

The Effect of Using “Segmentation” and “Merging” Strategies based on the Theory of TRIZ for Creative Problem Solving and Critical Thinking for Gifted Students

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Abstract

This study aimed at examining the effect of using the “segmentation” and “merging” strategies based on the Theory of TRIZ for Creative Problem Solving and Critical Thinking for Gifted Students. Purposeful sampling was used to select (106) gifted students who were divided into three groups. The first two groups were experimental group; one of them (n=35) was trained by the segmentation strategy the other group (n=35) was trained by the merging strategy. The third group was the control group which included (36) students, who were trained by the traditional method. Two instruments were used; the Creative Problem-Solving Skills test (consist of 30 items), which was developed by the researcher, and the Watson-Glaser Critical Thinking Appraisal (WGCTA-FS) that was adopted by the researcher. The training program for the “segmentation” and “merging” strategies was conducted. To ensure the validity and reliability of the two instruments (tests), the method of test and retest and the Pearson Correlation Coefficient were applied. Data were analyzed by the arithmetic means, standard deviations, variance analysis for (ANCOVA). The results found that there are statistically significant differences ($\alpha \geq 0.05$) for the two experimental groups based on the Creative Problem-Solving Skills Test and Critical Thinking Skills Test. The findings revealed the effectiveness of using TRIZ theory strategies (segmentation and merging) in improving thinking skills among the sample of the study. The study recommended using these two strategies and incorporating them into school curricula.

Keywords: Segmentation, Merging, Critical Thinking, Creative Problem Solving, TRIZ theory.

1. Introduction

In recent years, there has been an increasing demand for nurturing creativity in school contexts. Creativity and its learning process and skills are becoming an important measure for developing the curriculum standards. The conception of creativity has been influenced by many interactive factors such as environment, process, product, thinking skills, and personal factors (Runco, 2007). In particular, thinking skills have been viewed as a major element for nurturing and teaching creativity in the classrooms (Starko, 2018; Sternberg, 2010). Thinking skills are needed for individual daily life. It is a learned ability that an individual can possess through training to be acquired and developed. Thinking also can be taught to individuals from early childhood to advanced stages of life, and most thinking skills can be taught throughout the school years through the integration of these skills in student curricula from pre-school to college. Jarwan (2016) pointed out that the ability to think is more learned than natural, and perhaps the most important issues to consider when teaching thinking relates to the appropriateness of training students in good thinking, practicing critical judgments, creative thinking, and methods of problem-solving. Besides, training in collecting, evaluating, and using information for solving problems and making decisions in students' work and life in effective ways are part of these skills. Therefore, teaching thinking is an urgent necessity due to the fact that every student can develop his thinking skills, and that all teachers can help students to become good thinkers, regardless of their educational, social, economic, or cultural level.

The use of creative problem solving skills in education is one of the solutions for facing challenges in the modern world. This method relies on expanded thinking in problems, trying to reach unprecedented creative solutions, and providing solutions to the problems faced by the world (Tran and Hurle, 2016). A creative solution to problems is a process that can be used in several areas, and it provides a framework that regulates the use of specific tools and strategies to help generate, modify, and develop products of novelty and originality. The creative solution to problems is a framework of operations with an organizational function, which is a system of productive thinking tools based on understanding problems and opportunities, generating many uncommon diverse ideas and applying, evaluating, and developing proposed solutions. The function of creative problem solving is to transform data or inputs into tangible and valuable results (Seechaliao, 2017).

There have been many models and theories of creative solutions to problems. This study selected an advanced theory called the TRIZ theory known as the creative ways of solving problems, which was developed by the Russian scientist Henry Altshuller. This theory constitutes a practical model for systems based on a knowledge base and relies on specific actions, tools, and strategies that enable its users to apply the knowledge base to generate new solutions (Abu Jadu, 2007). The forty creative thinking strategies of TRIZ theory were reduced to twenty-nine strategies by Russian scientists. This reduction was justified by the focus of the excluded eleven strategies on precise scientific disciplines and the inability to use and apply them in various life activities (Abu Jadu and Novell, 2007; Abdo, 2008; Bowyer, 2008).

After the researcher's review of the forty creative thinking strategies, the focus was placed on twenty-three strategies that help in developing creative thinking skills for gifted students. This was highlighted also by Zahrani (2010), who indicated that the most appropriate future vision for attracting and caring for the gifted is to keep twenty-three strategies drawn out of forty strategies in TRIZ theory. The researcher has drawn the two most important strategies that may directly affect the development of students' skills in creative and critical thinking.

1.1. The problem of the study

Gifted education practices in Saudi schools focus mostly on the pull-out enrichment program in which the identified gifted students are instructed for a part-time in a special class during the school day (Aljughaiman, 2006). One of the main subjects of this enrichment program is creative thinking skills and creative problem solving. However, as Al-Qarni (2010) mentioned, little research has been conducted on the assessment of such subjects and how they influence students' thinking skills and creative problem solving. Therefore, the lack of evidence-based practices regarding the effectiveness of enrichment programs on students' abilities is becoming a critical issue.

