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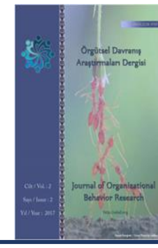

SURVEYING THE EFFECTIVENESS OF TEACHING THE PRINCIPLES OF CREATIVE PROBLEM SOLVING BASED ON TRIZ THEORY IN SOLVING MATHEMATICAL PROBLEMS IN THE JUNIOR HIGH SCHOOL STUDENTS IN ABADAN CITY

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ABSTRACT

The goal of any knowledge, including problem-solving mathematics, and the challenges within is knowledge. Gagné argued that problem solving is the best form of learning. This study aimed to survey the effectiveness of teaching the principles of creative problem solving based on TRIZ theory in solving mathematical problems in the junior high school students in Abadan city. This is a quasi-experimental, field and applied study. The statistical population was high school male students in the academic year of 2018-2018, of which an 80-person sample was selected by cluster sampling and available sample, 40 of which were in the control group and the other 40 people were in the experimental group. The experimental and control groups in the junior high school students consisted of 18 subjects for each group. Poliya's problem-solving strategies in control group and TRIZ creative problem solving strategies (principles) as well as Poliya's problem-solving strategies for the experimental group were taught for each group in 5 sessions and 75 minutes per each session. A 20-minute test was designed and conducted to measure problem-solving speed, and a 60-minute descriptive test was designed to measure problem-solving ability. The validity and reliability of both tests were tested and confirmed. The data collected from the test results were analyzed by independent t-test, indicating that the ability to distinguish between two means is statistically significant in the test, i.e. teaching TRIZ creative problem-solving strategies affects the ability to solve the problem of junior high school students. In addition, the results indicated that the difference between the two means is not statistically significant in the acceleration test i.e. teaching TRIZ creative problem-solving strategies does not affect the speed of problem solving among the junior high school students.

Keywords: *Creative Problem Solving, TRIZ theory, mathematical problem*

INTRODUCTION

The traditional view of innovation was nothing but inspiration and revelation which the owner of this inspiration was a creative person, and according to this, many believe that practical creativity is unconscious or comes to mind after fermentation of ideas (Mohammad Salah et al., 2011). At this time, the first model of the four-step Gestalt problem solving scheme was developed by Graham Wallace, called the Art of Thinking. The four steps in Gestalt problem solving are saturation (preparation): work on the problem until you have done everything you can; incubation: You put the problem out of your conscious mind and allow your subconscious to master it; Insight: The answer suddenly comes to your mind; validation: You review the solution (Schoenfield, 1992)

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However, contrary to the traditional view of the innovation, Genrikh Altshuller, the inventor of TRIZ theory, argued that creativity is not just an innate thing, but an acquired and teachable one (Basirzadeh: 2011, p. 11). Solving a creative problem through TRIZ is exactly like solving a mathematical equation. As known, many mathematical equations have already been publicly solved parametrically and there is no need to find and rediscover them, and just solve our own problems by replacing the numbers with the corresponding parameters. (Basirzadeh: 2011, p. 11). The word "TRIZ" is derived from the first letters of the words in a Russian phrase meaning "the theory of creative (innovative, heuristic) problem solving." Since 1946 to 1985, when Altshuller formally presented his theory in the journal of Psychological Issues as a problem-solving creative algorithm, she presented 40 principles for all industry-focused research; however, from 1985 onwards, Altshuller became convinced that research in this area had reached its pinnacle and that she had to move towards solving non-industrial problems (Saleh Abu Jadoo, 2004). In an experimental study conducted on middle school students by Barak and Mesika, it was found that that after teaching TRIZ, the creative thinking of the students in the experimental group improved significantly compared to the control group. (Barak and Mesika, 2007). In another study conducted among engineering students, the results indicated that these students reported a significant difference in problem solving style and their level of thinking and creativity after passing creative problem-solving classes (Belski, 2011). In addition, Mahmoud (2013) found that TRIZ theory-based strategies for developing creative thinking and sustainability skills include the effect of learning (sustainable learning) as well as the inverse relationship between developing creative thinking skills and reducing geometric anxiety.

