00	.32
	Application	41	Control	35	.00	.00			
			Experimental	33	.00	.00	-	-	-
	Synthesis	39	Control	35	.00	.00			
			Experimental	33	.12	.69	-1.00	32.00	.32
	Overall	101	Control	35	.00	.00			
			Experimental	33	.21	.85	-1.42	32.00	.16

Table 2 shows a comparison between the mean achievement scores of control and experimental group before treatment. For the knowledge level items, Levene's Test for Equality of variances gives the value of significance equal to .03 which was less than .05, so equal variances were not assumed. *p*-value for both control and experimental group was .32 [N = 35, Mean = .00 and SD = .00 for control group and N = 33, Mean = .09, SD = .52 for experimental group. *t* value for both control and experimental groups was *t* (32.00) = -1.00 at $p > .05$]. As the *p*-value was greater than .05, there was statistically no significant difference between the groups before the treatment in knowledge level items scores.

For the application level items, t could not be computed because standard deviations for both groups were 0. But the mean score indicated that both groups were equal in achievement before treatment.

For the synthesis level items, Levene's Test for Equality of variances gave a value of significance equal to .03 which was less than .05, so equal variances were not assumed. *p*-value for both control and experimental group was .32 [N = 35, Mean = .00 and SD = .00 for control group and N = 33, Mean = .12, SD = .96 for experimental group. The *t* value for both control and experimental groups was *t* (32.00) = -1.00 at $p > .05$]. As the *p*-value was greater than .05, there was statistically no significant difference between the groups before the treatment in synthesis level item scores.

The overall comparison before the treatment between the mean scores of control and experimental group on three Bloom's cognitive levels (Knowledge, application and synthesis) of educational objectives is also provided in the table. For an overall comparison, Levene's Test for Equality of variances gave a value of significance equal to .003 which was less than .05, so equal variances were not assumed. The *p*-value for both control and experimental group was .16 [N = 35, Mean = .00 and SD = .00 for control group and N = 33, Mean = .21, and SD = .85 for the experimental group. The *t* value for both control and experimental groups was *t* (32.00) = -1.42 at $p > .05$]. As the *p*-value was greater than .05, there was statistically no significant difference between the groups before the treatment

Table 3

Comparison of control and experimental groups after treatment

Unit	Level	Total Scores	Group	N	Mean	SD	*t*	df	*p*	Eta^2
Fundamentals of Geometry	Knowledge	21	Control	35	9.74	2.66	-23.96	66	.00	.90
			Experimental	33	20.91	.29				
	Application	41	Control	35	27.83	4.95	-15.02	66	.00	.78
			Experimental	33	40.82	.39				
	Synthesis	39	Control	35	.11	.67	-252.75	34.0	.00	.99
			Experimental	33	29.00	.00				
	Overall	101	Control	35	37.69	6.85	-44.28	66	.00	.96
			Experimental	33	90.73	.51				

Table 3 compares the mean achievement scores of the control and experimental group after treatment on the knowledge level items. For the knowledge level items Levene's Test for Equality of variances gave a value of significance equal to .00 which was less than .05, so equal variances were not assumed. The *p*-value for both control and experimental group was.00 [N = 35, Mean = 9.74 and SD = 2.66 for control group and N = 33, Mean = 20.91, and SD = .29 for experimental group. The *t* value for both control and experimental groups was *t* (66) = - 23.96 at $p < .05$]. As the *p*-value was less than .05, there was the statistically significant difference between the groups after the treatment in knowledge level items scores. The experimental group outperformed the control group with larger effect size ($Eta^2 = .90$) being evident.

For the application level items, Levene's Test for Equality of variances gave a value of significance equal to .00 which was less than .05, so equal variances were assumed. The *p*-value for both the control and experimental group was.00 [N = 35, Mean = 27.83, and SD = 4.95 for control group and N = 33, Mean = 40.82, and SD = .39 for experimental group. The *t* value for both control and experimental groups was *t* (66) = - 15.02 at $p < .05$]. As the *p*-value was less than .05, there was the statistically significant difference between the groups after the treatment in the application level items scores. The experimental group outperformed the control group with a larger effect size ($Eta^2 = .78$).

