EFFECT OF USING TANGRAM PUZZLES ON THE ACHIEVEMENT OF STUDENTS IN GEOMETRY AT PRIMARY LEVEL

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Abstract

Geometry is basically concerned with conversion of graphics in space. The spatial abilities of the students can be enhanced through geometrical teaching. In geometry, the teaching and learning process can be made interesting by using puzzles games. The present study was conducted to study the effect of tangram puzzles on students' achievement in geometry at primary level. The study was experimental in nature. The experiment was conducted in a private school of urban area of district Rawalpindi. There were total 46 students in grade four. These were divided into two groups (controlled group, experimental group). Duration of the experiment was three weeks. Cognitive domain of Bloom Taxonomy was selected to evaluate the students' achievement. Four levels of cognitive domain were selected which were Knowledge, Comprehension, Application and Analysis. For the analysis of data independent sample t-test was used. Significant difference in the achievement of students of both the group (controlled and experimental) was observed at Knowledge, Application, Analysis level of Bloom Taxonomy. While no significant difference in students' achievement was observed at Comprehension level. It was concluded that tangram puzzles are helpful teaching aids. It is being recommended that these puzzles should be added in teachers' training programs.

Keywords: *tangram puzzles, cognitive domain, geometry*

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1. Introduction

As the matter of fact no one can deny the importance of mathematics as a subject same is the case with geometry. It is the very important branch of mathematics. The word “Geometry” is the combination of two words “Geo” and “Metry”. American dictionary of culture defined geometry as “The branch of mathematics that treats the properties, measurement and relations of points, lines, angles, surfaces, and solids” (Webster, 2017). In mathematics geometry is concerned with the geometrical shapes, their identification and properties. In early 1950s Piaget and Inhelder did work on the developmental levels of children’s geometric understanding in "The Child's Conception of Space" (Piaget, 1967). “Geometry is helpful for the students in the sense that through geometrical thinking students can understand the world in which they live in a better way” (Pensen, 2003).

Puzzles are helpful in increasing the problem-solving abilities, independent learning abilities and motivation in students (Badger & Medina, 2015). Games can be used to enhance the geometrical thinking in students (Lee, Huang, Chou, Sun, Yeh, Huang & Chen, 2008). For the teaching of geometry tangram puzzles are helpful in developing children’s observation, shape analysis, imagination and logical thinking (Chen, 2010).

While teaching of mathematics the neglected area is geometry. The poor performance of students in geometry is due to lack of motivation towards learning and understanding of geometrical concepts and absence of required facilities (Adolphus, 2011). It is very important branch of mathematics and needs some special methods for the clarification of concepts such as Area, perimeter, equality of sides of geometrical shapes etc. For the proper understanding of geometry, it is important that the subject matter presented to the students is attractive and interesting (Koman, 1986). As being a developing country, we need to introduce such sort of supporting learning material which is cheap and easily available. Tangram is such a supporting material and it is very effective in clarifying the basic geometrical concepts (Bohning, 1997).

1.1 Objectives of the Study

1. To explore the effect of tangram puzzles on students' achievements in geometry.
2. To compare the achievement of the students taught using tangram and without tangram puzzles.
3. To explore the effect of tangram on students' achievement at different levels of Bloom Taxonomy.
4. To compare the gender wise achievement of the students taught using tangram puzzles.

1.2 Hypotheses

Two null hypotheses were formulated to guide the study:

H_{01}: There is no significant difference between the students' achievement at Knowledge, Comprehension, Application and Analysis Level when taught by using tangram puzzles and taught without the use of tangram puzzles.

H02: There is no significant gender wise difference between the students' achievement when taught by using tangram puzzles.

1.3 Significance of the study

Researches showed that most children can learn and understand mathematics. Even before the entrance of the children in formal primary school, some children can grasp the concepts and ideas that provide the base to more complex mathematical understanding. Thus, researcher tried to find a way which will be useful for the teachers in explaining the geometrical concepts. And it will be helpful for the curriculum developers of teachers' training programs to include such teaching aids in their curriculum for the teaching of mathematics. So, that students can study geometry with interest and will be motivated towards learning and understanding of geometrical concepts.

1.4 Delimitations

The study was delimitated to the cognitive domain of Bloom taxonomy and further delimited to the first four levels of cognitive domain which were Knowledge, Comprehension, Application and Analysis.