Although we know that thinking is a skill, many training programs offered to gifted students are still presented traditionally and lack the organizational dimension based on evidence and proofs. Therefore, the researcher decided to adopt a theory of high credibility that contributes to solving problems in creative ways, and through which we can develop educational methods based on thinking and creative solutions to problems. The problem of the present study is in investigating the impact of using the strategies of "segmentation" and "merging" from TRIZ theory strategies on the creative solution to problems and critical thinking among gifted students. The reasons for addressing this problem are the following:

- The reality of education in the Kingdom of Saudi Arabia is based on the use of the traditional approach in training. This approach depends on providing students with theoretical knowledge and information through indoctrination, memorization, and recollection without paying attention to teaching thinking skills, which make students unable to address with different life situations.
- Encouraging researchers and educators to pay attention to the development of creative and critical thinking through their suggestions (Jarwan, 2016; Seechaliao, 2017) and the recommendations of the 11th Arab Scientific Conference for the Gifted and Talented, which was held in Amman in 2015.
- The scarcity of studies tackling the development of critical thinking using a training program based on the principles of the theory of creative solution to problems "TRIZ" at the level of the Arab environment, especially for gifted students.

1.2. Questions of the study

The present study attempted to answer the following research questions:

- 1- Are there any differences in the mean scores of the gifted students in creative problem solving due to the use of TRIZ strategies (segmentation and merging)?
- 2- Are there differences in the mean scores of the gifted students in critical thinking due to the use of TRIZ strategies (segmentation and merging)?

1.3. Hypotheses of the study

The study tested the following null hypotheses:

- 1- There are no statistically significant differences ($\alpha \leq 0.05$) in the creative problem solving of gifted students due to the use of TRIZ strategies (segmentation and merging).
- 2- There are no statistically significant differences ($\alpha \leq 0.05$) in the critical thinking of gifted students due to the use of TRIZ strategies (segmentation and merging).

1.4. Significance of the study

The significance of this study stems from the following:

- 1- The ability of gifted students to acquire serious skills as a result of applying new thinking strategies in their scientific and practical lives that have not been addressed before in the academic curriculum in schools.
- 2- It is hoped that the current study will increase the scientific knowledge of teachers on the TRIZ strategies (segmentation and merging).
- 3- The ability of training curriculum designers, planners, and developers to benefit from the study so that two strategies of TRIZ theory are considered in new editions.
- 4- Trainers of self-development and teachers of gifted students can benefit from these strategies in their training sessions for teachers.
- 5- The possibility that the study will encourage researchers to conduct studies on other strategies of TRIZ theory, taking advantage of what is presented in therein.

1.5. Objectives of the study

This study aimed to achieve the following objectives:

- 1- Identifying the effect of using the "segmentation" and "merging" strategies of TRIZ theory on the creative solution to problems and critical thinking among gifted students, by showing which of them has a greater impact on this type of student.
- 2- Encouraging gifted students to use scientifically proven strategies that lead to creative outcomes.
- 3- Enabling gifted students in using logical and sequential thinking processes to realize the relationships between parts and links between products.
- 4- Providing talent and creativity supervisors and trainers with knowledge on these two strategies to be taken into consideration as reliable and approved strategies in training talented and gifted students.

1.6. Limitations and delimitations of the study

Limitations:

- 1- Spatial limitations: The study is limited to the summer program for gifted students in King Abdulaziz University in Jeddah (high school students, who are registered in the Directorate of Education as talented after being examined).
- 2- Time limitations: The summer semester of the school year (2019-2020).
- 3- Human limitations: Gifted students.
- 4- Knowledge limitations: Two training courses (training plans) based on two strategies from TRIZ theory (segmentation and merging).

Delimitation: The generalization of the results of this study is determined by the test of the creative solution to problems that the researcher has prepared and by its validity and reliability. The results also are determined by the brief test of critical thinking and its validity and reliability.

1.7. Terms of the study

TRIZ Theory: A systematic, humane-oriented methodology based on a knowledge base that aims to solve problems creatively. TRIZ is an abbreviation of four Russian words that is known in English as "the theory of inventive problem solving." This theory consists of (40) strategies (Al-Aziz, 2013). It is procedurally defined as a theory that relies on the use of a set of creative problem-solving strategies from which two applied strategies (segmentation/merging) can be used to improve critical thinking skills and find creative solutions to problems.

Creative solution to problems: It is a dynamic system of steps, procedures and mental skills, which works to find an original method or a new opportunity related to what leads to unfamiliar solutions to a problem that does not have a solution at first glance (Baumgartner, 2018). It is defined procedurally as the mental performance of the gifted students to understand and identify the problem presented to them and to suggest and implement the best solutions by using the skills of creative thinking and critical thinking.

Merging: It is one of the strategies of TRIZ theory, which includes spatial or temporal linking between systems that perform similar operations. The aim is for the system to perform balanced functions at the same time or at close intervals (Dew, 2006). It is procedurally defined as the strategies and methods that can be combined to improve thinking skills. Merging can be at the level of learning theories or at the level of training styles by integrating more than one method, such as the integration of individual learning with cooperative learning, formal education with informal. Merging can also occur at the level of learning methods by merging more than one medium of teaching and learning such as direct speech, dialogue, discussion, and virtual multimedia.