An instance of a math problem at the moment is problem solving, especially creative problem solving. In 25 years of teaching experience, about 11 years in public schools and 14 years in private schools, the researcher found that the skills of many students in public schools are solving pre-solved stereotype exercises, even if they have skills in math, and are virtually incapable of solving the problem as a new situation or challenge. In the school for the talented students, within which this study is conducted, students are at a higher level than those in public schools. However, with the exception of a handful of classes in each class, they show inability to solve problems such as their own supplementary textbook problems that require special creativity and initiative to solve in addition to the necessary knowledge.

James Quallick is known as one of the greatest researchers in this theory who evaluated and analyzed educational programs based on TRIZ theory. The curriculum became known for improving the speed and effectiveness of problem-solving compared to traditional methods, and indicated that students' minds and intellectual powers are more prepared to embrace new ideas in a short period of time. Therefore, it is worthwhile to conduct research in this field in our country, which has been done only in the technical field and has a lot of space in the non-technical, non-industrial and educational fields. Therefore, this study aimed to survey the effectiveness of teaching the principles of creative problem solving based on TRIZ theory in solving mathematical problems in the junior high school students in Abadan city.

THEORETICAL FOUNDATIONS

Problem solving

Meyer summarized three main aspects of problem-solving definitions: a) problem-solving is a cognitive activity, because the problem-solving problem occurs within the cognitive system; b) problem-solving is a process, as manipulating or performing special operations on knowledge is a problem solver, c) Problem solving is a directional activity, because the problem solver tries to achieve some goals.

Mathematicians such as Polyia and Schoenfield have a special place in contemporary mathematical problem-solving literature. Polyia's influence on problem-solving literature and his research studies on mathematical problem-solving education is remarkable. He points to four stages in solving a mathematical problem, such as understanding the problem, drawing a map, executing the map, and retrospection (Polyia, 1985, cited by Rokab Eslamizadeh).

The four-step problem-solving model from Polyia's point of view

From Polyia's point of view (1962), the problem is: "From the necessity of consciously searching for the right means to achieve a goal, but in the face of unattainable things, problem solving means finding this means" (Karami Zarandi, 2010). In the Poliya's model, four main steps are taken to solve each problem: understanding the problem, drawing a map, executing the map, reviewing. People engaged in problem-solving can learn appropriate individual and strategic skills in the form of this framework and develop their knowledge. It is worth noting that all components of this model are interacting with each other. According to Poliya, it is valuable to summarize and group the questions and suggestions that arise when discussing problems. These questions are useful for solving problems that work on their own. Here are some helpful questions and suggestions that can help you in any of these steps (Polyia, 1990).

First, you need to understand the problem:

What is unknown? What is the data? What is the condition? Is it possible to fulfill the condition of the problem? Is the condition of the issue sufficient to determine the unknown? Or is that not enough? Or is it superfluous? Or is it contradictory? Draw a shape. Use appropriate signs. Separate the different parts of the condition. Can you put them on paper?

Second, find the connection between the data and the unknown:

You may consider an ancillary problem if there is no direct link between the data and the unknown. Finally, you need to find a map to solve the problem.

Third, performing the map

While performing the problem solving map, check and try every step you take, can you clearly see that the step taken was correct? Can you prove it right?

Fourth, try the obtained answer

Can you check the result? Can you get the result in another way? Can you apply the result or method to another problem? (Poliya, 1944).

Schoenfield and his four components in problem solving

According to Schoenfield, students exhibit different behaviors while solving the mathematical problems, the most important of which are: Analyzing the problem, selecting the appropriate mathematical knowledge, map design, implementing it and re-examining the answer. He argued that what guarantees success in solving a problem is paying attention to four components such as resources, approaches, control and belief system (Rokab Eslamizadeh, 2012).

In examining students' beliefs, Schoenfield showed that most of them think that there must be an existing and ready-made method for solving the problem, and that this method should lead to an answer quickly. He noted that most students believe that all problems have an answer, and that there is only one right answer for each problem and one right solution. In addition, ordinary students cannot be expected to understand mathematics, but simply memorize and apply mathematical procedures. He considered that what makes a person successful or unsuccessful in solving a problem is paying attention to or not paying attention to the following four areas.