2. Literature Review

The present age is the age of science and technology. New methods and techniques are in practice for the teaching of mathematics especially geometry. The concepts of 2D and 3D shapes can be best explained to the students using computer based programs (Sinclair & Bruce, 2015). As geometry is basically concerned with the graphics, space, shapes etc. these concepts can be best understood by the students with the use of games either on computer or physically played by the students as tangram puzzles.

2.1 History of Tangram

The old name of tangram was "Qiqiaoban". It is an old Chinese game. It consists of seven tans where tans mean shapes. The main objective of tangram puzzles is to make different shapes by using its entire seven pieces (Elffers, 1976). Tangram puzzles may have roots in the Yanjitu furniture set of song dynasty which was introduced by Siming Huang. The oldest printed references were found in Chinese book which was written in 1813, in the regime of Jiaqqing Emperor (Slocum, 2003). In west, the word tangram was used by Thomas Hill in 1848. Tangram puzzles consists of one small square, two small congruent triangles, two large congruent triangles, one medium size triangle and one parallelogram.

2.2 Researches on Tangram Puzzles

Recent researches done on tangram puzzles are based on computer supporting games of tangram puzzles. But previous researches consisted of manual work done by students in groups and individually in the class with tangram puzzles. Ronald presented 330 tangram puzzles (Read, 1965). Kubota (1976) made a toolkit consisting of activities of tangram puzzles helpful for teachers. Through tangram puzzles teachers can develop positive attitude towards geometry in students (Bohning & Althouse, 1997). Tangram puzzles are helpful in finding the relations among geometric shapes (Adverbach, 2000).

Tangram puzzles can be used to facilitate the independent learning and enhancing spatial abilities of the students when taught in the computer-supported collaborative learning environment with

Tablet PCs (PinLine, Shao, & Hsiang, 2011). Tangram puzzles can be used to enhance the multitude mathematical concepts and it is an interesting way for enhancing mathematical concepts especially in the field of geometry (Xiaoxi, 2012). In his research article professor Xiaoxi (2012) explained the proof of the theorem "How many convex polygons can you make with the tangram". Visual geometric construction and justification abilities can be enhanced by using tangram puzzles facilitated by computer based GSP (Medhat, Siddo, & Issa, 2011)

A very interesting work done by Dover Adult Learning Center. This center introduced the collection of tangram puzzle activities for the teachers to use these tangram puzzles in the class room with students. These tangram puzzle activities were not just for mathematics but also included tangram puzzle activities for history, language, art, writing, science. These tangram puzzle activities can be adopted to any lessons in classes ranging from level 1 to Diploma classes (Hanson, 2012).

Research done in Malaysia also showed that tangram activities carried out in large class help in-service primary school teachers to develop geometric thinking in students. Tangram activities fostered their interest and appreciation towards geometry (Siew, 2013).

Khairiree (2015) explained that tangrams are helpful in developing creative thinking in students if these are used by GSP to drag, rotate and translate the pieces of tangram to form the given shape. Through such activities students could express their geometric imagination and their understanding of mathematical concepts.

Suan Sunandha Rajabhat University allocated budget to conduct community academic services to mathematics teachers. Under the community services, the budget was allocated to conduct the training workshops on the use of GSP as a tool in mathematics classes. And the action research was conducted to explore the classroom environment of creative thinking in mathematics with Tangram puzzle and (GSP) approaches. Tangram puzzle and (GSP) were introduced in Secondary Mathematics Textbooks in Thailand (Krongthong & Khairiree, 2015).

Tangram puzzles are also kind of teaching aids that can be used for the clarification of geometrical concepts. Present study aimed at to evaluate the effectiveness of tangram puzzles on the students' achievement in geometry at primary level.

3. Methodology of the Study

The present study was an experimental study. The study was conducted for three weeks in Anam Public School situated in urban area of district Rawalpindi. Unit 7 of "Geometry" from the mathematics book of Bluebell series **"Step in Mathematics 4"** was selected for the study. From unit 7 of the book the selected topics were "Points, Line and Line segments", "Parallel, perpendicular and Intersecting Lines", "Rays and Angles", "Classifying Triangles", "Areas of Triangles", "Perimeters of Triangles", "Areas of Quadrilaterals", "Perimeters of Squares and Rectangles".