Segmentation: One of the strategies of TRIZ theory to solve problems by dividing the system into several parts so that each of them is independent of the other. Although the fundamental goal here is to group the parts into similar groups, and if this system is divided in advance, the degree of division or segmentation may be increased until the solution of the problem becomes (Souchkov, 2018). It is defined procedurally as the strategy by which the educational situation is

divided into small units to facilitate understanding of the interrelationships between the parts of the educational position and to deal (in a new way) with the parts and interconnections.

Critical Thinking: The current study adopts the definition of Watson and Glaser (1991) which states that critical thinking is "a continuous attempt to test facts or opinions in light of the evidence assigned to them instead of jumping to the results, and this includes knowing logical research methods that help determine the value of evidence of various aspects, reaching sound results, testing the validity of the results, and evaluating the arguments in a purely objective way (Al-Mubadal, 2010). It is defined procedurally as the degree obtained by the student in the Watson-Glaser Critical Thinking Test, tailored to the Saudi environment.

Gifted Students: Based on the context of this study, the current study adopted the definition of gifted students in Saudi Arabia as approved by the Ministry of Education;

The gifted student has aptitudes and extraordinary abilities or a distinguished performance from his/her peers in one or more domains considering by the society, particularly in the domain of intellectual talent, creative thinking, academic achievement, special skills and abilities, and the student needs specialized educational services that are not inclusively available in the mainstream school programs (AlNafie, AlGateai, AlDudiban, AlHazmi, & AlSaleem, 2000, p. 18).

2. Theoretical Framework

The current study was underpinned by the paradigm of giftedness in the Saudi educational context. In particular, the study was influenced by the official policy of education, which provided the foundations of giftedness. The official policy declared the value of identifying gifted students and supporting their talents and needs (Ministry of Education, 1995). The policy highlighted three foundations of educating gifted students:

- the states give special care to gifted individuals to develop their talents, direct them properly and open opportunities for their talents;
- concerned authorities shall determine the means of discovering talents, the special program for educating talented and the privileges given to them for encouragement; and
- means of scientific research are made available to talented individuals to benefit from their capacities, without forgetting to offer them Islamic guidance. (Ministry of Education, 1995, p. 35)

Following such policy, the Ministry of Education established the project of "Talent Search and Nurturing for the Gifted Students" and thereby the first national program of identifying and nurturing gifted students in Saudi schools emerged during the period from 1990 to 1996 (AlNafie, AlGateai, AlDudiban, AlHazmi, & AlSaleem, 2000). Based on the definition of gifted students in Saudi Arabia, the procedural definition included four primary criteria for identifying gifted students:

- 1) *Intelligent students:* those students who scored 120 or more on the modified and Arabized Wechsler Intelligence Scale for Children-Revised (WISC-R);

- 2) *Talented Students*: those students who achieve 90% or more on their overall academic achievement as well as achieving 90% or more in math and/or science subjects, in the past following two years before commencing the school gifted program.
- 3) *Students with Creative Thinking*: those students who scored 115 based on Figural Torrance Tests of Creative Thinking (TTCT), Figural –B Form, which translated and adapted to Saudi culture. This test includes four components that are fluency, flexibility, originality, and elaboration; and
- 4) *Students with Special Abilities and Skills*: those students who scored well on *cognitive abilities scale*, which comprises four abilities; linguistic, numerical, spatial and deductive, *interests scale* and *teachers' nominations*

As a result, the definition and the identification approach of gifted students in the Saudi context shaped the study's methodology concerning the sample selection.

Also, the study was underpinned by the philosophy of the school enrichment program, which was developed by Aljughaiman (2006). The program was defined as the pull-out program in which the identified gifted students are grouped in a special class for a while during the school day and instructed by the teacher of gifted students. The program was defined as;

The general program designed and instructed by the teacher of gifted students to provide educational experiences characterizing diversity and deepness in scientific and intellectual fields that are often unavailable in the regular school curriculum. The enrichment program adopts an essential topic, which forms the general scientific content of this program, and a major program to develop thinking abilities suggested by the committee that supervises the program, to undertake it through one academic year or more (Aljughaiman, 2006, p. 59).

In particular, the study was influenced by Aljughaiman's Osis Enrichment Model (Aljughaiman2006; Aljughaiman, Nofal, & Hein, 2016). Figure 1 shows the model's three axes (i.e., Research and Thinking Skills; Personal and Social Skills; Learning and Academic Skills). For the current study, thinking skills involve skills that tailor to "creative and analytical abilities" as mentioned by Aljughaiman, Nofal, and Hein (2016, p. 204).

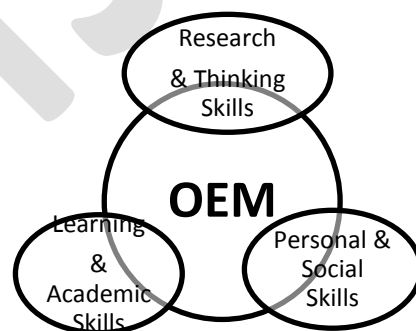


Figure 1. Aljughaiman's Osis Enrichment Model (OEM)
Source: Adapted from Aljughaiman, Nofal, & Hein, 2016, p. 205.