For synthesis level items Levene's Test for Equality of variances gave a value of significance equal to .05, so equal variances were not assumed. The *p*-value for both control and experimental group was.00 [N = 35, Mean = .11, and SD = .67 for the control group and N = 33, Mean = 29.00, and SD = .00 for the experimental group. The *t* value for both control and experimental groups was *t* (34.00) = -252.75 at $p < .05$]. As the *p*-value was less than .05, there was a statistically significant difference between the groups after the treatment in synthesis level items score. The experimental group outperformed the control group with larger effect size ($Eta^2 = .99$).

Overall comparison before the treatment between the mean scores of the control and experimental group on three Bloom's cognitive levels (Knowledge, application and synthesis) of educational objectives is also given in the table. For overall comparison Levene's Test for Equality of variances gave a value of significance equal to .00 which was less than .05, so equal variances were not assumed. The *p*-value for both control and experimental group was.00 [N = 35, Mean = 37.69, and SD = 6.85 for control group and N = 33, Mean = 90.73, and SD = .51 for the experimental group. The *t* value for both control and experimental groups was *t* (66) = - 44.28 at $p < .05$]. As the *p*-value was less than .05, so there was a statistically significant difference between the groups after the treatment. The experimental group outperformed the control group with larger effect size ($Eta^2 = .96$).

Discussion

Analogies, as a tool for learning, are a long-standing linguistic resource for human beings. Learning, by perceiving similarities across phenomena is a strategy for promoting conceptual clarity. The conscious use of analogies for formal learning in the teaching/learning process was employed in this study through the selection and development of analogies that were helpful for understanding geometrical concepts. The results revealed the substantial contribution of using this approach for learning geometrical concepts. Following are some implications of using analogies in the development of conceptual understanding.

Increased Interest

Students chose such analogies from their everyday experiences. These analogies increased their interest level. This factor contributed more the high achievement of students in the experimental group. This finding accords with the results of Weaver & Prince (1990), Benkoski & Greenwood

(1995), Venville & Treagust (1996), Seligmann (2007), Patil (2012), Chandrasekaran (2014), and Fatemipour & Kordnaeej (2014).

Reduced Abstraction

The use of analogies from students' everyday experiences reduced the abstraction level of concepts enabling students to see mathematical concepts in a more concrete and tangible form. Their level of imagination to see relationships improved markedly. This result accords with the results of Heid (2008), Chandrasekaran (2014) and Abed, Davoudi, and Hoseinzadeh, (2015). Due to the reduced abstraction level, abstract concepts became more concrete and tangible. As a result, students performed highly in their understanding of the abstract concepts. This result aligns with the findings of Newby and Stepich (1987), Biermann (1988), Thiele and Treagust (1994), Dunican (2002), Kaper and Geodhart, (2003),

Enhanced Group Interaction

The Synectics model of teaching enhanced group interactions during the treatment. Both student-student and teacher-teacher interaction worked at an optimum level. This, in turn, contributed to the conceptual understanding and academic achievement/attainment of the experimental group students in the posttest.

Time Management

Time management is always a serious issue while using naturalistic methods. Lessons of the study were arranged on the bases of selected concepts. Analogies used for one concept transferred to the understanding of other related concepts. While studying successive concepts, analogies used in earlier concepts helped could be "recycled" for greater teaching proficiency.

Selection of Relevant Analogies

The selection of apt analogies was another issue. Thorough knowledge of the things present in the environment and careful analysis of the analogy used, this issue of appropriateness was resolved over time.

Conclusion

Results of the study lead to the conclusion that equal ability students in the experimental group outperformed the control group in the post-test with a larger effect size being demonstrated. The students' achievement was high which can be attributed to the contribution of the Synectics model of teaching. Use of this model in the classroom enhances the understanding of geometry concepts. The use of analogies reduced the level of abstraction of abstract concepts, contributed to their understanding of abstract concepts of geometry and in turn enhanced higher order thinking skills of students in the experimental group.

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