Pre-test was taken from the topics "*Points, Line and Line segments*", "*Parallel*, *perpendicular and Intersecting Lines*", "*Rays and Angles*"

While post-test was taken from the topics "*Classifying Triangles*", "*Areas of Triangles", "Perimeters of Triangles", "Areas of Quadrilaterals", "Perimeters of Squares and Rectangles*".

The students' achievement was evaluated based on domains of Blooms' Taxonomy. Pre-test and post-test were developed based on Cognitive Domain. For the present study four levels from Cognitive Domain (Knowledge, Comprehension, Application, and Analysis) were selected.

3.1 Research Design

Pre-test post-test design was used for the present study.

3.2 Population

The enrollment of students at primary level in the private schools of district Rawalpindi is 373,741 (CDG, 2010). The population of the study was all the students of grade four studying in the Private schools of district Rawalpindi.

3.3 Sample of the study

The sample of this research study was grade four students of Anum Public School situated in the urban area of district Rawalpindi.

There were two sections of grade four in that school. These two sections were randomly classified as controlled group and experimental group. The detail of sample is given in table #1.

Table 1 Details of Sample

S. No	Group	Total Students	Boys	Girls
1.	Controlled Group	23	12	11
2.	Experimental Group	23	17	6

Researcher taught herself to both the groups. The duration of period was 40 minutes. The learning material for both the groups was also same. The test was validated by the subject Specialists. Three items were discarded from the comprehension level items and two items were changed from application level. The reliability for pretest was 0.78 and for posttest was 0.81.

3.4 Pre-test

Before the start of the experiment the topics "Points, Lines and Line Segments, Parallel, Perpendicular and Intersecting lines, Rays and Angles" were taught. These topics were taught without the use of tangram puzzles to both the groups. And pretest was taken from these topics.

3.5 Post-test

While post-test was taken from the topics "Classifying Triangles", "Areas of Triangles", "Perimeters of Triangles", "Areas of Quadrilaterals", "Perimeters of Squares and Rectangles".

3.6 Beginning of the Experiment

After conducting the pre-test, researcher started the experiment and all the conditions were same except that the experimental group was subjected to the treatment. Topics selected for the experimental study were:

Classifying triangles (depending upon sides, depending upon angles), Area of the Right Triangles, Perimeter of the triangles, Area of the Quadrilaterals, Perimeters of Square and Rectangles. Researcher taught the topic "types of triangle" to the controlled group class

without the use of tangram puzzles. While in experimental group class, researcher introduced to the students about tangram puzzles, how these pieces can be constructed. Then taught the same topic with the help of tangram puzzles to the experimental group class. Activity (figure 1) was conducted to explain the types of triangles with the help of tangram puzzles.

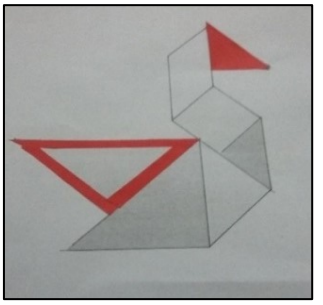

Figure 1: tangram puzzles to explain the types of triangle

The topics; Area and Perimeter were taught to the students of controlled group on the white board. While the same topics were taught to the students of experimental groups with the help of tangram activity as shown in figure 2 and area of triangles were explained by the activity shown in figure 3