Furthermore, the current study recognized the international perspective on giftedness that considers creativity as a major component of gifted education. To illustrate, the study supports the three-ring conception of giftedness, which defines giftedness as an interaction between three clusters of traits; “above average ability, task commitment, and creativity” (Renzulli, 2005, p.256). Also, the study was reinforced by Sternberg’s “WICS Model of Giftedness,” which consists of four components; wisdom, intelligence, creativity, and synthesized (2005, p. 327). Following these well-known models of giftedness, the study contextualizes creativity through using the theory of TRIZ as an approach for enhancing gifted students’ creative skills, which include creative problem-solving and critical thinking skills.

3. Literature Review

There is a vast literature studying the relationship between TRIZ theory and thinking skills. For example, Al-Khayat (2012) investigated the impact of a training program based on TRIZ theory in developing metacognitive skills among Al-Balqa Applied University students. To achieve the objectives of the study, a set of skills based on TRIZ theory (segmentation, merging, and extraction) was proposed, and a training program for those skills was built. The study also developed a test of metacognition to identify the effect of the training program. The study used the semi-experimental approach, and the sample was divided into two experimental and control groups. The results showed that there are statistically significant differences in the effectiveness of the training program in developing thinking skills of metacognition, and in favor of the experimental group.

Sabri and Al-Hazmi (2013) conducted a study on the effectiveness of some principles of the "TRIZ theory" in developing creative thinking skills among primary school pupils. The study included the use of (6) principles from the "TRIZ theory" in teaching the sixth-grade science course in Al-Madinah Al-Munawwarah. These skills were (separation and extraction, pre-work, converting harmful to good, counter-preliminary work, ostracism and renewal, copying). The sample of the study consisted of (42) students in the sixth grade of primary school enrolled in the Gifted Care Center in Al-Madinah Al-Munawwarah, who were divided into two groups (experimental and control (21 students for each)). The researchers used several tools, including the test of innovative thinking in science. The results of the study showed better performance for the experimental group students after being taught the science course using the principles of TRIZ theory.

Ayasrah (2015) conducted a study to investigate the effect of a training program on creativity and innovation according to the Theory of Inventive Problem Solving (TRIZ) in the development of thinking skills, creativity, and innovation. The sample of the study consisted of 22 female gifted and talented students in Al-Borj secondary school, who were divided into two groups, experimental and control. The researcher has designed and built a comprehensive and complete training program by focusing on a group of basic skills in the theory of TRIZ. The experimental

group was taught using the training program on and the control group was taught by the conventional method. The results showed no differences between the two groups before applying for the program whereas the difference was clear between the two groups after applying it where the favor was for the experimental group.

Ashour (2015) investigated the effectiveness of the program based on a theory for a creative solution for problems which known as TRIZ Theory and knowing its effectiveness on developing Creative Thinking and Mathematical Communication skills for fifth graders. The study designed a program based on TRIZ theory which including Mathematics activities suite the level of the fifth graders. The researcher used the experimental approach on the purposive sample consisting of 82 students from the Al Buriy primary school for boys. The sample was divided into two groups, 41students experimental group and also 41students control group. The results of the study showed statistically significant differences between the mean scores of the experimental group and the control one in the Creative Thinking skills test and the Mathematical communication skills test. The result also showed the effectiveness of the proposed instructional program.

Sobeh (2015) conducted a study to establish a proposed program based on some principles of TRIZ theory and acknowledging its effectiveness in developing the skills of classification and decision making related to the science of 9th-grade students. The study constructed a program that depends on some principles of TRIZ theory, for which the tools of the study have been constructed to test the skills of classification; they consist of 25MCQ items and deal with five skills. The sample of the study consisted of 51 students from the ninth grade, who were divided into two groups: an experimental group, which consists of 25 students and a control group, which consists of 26 students. The results of the study indicate that there are statistically significant differences at ($\alpha \leq 0.05$) in the mean scores of the experimental group students and control group students in the post-test of classification skills and decision-making skills. The results showed the effectiveness of the proposed program.

Fawaz (2017) investigated the effectiveness of a training program based on the theory of creative solutions to problems (TRIZ) in developing decision-making skills among tenth-grade students in Ajloun. The study developed a test of decision-making skills for the upper basic stage and built a TRIZ-based training program. The sample of the study consisted of (71) female students from the tenth grade, who were divided into an experimental group (n=35) and a control group (n=36). The results of the study showed a statistically significant effect of the training program based on TRIZ theory in developing the decision-making skill of tenth-grade students in all fields, and the tool as a whole, in favor of the experimental group. The results also indicated that there was a high degree of retention of decision-making skills because of the application of the training program, as no statistically significant differences appeared between the post-test and follow up tests on the experimental group.

Qing et al (2017) conducted a study to summarize a teaching approach to impart innovative knowledge. The study aimed at helping students to establish the following thinking, "according

to the difficulties encountered in photovoltaic technology, identify and find the key problem, converted into the standard TRIZ problem, find their solutions. The study was based on building a program for university students to help in using TRIZ theory in their studies. Almost 80 teachers and 3220 students benefit from exploration and practice. The results show that this approach plays an important role in cultivating students' creative thinking, where students selected a good topic to improve the success rate of creation and innovation by combining special features with a resource.