1. **Resources**: In order to analyze the problem-solving process by the individual and to understand the evolution of the solution to the problem, we first need to know what tools or basic information the problem solver has at the beginning, which is called resource information (Rokab Islamizadeh, 2012). Resources are actually a set of behaviors and information that the problem solver considers to be right or wrong and uses them to solve the problem. In some cases, a misunderstood method distracts him from the successful solution of the problem and destroys his solution (Farhadian, 2009).
2. **Heuristics**: They are general suggestions that help a person understand the problem better and progress in solving mathematical problems, such as using auxiliary elements in problem solving, drawing, proving, for example, violations, return solutions, generalizations, etc. (Rokab Islamizadeh, 2012).
3. **Control**: According to research by Schoenfield and Silver, heuristics alone cannot guarantee success in problem solving; rather, the key to success in problem solving is metacognition, which is in fact the main issue of control. In other words, what is known as metacognition in the field of control is choosing and following the right methods, recovering from inappropriate options and generally reviewing and monitoring the whole problem solving process, which is of great importance (Rokab Islamizadeh, 2012). Problem solvers with good control can make the most of their resources and solve relatively difficult problems with little efficiency; however, by not controlling, they waste their resources and cannot easily solve the problems in their field of study (Farhadian, 2009).
4. **Belief system**: Beliefs are considered as one of the effective factors in solving math problems; for example, one can refer to one's beliefs about the nature of mathematics, mathematical objects and learning. In fact, all the decisions that a person makes when solving a problem are due to her beliefs (Rokab Islamizadeh, 2012).

Although the factors influencing the solution of the problem presented by Schoenfield have been proposed in the field of solving mathematical problems, his views can be applied in other fields. (Farhadian, 2009).

Creative problem solving

Creative problem solving is a strategy aimed to improve the learner's ability through guiding, advising, and justifying the mental powers to get on the right direction to achieve that goal (Majdi Aziz, 2009: 541). The scholars divide the problem into the following categories:

***A. Closed-ended problems*:** These problems have only one correct answer and there is only one way to solve them. Such problems are simple and well-known, such as how to obtain the size of a charter with specific dimensions?

***B. Open-ended problems*:** There are problems for which there is not just one correct answer, but a number of correct answers. In addition, there are a number of solutions to reach the answer, such as drawing a triangle with an area of 30 cm^2 and explaining its drawing. In this context (Ayman Amer, 2003, Van Gundi, 2005, Saleh Abu Jadoo and Bakr Nofel, 2007), the problems are classified as follows:

Well-structured problems are the ones for which there is enough information to reach common solutions, which the information on the current state of the problems and what we need to achieve are clearly stated in the problems. These issues are known to have a clear solution.

Ill-structured problems are the ones in which the information in the problem is not sufficient and there is not enough guidance to solve the problem. This does not mean that the information in the proposed problem is incomplete or incorrect, and achieving the answer to the problem requires creative thinking despite the information is complete. Such problems are solved in unexpected (innovative) ways and require a lot of time and effort.

Creative problem solving is generally defined as any type of individual or group activity which produces new solutions (Paccio, 1994). In this context, Torrance and Goof (1989) point out the need to solve the problem which the creative solution of the problem first appears as the feeling of the need to solve the problem and the feeling of lack of information, followed by ideas and hypotheses which guide the person involved in the problem to achieve multiple solutions. Osborne and Traffinger point to imagination. As Osborne puts it, creative problem solving relies on imagination and results in heuristic solutions (Paccio, 1994). The study conducted by Al-Khayat (2012) was related on the effect of a TRIZ theory -based curriculum on developing metacognitive thinking skills in students at Belqa University of Applied Sciences. The results indicated a significant statistical difference in the effectiveness of the training program implemented in metacognitive thinking skills in favor of the experimental group. Creative problem solving requires both types of thinking (divergent thinking and convergent thinking) because thought production operations require divergent thinking to achieve a variety of ideas, while bringing ideas closer together and choosing the best solution requires convergent thinking (Van Gandi, 2005).