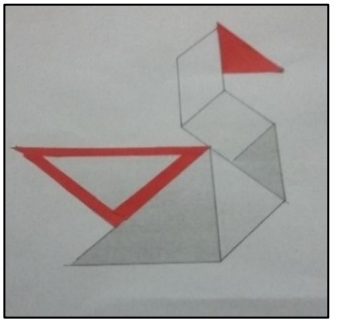

Figure 2 tangram puzzle to explain the concept of area and perimeter

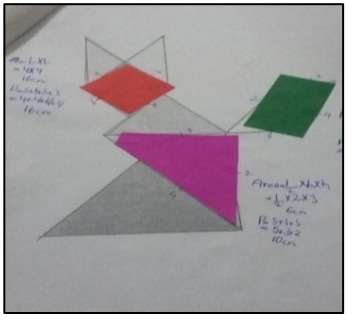

Figure 3 tangram puzzles to explain the concept of area of triangle

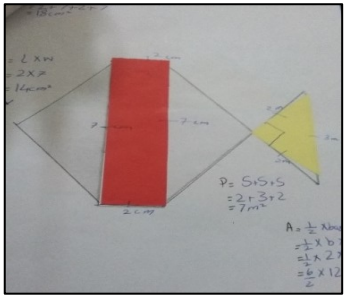

Figure 4: tangram puzzle activities in the class

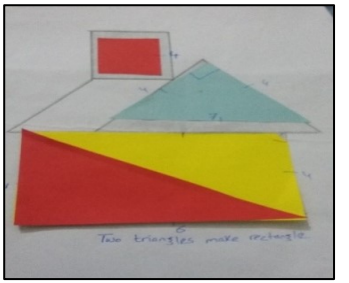

Figure 5: tangram puzzle activity in the class

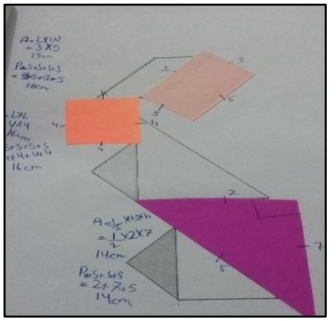

Figure 6: tangram puzzle activity for area and perimeter

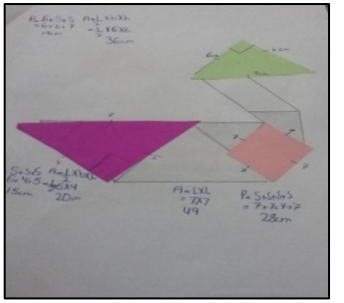

Figure 7: tangram puzzle activity for area and perimeter

Figures 4, 5, 6 and 7 showed different activities done in the class to calculate the area and perimeter of different geometrical shapes with the help of tangram puzzles. Students showed a lot of interest in doing tangram puzzle activities in the class.

3.7 End of the Experiment

After completing the selected learning material post-test was taken from controlled group and experimental group.

4. Analysis of Data

3.8 Pretest Data Analysis

Table 2: Pretest Results of Controlled group and Experimental group

Cognitive Domain Levels	Groups	N	Mean Value	t	df	P value
Knowledge	Controlled	23	4.57	0.725	44	0.472
	Experimental	23	4.74			
Comprehension	Controlled	23	4.76	0.273	44	0.786
	Experimental	23	4.69			
Application	Controlled	23	4.69	0.597	44	0.554
	Experimental	23	4.82			
Analysis	Controlled	23	4.82	0.464	44	0.645
	Experimental	23	4.73			

The above table showed the pre-test data analysis of controlled group and experimental group. It showed that there was no significant difference in students' achievement in geometry when analyzed on 0.05 significant level by using independent sample t-test.

4.2 Post test data analysis

Hypothesis # 1 "There is no significant difference between the students' achievement at Knowledge, Comprehension, Application and analysis Level when taught by using tangram and taught without the use of tangram puzzles".

Table 3 Posttest data analysis of controlled group and experimental group for the four levels of cognitive domain

Cognitive Domain Levels	Groups	N	Mean Value	t	df	P value
Knowledge	Controlled	23	3.73	2.698	44	0.010
	Experimental	23	4.67			
Comprehension	Controlled	23	3.76	0.496	44	0.623
	Experimental	23	4.00			
Application	Controlled	23	3.41	2.858	44	0.006
	Experimental	23	4.39			
Analysis	Controlled	23	8.78	3.947	44	0.000
	Experimental	23	13.08			

The above table showed the analysis of data for controlled group and experimental group for the four levels of cognitive domain at 5% level of significance. Significant difference was found at Knowledge level, Application level and Analysis level. While no significant difference was found at Comprehension level. Although, there was a difference

in mean scores of two groups i.e. the mean score for controlled group was 3.716 and for experimental group was 4.002 but this difference was not significant.

Hypothesis # 2 There is no significant gender wise difference between the students' achievement when taught by using tangram.

The above hypothesis was evaluated by comparing the posttest results of boys and girls of experimental group.