Al-Rweilyet al (2019) conducted a study to identify the effect of an instructional strategy based on the theory of (I-TRIZ) in improving inquiry thinking of mathematics among middle school students in the Kingdom of Saudi Arabia. The study sample followed the semi-experimental approach and was applied on (43) student of second primary schools in Al-Jouf area. The sample was divided into an experimental group (22) and a control group (21). The results of the study showed that there were statistically significant differences at the level of significance ($\alpha \geq 0.05$) due to the teaching method in the skills of Inquiry thinking (Data collection, hypothesis assignment, inference, and interpretation). The results showed that the improvement of the experimental group in the skills of inquiry thinking (63%). One the other hand, the results did not show an improvement in the skill of experimentation of inquiry thinking skills.

Hamdan and Khansa (2019) investigated the efficiency of using (TRIZ) theory in the collection of basic fourth- grade students in Social Studies. The study adopted on experimental approach and was applied on a sample of (50) male and female students divided into two groups: an experimental group of (25) students, who studied by (TRIZ) theory, and a control group of (25) students, who studied by traditional manner. The results of the study showed significant statistical differences between the mean scores of students in the experimental group for the pre and post of achievement test as a whole, in favor of the post-application. There were significant statistical differences between the mean scores of students of the experimental group and the control group in the post achievement test as a whole, and in favor of the experimental group.

4. Methodology

In the implementation of his study, the researcher adopted the semi-experimental approach that examines the effect of an independent variable on a dependent variable, because it is the most appropriate approach. The study was applied to three groups: the first experimental group, which was trained by the segmentation strategy, the second experimental group, which was trained using the merging strategy, and the third control group, which was trained in the traditional method. The tools of the study were two tests, one for creative solutions to problems and one for critical thinking. The three groups were subjected to a pre-test of creative problem-solving skills, and the critical thinking test to measure these two skills before teaching them with the proposed TRIZ strategy. After their training, a posttest for the skills of creative solutions to problems and critical thinking was conducted to measure the effect of using an experimental treatment on the three groups.

4.1. Sample of the study

The study sample consisted of high school gifted students who participated in the three classes of the summer enrichment programs, which were hosted by King Abdulaziz University in the city of Jeddah. Such programs are annually offered by King Abdulaziz and his Companions Foundation for Giftedness and Creativity (Mawhiba, n.d.) for school-identified gifted students. The sample was chosen, and then distributed to three groups randomly, as follows

1. The first experimental group was taught by the segmentation strategy, and it included (35) students.
2. 1. The first experimental group was taught by the merging strategy, and it included (35) students.
3. The control group: It was taught by the traditional methods, and it includes (36) students.

4.2. Tools of the study

The tools of the study were the following:

First: The critical thinking test:

The researcher adopted the Watson-Glaser test for critical thinking (the brief version WGCTA-FS) as tailored to the Saudi context and used it in Al-Mubadal (2010).

Reliability:

Al-Mubadal (2010) indicated that the reliability was calculated in two ways: the first is the internal consistency, and it was calculated by the correlated correction of the paragraph with the degree of the sub-test that belongs to it, where the correlation coefficients ranged between (0.21-0.67). The second method was reliability by the Cronbach Alpha method, where the reliability coefficients for the critical thinking test and its sub-tests ranged between (0.64 - 0.91), which indicated that the test has a high degree of stability.

Validity:

It was calculated by the method concurrent validity, where the correlation between the critical thinking test (the brief version) and the critical thinking test that we codified on the Saudi context by Abdul Salam and Suleiman (1982) were (0.31-0.89), which indicated the model enjoys an acceptable level of validity (Al-Mubadal, 2010).

Second: The creative problem-solving test

Paragraphs of tests were built in the form of life situations that the gifted student may experience, which were arranged in descending order according to the appropriate solution to the least of it. Each paragraph included four possible solutions for the same situation, whether these positions related to the student's school life or personal life. The justification for designing the test in this way was to reveal the student's ability to solve the problem (situation), using the method of creative problem solving.

Reliability:

Reliability of the creative problem solving was measured in two ways:

- 1- Reliability through internal consistency: The reliability of the test of creative problem-solving was verified after applying it to (30) talented students who did not participate in the training program, where consistency was calculated using the method of internal consistency of the test as a whole using the Cronbach Alpha equation, which was (0.930). Reliability was also calculated using the internal consistency method of the sub-dimensions of the test.
- 2- Reliability by the test-retest method on a pilot sample of (30) talented students who have similar qualities as the current study sample. This group was chosen from outside the study sample, and the interval between applying the test and returning it was two weeks, for which the researcher applied the test himself. The correlations coefficients of stability were calculated (0, 84) and the coefficient is considered appropriate and can be trusted.

Validity:

The validity of the test was verified by presenting its initial form to a group of judges from specialists in the field and with experience in the educational field, chosen from university professors and specialists in special education, in addition to a group of those with a specialization in talent and creativity. The test was also presented to some supervisors and teachers working in the field of gifted teaching. The aim of this was to judge its content, the formulation of the paragraphs, the appropriateness of each paragraph with the dimension it measures, the correctness of the proposed answers, and the suitability of the language formulation to gifted students and their culture. According to the judges' notes, some paragraphs of the test were reformulated, and the scale in its final form contains thirty paragraphs. Each paragraph has four options, from which the student chooses what he deems appropriate.