TRIZ theory and creative problem solving

Some experts describe TRIZ as "a kind of algorithmic approach to creatively solving technical and technological problems." In short, TRIZ is the result of analyzing more than 3 million patents around the world to determine how inventors, as the creative elite of the international community, solved their innovations. The answer to this question led to the discovery of very effective laws and tools for innovation which are being published and expanding in the world under TRIZ knowledge (Amani, 2015). TRIZ training is widely used in the world today and in Europe, a project called Tetris, which means teaching TRIZ in schools, is being pursued with great effort and has yielded very brilliant results (Marsh, Waters, & Mann, 2002).

In another study, the effectiveness of TRIZ education course was assessed by conducting a creativity test and a creativity attitude questionnaire, indicating that there have been many improvements in students' attitudes toward creativity. In addition, significant progress has been made in the performance of students in solving creative test (Khomenko and Sokol, 2000). Savransky (2002) argued that TRIZ theory is a systematic and organized theory, with a human vision based on knowledge and cognition, the aim of which is to solve problems in a heuristic way. In other words, TRIZ is a systematic method (regular, syatematic and principled), knowledge-based and human-based (human-based knowledge) in creative problem solving. Gould Smith (2005) believed that TRIZ theory is an organized theory which works on solving difficult problems that do not have a familiar solution (Mahmoud, 2012). Hippel (2003) emphasized that strategies of this theory are used in non-industrial fields such as management, education, etc. In addition, Al-Awizi (2014) considered this theory as more than a method for solving engineering and industrial problems and considers it as a science similar to mathematics which can be used in various fields (Hia Ashur, 2015). TRIZ knowledge are called with descriptive letters and titles such as systematic innovation, inventive creativity, creativity and innovation technology, inventive methodology, inventive algorithm, innovative problem solving methodology, innovative and innovative problem solving methodology, creativity and innovation engineering, creativity methodology, patent creativity, creanovatology, technology and the like (Golestan Hashemi, 2003).

METHOD

The present study is a quasi-experimental and field study and an applied research. The statistical population included 3945 students studying in the first high school of the junior high school students in Abadan city in the academic year 2017-18. An 80-person sample was selected by cluster sampling and available samples, 40 subjects of which were in the control group and another 40 subjects were in the experimental group. Control and experimental groups studying in the junior high school students were formed. Part of the research was holding TRIZ Principles training classes on creative problem solving. Here are some examples of issues used to teach TRIZ strategies.

Sample problem:

An Ice Cream Store sells fruit ice cream with five different flavors. A group of children came and each of them chose two different flavors. If no two children have chosen the same combination of flavors, and each combination may have been selected from two flavors by a child, then how many children have purchased ice cream?

A) 5 B) 10 C) 20 D)25 E)30

This principle uses a simple copy instead of a complex structure. Instead of using an object which has a complex structure, it is expensive and sensitive. Furthermore, it is not easy to work with and sometimes it is inaccessible. We use a simplified and cheap copy of it. We replace an object or system consisting of several objects with a copy or optical image. A scale is used to make the image smaller and larger.

DISCUSSION:

In solving the above problem, instead of ice cream and its 5 different flavors, five different letters of the alphabet (for example, A, B, C, D, E) and their mutual combinations (A, B, A, C, A, H). And ...) can be used.

By examining 300 of the 10 Kangaroo test questions during 2001-2010 in the junior high school students, 28 research-appropriate questions were selected as the test questions and their validity and reliability were selected to construct a suitable criterion. Since TRIZ problem-solving strategies are new to math teachers, it was necessary to provide the necessary explanations about these strategies by holding some sessions. In one session, 10 teachers were invited and the validity of 26 questions of the proposed questions was confirmed for research with the presence of eight math teachers, including two from the district's mathematics department, and two more were removed. The way to quantify the votes of the members of the validity determination group was calculated through the Content Validity Ratio (CVR) and using the formula $CVR = \frac{n_e - \frac{n}{\text{٢}}}{\frac{n}{\text{٢}}}$ which n_e is the number of group members which considered the question necessary n is the number of group members, the result of which is shown in Table 5.3.