Table 4 Posttest results of experimental group to analyze the gender wise difference in students' achievement in geometry

Cognitive Domain Levels	Gender	N	Mean Value	t	df	P value
Knowledge	Boys	17	4.55	0.052	21	0.959
	Girls	6	4.58			
Comprehension	Boys	17	4.11	0.062	21	0.951
	Girls	6	4.16			
Application	Boys	17	4.11	0.172	21	0.865
	Girls	6	4.00			
Analysis	Boys	17	13.00	0.000	21	1.000
	Girls	6	13.00			

The above table showed the post-test results of experimental group to see the gender wise difference in students' achievements in geometry at four levels of Cognitive Domain. As p value at each level is greater than 0.05 which showed that there was no gender wise significant difference in students' achievement in geometry of experimental group at the four levels of Cognitive Domain. Hence both boys and girls were equally facilitated by the tangram activities done in the class.

Table 5 Comparison of means of Post-test results of controlled group and experimental group for the different levels of Cognitive Domain

Levels of Cognitive Domain	Means of levels of Cognitive Domain for controlled group	Means of levels of Cognitive Domain for experimental group	Differences in means for both the groups
Knowledge	3.73	4.67	0.94

Comprehension	3.76	4.02	0.26
Application	3.41	4.39	0.63
Analysis	8.48	13.03	4.55

The above table showed the level wise difference in the means of controlled group and experimental group. The highest difference was observed in the Analysis Level of Cognitive domain which verified that tangram puzzle activities were helpful in developing the higher order learning in students.

Table 6 Post-test results of experimental group for the concepts of Area and Perimeter at Analysis Level of Cognitive Domain of Bloom Taxonomy

Analysis Level of Bloom Taxonomy	N	Mean	t	df	p value
Area	23	6.87	0.31	44	0.682
Perimeter	23	7.00			

The above table showed the comparison of students' achievement at the Analysis Level for the concepts of Area and Perimeter. Independent sample t-test was applied at 0.05% of level of significance. The results showed that there was no significant difference between the students' achievements in geometry when the results of experimental group were compared at Analysis Level for the concepts of area and perimeter. That showed that both concepts were equally understood by the students with the use of tangram puzzles activities.

5. Findings

Through the analysis of data, the following findings emerged. The details of the findings are as under:

1. The results of pre-test showed that there was no significant difference in the students' achievement in geometry at Knowledge Level, Comprehension Level, Application Level, and Analysis Level (table # 2).
2. The results of post-test showed that there was a significant difference in students' achievement in geometry at Knowledge, Application and Analysis Level when controlled group was taught without the use of tangram and experimental group was taught with the use of tangram. But no significant difference was found at Comprehension level (table # 3).

3. There was no gender wise significant difference in students' achievements in geometry at Knowledge Level, Comprehension Level, Application Level and Analysis Level (table # 4).
4. The highest difference was observed at Analysis Level of Cognitive domain as compared to the Knowledge, Comprehension and Application Level (table # 5).
5. There was no significant difference between the students' achievements in geometry regarding the concept of Area and Perimeter at Analysis Level of cognitive domain (table # 6).

6. Discussion

Results of pretest showed that both the groups had same achievement in geometry.

The overall comparison of the controlled group and experimental group showed that there was a significant difference between the students' achievements in geometry when taught by using tangram puzzles and without the use of tangram puzzles. This is in accordance with the research work done by (PinLine, Shao, & Hsiang, 2011). The results of Chen work also showed that students' interest and learning can be enhanced by using tangram puzzles in geometry. Chen (2010) had done the research with the use of tablets containing tangram puzzles games but in the present research, tangram puzzles were used without tablets. Students played and learnt with hands on experience. This further showed that tangram puzzles were helpful in creating the interest in students without tablets and computer support games (Chen, 2010).

Post-test results showed significant difference in the students' achievements in geometry at Knowledge Level when taught by using tangram. This fact was also explained by Song (2002) according to him puzzles games were helpful in clarifying the mathematical concept.

The results of post-test showed that at application level, there was a significant difference in students' achievement in geometry when taught by using tangram puzzles. This is in accordance with the

research work done by Siew (2013), he also explained that tangram activities are helpful in the development of the creativity in students.

At Analysis Level, the results of post-test showed that there was a significant difference in students' achievement in geometry when taught by using tangram puzzles and without the use of tangram puzzles. Kubota (1976) also explained that tangram puzzles were helpful in developing higher level thinking in students.