Third: The TRIZtheory-based instructional program

The researcher has prepared two training plans for the program based on the TRIZ theory, according to two strategies of theory (segmentation and merging). Each plan included an introduction, which included the definition of the strategy, clarification of the training procedures, preparation, implementation, and the means of evaluation of that strategy. The researcher also designed the plans by defining the educational goals used and the action plan of the training after introducing the strategy, the procedures for implementing, and how students can be evaluated.

To ensure the validity of the plans according to these two strategies, these plans were presented to a group of judges with specialization in the field of special education, talent, and creativity, as well as some teachers of gifted students with experience and competence in this field, to amend what must be modified. The researcher made the necessary adjustments accordingly.

1. The training plan according to the segmentation strategy

In this plan, students were given a set of training tasks as a coherent unit (the problem), and they were asked to find solutions using the segmentation strategy so that the solution has the method of thinking that has the characteristics of original, flexible and fluent creative thinking and the interconnectedness between these elements.

In the segmentation strategy, it is necessary to present a new concept to solve problems by allowing the teacher to allow students to look at the topic (the problem) from different angles and having new experiences. This could be achieved by encouraging them to record the problem before doing the division process, then reflecting on what happens when they get involved in the division process. Students then become involved actively because in this case they are introduced to new concepts once they use them.

2. The training plan according to the merging strategy

In this plan, students were given a set of training tasks based on merging two skills or a set of skills to obtain a new and developed product (solution to a problem). This is done after presenting the product or the final solution to them as a one-time identification form. Then they are required to find solutions using the merging strategy so that the solution is characterized (contains) a way of thinking that has the characteristics of original, flexible and fluent creative thinking while paying attention to the interconnectedness in situations using critical thinking skills.

The trainer must clarify to the student to follow the following four steps for the merging method:

- Presenting the problem (topic) and discuss the dimensions of the topic with students.
- Providing a set of skills/tools/equipment.
- Finding the connection between skills/tools/equipment.
- Finding creative solutions by linking (merging) two or more skills/tools/equipment.

4.3. Statistical analysis

To answer the study questions and test their hypotheses, the researcher used the following statistics:

1. ANCOVA analysis to test the first and second hypotheses.
2. Scheffe' Test for dimensional comparisons to determine individual differences.
3. Pearson correlation coefficient to ensure the stability of the test of the creative solution to problems.

5. Results of the study

5.1. Results of the first question

The first question of the study was “Are there any differences in the mean scores of the gifted students in creative problem solving due to the use of TRIZ strategies (segmentation and merging)?”

To answer this question, the mean scores and standard deviations of the performance of the study sample were calculated in the pre and posttests of the creative problem-solving skills of gifted students,. The results are shown in Table (1).

Table 1. The mean scores and standard deviations of the performance of the study sample in the pre and posttests of the creative problem-solving skills of gifted students according to using TRIZ strategies (segmentation and merging).

Training strategy	No.	Pre test		Posttest	
		Mean score	Standard deviation	Mean score	Standard deviation
Segmentation strategy	35	21.23	5.23	36.80	5.96
Merging strategy	35	22.66	4.85	53.95	2.11
Control group	36	24.55	6.00	31.28	5.95
Total	106	22.81	5.36	40.68	4.67

Table (1) shows that the mean scores of the performance of the study sample in the posttest of the creative problem solving according to the merging strategy were (53.95), which is higher than mean scores students who were trained using the segmentation strategy, which was (36.80). The control group, which was trained using the traditional method, came in the last rank with a mean score of (31.28). ANCOVA analysis was performed as shown in Table (2).

Table 2. ANCOVA analysis for the performance of the study sample on the posttest of creative problem solving according to using TRIZ strategies (segmentation and merging).

Source of variance	Squares sum	Freedom value	Mean score	F-value	Sig.
Pre test	799.905	1	799.905	35.977	0.000
TRIZ strategies (segmentation and merging).	9895.155	2	5099.121	221.055	*0.000
Error	2412.415	107	23.015		
Total score	12724.559	111			

*Significant at ($\alpha \leq 0.05$).

Table (2) shows that F-value was (221,055) and with a level of significance of (0.000), which indicates the presence of statistically significant differences between the mean scores of the performance of the study groups in the posttest of creative problem solution after using the TRIZ's strategies (segmentation, merging). This means rejecting the first null hypothesis, which states that: there are no statistically significant differences ($\alpha \leq 0.05$) in creative problem solving of gifted students due to the use of TRIZ strategies (segmentation and merging). The adjusted mean scores were also extracted as appear in Table (3).

Table 3. The adjusted mean scores and standard errors of the performance of the study sample in the posttest of creative problem solving according to using TRIZ strategies (segmentation and merging) compared to the traditional method

TRIZ strategy	No.	Adjusted mean scores	Standard error
Segmentation strategy	35	37.95	0.75
Merging strategy	35	55.11	0.79
Control group	36	30.95	0.80

Table (3) indicates that the adjusted mean score for the experimental group trained by the merging strategy was (55.11), while the adjusted mean score for the group trained by segmentation strategy was (37.95). The adjusted mean scores of the control group taught by the traditional method were (30.95). To find out the presence of the differences, Scheffe' Test was used to identify the statistical differences as shown in Table (4).