Table 1. Content validity ratio of test questions

Question number	*CVR*	Question number	*CVR*	Question number	*CVR*	Question number	*CVR*
1	1	8	0/75	15	1	22	1
2	0/75	9	0/75	16	1	23	1
3	0/75	10	0/75	17	0/75	24	0/75
4	1	11	1	18	0/75	25	0/75
5	1	12	0/75	19	0/75	26	1
6	0/75	13	1	20	1	27	0/25
7	0/75	14	1	21	1	28	0

Since the number of members of the validity determination group was 8, the minimum acceptable value is 0.75. In addition, if it is equal to or greater than 0.75, the question will be accepted unconditionally. As shown in Table 5, the last two questions should be omitted.

To examine the reliability, 28 questions in a sample of 43 people (two junior high school studentsrs) were applied. The test results were examined through Cronbach's alpha coefficient method, the results of which are shown in Table (2):

Table 2. Reliability of the self-made test

Test	Cronbach's alpha
Eighth - Ability	0/720
Eighth - Speed	0/753

The research method was that the junior high school students was divided into experimental and control groups through the test results of the first round of the eighth students at Shahid Beheshti Educational Center. Then, they were taught 5 sessions (approximately 75 minutes per session) by the researcher. In the control group, only 8 of Poliya's problem-solving strategies used in the first chapter of Book VII were used to solve the problem. In addition to Poliy's problem solving strategies, creative problem solving strategies were taught and used to solve problems in the experimental group. At the end of this training course, a test was conducted as a acceleration test with 9 questions and a response time of 20 minutes and a separate descriptive test with 9 questions for the seventh grade and 10 questions for the junior high school students and a response time of 60 minutes. To analyze the data, descriptive statistics of the mean index (the strongest central index) and standard deviation (standard deviation) and independent inferential statistics of the independent t-test were used to compare the means and the significance level of the test.

Research hypotheses

Hypothesis 1. Teaching TRIZ creative problem-solving strategies (principles) has an effect on students' problem-solving ability.

Hypothesis 2. Teaching TRIZ creative problem solving strategies (principles) has an effect on the speed of the students' problem solving.

FINDINGS

To analyze the data, the normality of the data was first tested by Kolmogorov-Smirnov test.

Table 3. Kolmogorov-Smirnov test results of problem solving ability

	Junior high school students of experimental group	Junior high school students of control group
Number of data	16	16
The mean in normal distribution	15/0313	12/0938
Standard deviation in normal distribution	3/52358	4/05881
The absolute value of the maximum deviation value	0/118	0/206
The highest positive deviation	0/118	0/103
The highest negative deviation	-0/115	-0/206
The statistical value of z Kolmogorov-Smirnov	0/471	0/825
value sig	0/980	0/504

According to the last row of Table (3), the significance level of Kolmogorov-Smirnov test is greater than 0.05; therefore, the data in both experimental and control groups have a normal distribution.

Table 4. Kolmogorov-Smirnov test results of problem solving acceleration test

	Junior high school students of experimental group	Junior high school students of control group
Number of data	16	16
The mean in normal distribution	5/5625	5/5000
Standard deviation in normal distribution	1/67207	1/50555
The absolute value of the maximum deviation value	0/180	0/193
The highest positive deviation	0/137	0/193

The highest negative deviation	-0/180	-0/182
The statistical value of z Kolmogorov-Smirnov	0/720	0/770
value sig	0/678	0/593

According to the last row of Table (4), the significance level of Kolmogorov-Smirnov test is greater than 0.05; therefore, the data in both experimental and control groups have a normal distribution.

Hypothesis 1. Teaching TRIZ creative problem-solving strategies (principles) has an effect on students' problem-solving ability.

Table 5. Comparing the mean of the two experimental and control groups of the ability test in the junior high school students

T-test to equalize the means							Leven's test		
Reliability interval 0.95		Standard deviation error	Mean difference	Sig significant level	Degrees of freedom	t Statistics			
upper bound	Low bound						Sig	F Statistics	
-0/19325	-5/68175	1/34373	-2/93750	0/037	30	-2/186	0/820	0/053	Assuming equality of variances
-0/19097	-5/68403	1/34373	-2/93750	0/037	29/419	-2/186			Assuming non-equality of variances

According to the results of the Leven's test in Table (5), the significance level of the test is 0.820, which is greater than 0.05; therefore, the hypothesis of equality of variances is accepted. Therefore, the results of the first line is used. The value of the t-test statistic in this table is 2.86 with a degrees of freedom of 30 and a significance level of 0.037. Because the significance level of the t-test is less than 0.05, the null hypothesis is rejected and the hypothesis is incorrectly accepted. Therefore, it can be concluded with a reliability of 0.95 that the difference between the two means is statistically significant and the hypothesis is confirmed, i.e. teaching TRIZ creative problem-solving strategies (principles) affects the ability to solve the problem of junior high school students.