Russell and Bolonga (1982) also explained through their research work that tangram activities were helpful in presenting specific mathematical concepts to the students as during the present experimental research topics such as types of triangles depending upon length of sides and types of triangles depending upon angles were taught to the students and the students of experimental group showed better understanding of these concepts. This showed that tangram puzzles were helpful teaching aids as indicated by Xiaoxi (2012), he also explained that tangram puzzles considered to be very helpful in enhancing multitude mathematical and geometrical concepts. He explained convex polygon theorems by using tangram puzzles. The present study focused on the teaching of geometrical concepts of related to triangles and Quadrilateral (types of triangles, area, perimeter of triangles, quadrilaterals). Thus, tangram puzzles were helpful in explaining the simple and complex geometrical concepts (Xiaoxi, 2012).

Students of experimental group showed better result at this stage which is in accordance with the work done by Adverbach (2000), they also proved through their research work that tangram puzzles were helpful in finding the relations between geometrical shapes. Moreover, while constructing triangles students can understand the similarities and differences between different geometrical shapes. That would be helpful for the improvement of psychomotor skills of the students. Medhat, Siddo & Issa (2011) investigated the tangram based study in Radical Constructivism (a way of knowing and learning) and proved that tangram puzzles were helpful in developing creativity in students. She had done it with two students (Medhat, Siddo & issa, 2011). But,

in the present study researcher taught through tangram puzzles to the whole class.

Analysis of data showed that there was no gender wise significant difference at Knowledge, Comprehension, Application and Analysis level. Same results were shown by Badger & Medina (2015). The analysis of data to evaluate the difference in the means of controlled group and experimental group at the different levels of Bloom Taxonomy showed that the highest difference was observed at an Analysis Level of Cognitive Domain which again verified that tangram puzzle activities were helpful in developing the higher order learning in students. The same result was obtained by PinLine (PinLine, Shao, & Hsiang, 2011). He worked with his team on grade 6 students in Taiwan and used computer based programs for tangram puzzles activities. The present study was done on the grade four students and without the use of computer based programs and the results of the study showed that higher order learning had been enhanced in students. Which verified that tangram puzzles activities were also helpful in the development of higher order learning at primary level.

When data was analyzed to see the clarification of two concepts which were area and perimeter at Analysis Level. No significant difference was found which showed That both the concepts were equally understood by the students with the use of tangram puzzle activities. The present experimental study results were in accordance with the study done by Davis (1995) which revealed that puzzles games could create interest in students and develop the habit of independent thinking. Chen (2010) also explained that tangram puzzles were helpful in finding the relations between the geometrical shapes. Russell and Bologna (1982) said tangram puzzles are helpful in developing creative thinking in students. The significant difference between the results of controlled group and experimental group at Knowledge, Application and Analysis level showed that tangram puzzles were helpful in developing the creative thinking, concept building and enhancing multitude geometric concepts.

7. Conclusions

Keeping in view the statistical analysis of data and findings of the study following conclusions were drawn;

1. Tangram puzzles are helpful teaching aids, especially in enhancing the students' achievement in geometry.
2. Students' achievement in geometry was enhanced at Knowledge level, Application level, and Analysis level, when they were taught by using tangram puzzles.
3. Enhancement of students' achievement in geometry especially at Application Level and Analysis Level sowed that tangram puzzles were helpful in development of higher order learning in students.
4. Both boys and girls were equally facilitated by the tangram puzzles activities.

8. Recommendations

In the light of findings and conclusion of the study, following recommendations were made:

1. Since tangram puzzles had shown a significant positive effect on the students' achievement in geometry so such teaching aids may be included in teachers' training programs.
2. Mathematics is an important subject and the present age is the age of science and technology hence the importance of mathematics as a subject has increased a lot. Teaching of mathematics may also be now become systematic. It may be divided into teaching of mathematics, teaching of algebra and teaching of geometry, along with the specific teaching aids for mathematics, algebra and geometry.
3. It is recommended that some research work could be done to see the effectiveness of tangram puzzles for the other mathematical concepts, e. g. percentage, sets etc.
4. Studies may be launched with students from different cultural backgrounds such as urban and rural areas with a larger sample.
5. Further researches may be done to see the effect of tangram puzzles on students' achievement by considering the other

levels of Bloom Taxonomy e.g. Synthesis Level, Evaluation Level and Affective domain etc.

6. Further researches may be done with secondary and higher secondary students.

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