Table 4. Scheffe' Test of the adjusted mean scores for the test of creative problem solving according to using TRIZ strategies (segmentation and merging) compared to the traditional method

TRIZ strategy	Mean score	Segmentation strategy	Merging strategy	Traditional method
		37.95	55.11	30.95
Segmentation strategy	37.95	-	-	*7.53
Merging strategy	55.11	*16.11	-	*24.01
Traditional method	30.95	-	-	-

This indicates that the difference was in favor of the experimental group that was trained using the merging strategy when compared to (the group that was trained using the segmentation strategy, and the control group trained by the traditional method). The table also shows that the differences were in favor of the group that trained the segmentation strategy when compared to the control group trained by the traditional method. There were also statistically significant differences in the adjusted creative problem-solving test between the control group and the segmentation strategy, and in favor of the segmentation strategy.

This result is attributed to the effectiveness of training using the TRIZ's strategies (segmentation and merging) that focus on practical application and linking the training content in the way of thinking used to solve problems. This method helped students to learn new strategies at the same time by discovering the relationships between the parts and then creatively reconnect them, and thus improves the critical thinking skills and creative problem solving skills. In addition, these two strategies enable students to take advantage of their previous experiences and the trainer's

renewed experiences to consolidate the information that the student receives and in which an applied effect is made in terms of dividing problems into smaller parts or merging the components.

In the segmentation strategy, the educational situation is divided into small units to facilitate understanding the interrelationships between the parts of the educational position and deal (in a new way) with the parts and interconnections efficiently. In this strategy, students are given a set of training tasks on the topic (the problem) and they are required to find solutions using the segmentation strategy to find a solution based on thinking that carries the characteristics of creative thinking and critical thinking.

In the merging strategy, spatial or temporal linking between systems lead to improving thinking skills by giving students a set of training tasks based on merging two skills or a set of skills to obtain a new or developed (as a solution to the problem) product. Students then were required to find solutions using the merging strategy, which must contain a way of thinking that has the characteristics of creative thinking and critical thinking.

These findings the merging group students were superior to the students of the segmentation group in the creative problem solving could be explained by the nature of the merging strategy that provides students with a visualization of the creative way to solve problems through logical thinking and finding the relationship between the small parts and then merging them differently. This strategy is also characterized by analyzing, concluding, and making judgments in an interactive and fun way while staying realistic, which is different from the segmentation strategy.

These results agree with Chiu (2009), which indicated that there is a positive effect of the TRIZ theory on the level of creative problem solving compared to the traditional methods in teaching mathematics. The findings also are consistent with the results of Sabri and Al-Hazmi (2013) that confirmed the positive impact of TRIZ theory in developing the skills of creative problem solving, and with Al-Osaimi study (2016) that aimed at developing creative thinking skills for gifted and ordinary students through using the TRIZ theory. This study also agreed with some studies on the effectiveness of using some of the TRIZ's principles in developing the skills of creative solutions to problems such as Barak (2009) in solving educational problems and Mahmoud (2013) in teaching science.

5.2. Results of the second question

The second question of the study was “Are there differences in the mean scores of the gifted students in critical thinking due to the use of TRIZ strategies (segmentation and merging)?”

To answer this question, the mean scores and standard deviations of the performance of the study sample were calculated in the pre and posttests of the critical thinking skills of gifted students after applying TRIZ's strategies (segmentation and merging) as shown in Table (5).

Table 5. The mean scores and standard deviations of the performance of the study sample in the pre and posttests of the critical thinking skills of gifted students according to using TRIZ strategies (segmentation and merging).

TRIZ strategy	No.	Pretest		Posttest	
		Mean score	Standard deviation	Mean score	Standard deviation
Control group	36	116.55	9.90	118.55	10.94
Merging	35	117.95	15.97	130.96	8.94
Segmentation	35	115.44	11.19	121.85	12.12
Total	106	116.64	12.42	123.62	11.75

Table (5) shows that the mean scores of the performance of the study sample in the posttest of critical thinking test among gifted students, according to the merging strategy, was (130.96), which is higher than the mean scores of the study sample taught by segmentation strategy, which was (121.85). The score of the control group trained using the traditional method came in last with a mean score of (118.55). ANCOVA analysis was performed and Table (6) shows the results.

Table 6. ANCOVA analysis for the performance of the study sample on the posttest of critical thinking according to using TRIZ strategies (segmentation and merging).

Source of variance	Squares sum	Freedom value	Mean score	F-value	Sig.
Pre test	2018.731	1	2018.731	20.168	0.000
TRIZ strategies (segmentation and merging).	2269.059	2	1134.530	11.334	*0.000
Error	10710.276	107	100.096		
Total score	15192.324	110			

*Significant at ($\alpha \leq 0.05$).

Table (6) shows that F-value was (11.334) and with a level of significance of (0.000), which indicates the presence of statistically significant differences between the mean scores of the performance of the study groups in the posttest of critical thinking after using the TRIZ's strategies (segmentation, merging). This means rejecting the second null hypothesis, which states "There are no statistically significant differences ($\alpha \leq 0.05$) in critical thinking of gifted students due to the use of TRIZ strategies (segmentation and merging)." The adjusted mean scores were obtained as shown in Table (7).