Hypothesis 2. Teaching TRIZ creative problem solving strategies (principles) affects the students' speed of problem solving.

Table 6: Comparison of the mean of experiments and control groups of the junior high school students of the acceleration test

T-test to equalize the means							Leven's test		
Reliability interval 0.95		Reliability interval 0.95	Mean difference	Sig significant level	Degrees of freedom	t Statistics			
upper bound	upper bound						Sig	F Statistics	

1/08628	-1/21128	0/56250	-0/06250	0/912	30	-0/111	0/397	0/738	Assuming equality of variances
1/086680	-1/21180	0/56250	-0/06250	0/912	29/676	-0/111			Assuming non-equality of variances

According to the results of the Leven's test in Table (6), the significance level of the test is 0.397, which is greater than 0.05; therefore, the hypothesis of equality of variances is accepted. Therefore, the results of the first line are used. The statistical value of t-test is 0.111 with a degree of freedom of 30 and a significance level of 0.912. Since the significance level of the t-test is greater than 0.05, the null hypothesis is accepted. Therefore, it can be concluded with 0.95 confidence that the difference between the two means is not statistically significant and the second hypothesis is rejected, i.e. teaching TRIZ creative problem solving strategies (principles) has no effect on the speed of problem solving in junior high school students.

DISCUSSION AND CONCLUSION

This study aimed to investigate the effect of TRIZ teaching strategies on creative problem solving in the junior high school students of Shahid Beheshti Educational Center in Abadan. Significant results were obtained from analyzing the obtained data, which some recommendations and suggestions are provided for teachers and researchers for future research after referring to them and comparing the research with foreign research. Based on the results with a confidence of 0.95, it can be concluded that the difference between the mean of the experimental and control groups is statistically significant i.e. TRIZ teaching creative problem-solving strategies affects the growth of problem-solving ability among the junior high school students. Accordingly, the difference between the mean of experimental and control groups is not statistically significant, TRIZ teaching creative problem-solving strategies does not affect the speed of solving the problem of junior high school students.
Examples of the work of students in the experimental group:
9. On a rural Friday market, villagers can use the table below to exchange their pets. How many chickens should Mr. Kadkhodazadeh bring with himself so that he can buy a goose, a turkey and a rooster?

1 turkey	5 roosters
1 goose+2 chickens	3 roosters
4 chickens	1 goose

A) 18	B) 17	C) 16	D) 15	E) 14

It lays 12 chickens and takes 3 geese. It holds one. (It has 1 goose is remained.)
It gives 2 geese with 4 chickens and 6 roosters and holds one. (1 rooster is remained.)
He gives 5 roosters and takes a turkey. (It has 1 turkey.)

So he gave a total of 16 chickens.
The results of this study indicate that there is a significant difference between the meanings of both experimental and control groups in favor of the experimental group, indicating the increasing problem-solving ability based on the training programs of TRIZ. This finding is in line with the findings of Lori (2009), Boyer (2008) and Vincent and Mann (2000). All these investigators confirmed the growth of problem-solving ability in the experimental group based on implementing TRIZ approaches-based training program.

Suggestions

It is necessary to introduce and teach TRIZ theory strategies to math teachers through curricula such as in-service classes or workshops and included in the curriculum of Farhangian University as a compiled course unit. Research and discussion should be conducted by teachers and experts in the field of matching the strategies of this theory with some mathematical problems. Recently, a section (section 16) in the textbook of Entrepreneurship and Production Workshop, the tenth grade of the second year of high school for mathematics and physics, experimental sciences, literature and humanities, and Islamic sciences and education is dedicated to the subject of Innovation and TRIZ (Second Edition, 2017). According to the researcher, it is possible to acquaint the first secondary students with this theory with the necessary expert discussions to consider parts of their books to deal with this theory.

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