Table 7. The adjusted mean scores and standard errors of the performance of the study sample in the posttest of critical thinking according to using TRIZ strategies (segmentation and merging).

TRIZ strategy	No.	Adjusted mean score	Standard error
Control group	36	119.58	1.69
Merging strategy	35	130.78	1.72
Segmentation strategy	35	123.04	1.55

Table (7) indicates that the adjusted mean score for the experimental group trained by the merging strategy was (130.78), while the adjusted mean score for the group trained by segmentation strategy was (123.04). The adjusted mean score of the control group taught by the traditional method was (119.58). To find out the presence of the differences, Scheffe' Test was used to identify the statistical differences as shown in Table (8).

Table 8. Scheffe' Test of the adjusted mean scores for the posttest of critical thinking according to using TRIZ strategies (segmentation and merging)

Strategy	Mean score	Merging strategy	Segmentation strategy	Control group
TRIZ strategy		130.78	123.04	119.58
Merging strategy	130.78	-	*7.74	*11.20
Segmentation strategy	123.04		-	3.46
Control group	119.58			-

Table (8) indicates that the difference was in favor of the experimental group that was trained using the merging strategy when compared with the control group that was trained using the traditional method and the experimental group that was trained using the segmentation strategy.

These results could be attributed to the fact that training in the strategies of (segmentation and merging) allowed addressing with the issue (the problems presented) in a logical sequence to identify the links, reveal the relationships between them, and finally their division or merging. The two strategies, especially the merging strategy, motivate students to conclude and Logical thinking, then judging things and making decisions to come up with a final solution. These activities encourage students to participate actively in the training room and the surrounding environment. Students felt they are doing something unfamiliar and felt comfortable and diverse, freeing their energies and creativity, which positively affected their clear interaction with the teacher.

The merging strategy investigates the nature of the links and relationships between the final component, and the use of higher-order thinking skills such as conclusion, application, analysis, synthesis, and evaluation, which allows students to use a prior mental map of how the final solution will be. Students were more motivated in this strategy because it helps to increase critical and safe thinking. Every solution to the problem was accepted and appreciated by the teacher, which encouraged even the shy student to speak and discuss without embarrassment. The researcher observed when applying the method that students interacted actively with each other and with the teacher.

The reason for this result is also due to the students' superiority in the test of creative problem solving and the development of their abilities to interact effectively by receiving training with this strategy. Students were exposed to a training method that contributed to raising the degree of their active participation without any hesitation and with clear confidence, which helped in elevating critical thinking skills.

The results of this study are also consistent with Ayasrah (2015), which assessed the level of critical thinking among gifted students and showed that the level of critical thinking of students with high achievement was higher than gifted students and the performance of gifted students was higher than ordinary students.

The results also agree with results of previous studies (Sabri and Al-Hazmi, 2013; Fawaz, 2017, Sobeh, 2015; Ashou, 2015), which all indicated the positive impact of using TRIZ's theory and strategies in improving critical thinking and thinking skills among different samples of students from different disciplines. On the other hand, the findings disagree with Al-Rweilyet al (2019), which did not show an improvement in the skill of experimentation of inquiry thinking skills after using TRIZ strategies.

6. Conclusion and Recommendations

Conclusion

The results of this current study revealed a positive effect of training using the TRIZ strategies (segmentation and merging) in improving critical thinking skills and creative problem-solving skills compared to the traditional methods of teaching. The results of this study also showed better achievements of the experimental group students (taught by merging strategy) in critical thinking and creative problem solving over the other experimental groups (taught by segmentation strategy) and the control group taught by the traditional method. These findings show that training in the merging strategy seeks the nature of the connection and relationships between the final component, uses higher-order thinking skills such as conclusion, application, analysis, synthesis, and evaluation. This study revealed that using TRIZ theory strategies could be a helpful method to improve the different skills of gifted and talented students. Moreover, empirical studies showed the impact of such strategies in enhancing the thinking skills capacities among not only school students, but also university students, especially in science majors.

Recommendations

In light of the results of the study, we recommend the following:

- Some of the results of the current study confirmed the better achievement of the students who were trained according to the segmentation and merging strategies than the control group. Therefore, the researcher recommends encouraging teachers working in the field of education to use strategies of TRIZ theory in general and segmentation and merging in particular.
- Since the results were in favor of the merging strategy in the test of creative problem-solving skills and in the critical thinking test, the researcher recommends holding training courses for teachers of gifted students on how to use segmentation strategies and merging in the educational learning process, because of their impact in increasing levels of creative and critical thinking.
- The researcher recommends including educational materials for activities and methods that increase the application of elements of critical thinking in the school curriculum.
- - The researcher recommends providing educational content based on the application of the TRIZ theory, especially in materials of a scientific nature.
- Conducting field studies dealing with TRIZ theory strategies in general, segmentation, and merging strategies with other variables other than the creative problem solving and critical thinking.
- Providing professional development programs for in-service teachers on how they offer enrichment activities in the classroom based on TRIZ theory.

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