Why Thought Experiments Should Be Used as an Educational Tool to Develop Problem-Solving Skills and Creativity of the Gifted Students?

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ABSTRACT

Many educational tools that are recommended for the training of normal students are often encountered in programs that do not work very well and are subsequently abandoned. One of the important points that program developers should now consider is that teaching tools are presented in accordance with individual differences. It is seen that the instructional approach suggested as argument-based learning is tried to be applied in Turkey. However, the tools used are the basic argumentation tools. It has been argued in this study that the use of "thought experiment", one of the advanced argumentation tools, is appropriate for gifted students rather than normal students. The evidence-based data on thought experiments in which important scientists used in the history of science rather limited. In this study, the thought experiments are explained and the arguments about why the thought experiments should be used in gifted education are presented by providing information about important thought experiments and types.

Keywords

gifted education, creativity, intuition, advanced argumentation, thought experiment

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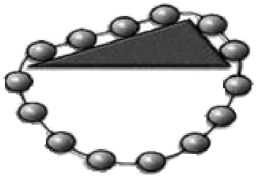
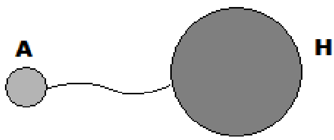
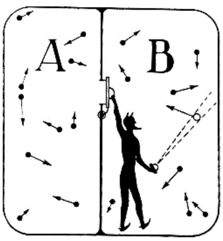
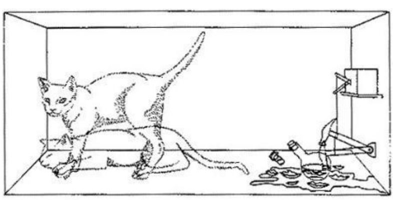
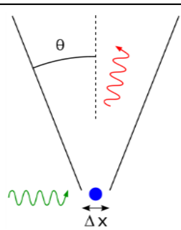
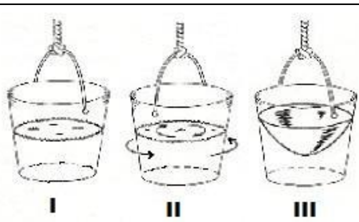
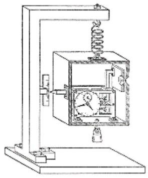
Introduction

Creativity is a human behavior that manifests itself with two important characteristics. These are doing extraordinary (original or unique) and appropriate (beneficial or aesthetic) works (Csikszentmihalyi, 1988; Baer, 1996, 1998; Starko, 2005). This characteristic of humanity has caused him to innovate and progress in many fields. This important behavior has also been defined as problem solving by the people who have worked in the field of creativity (Gardner, 1994). In order for creativity to develop in the specific field, it is necessary to develop creative processes that lead to the advancement of that field with the depth of knowledge, which means that divergent thinking exercises that promote general creativity should be done in the specific field (Baer 1996; Baer, 1998; Csikszentmihalyi, 1988). In this study, thought experiments, which have been an important tool used by creative people in their creative processes in science, will be briefly explained, and why they should be used in gifted education will be emphasized.

The concept of "thought experiment" was put forward by the physicist and philosopher Ernst Mach (Mach,1893/1960), and many pioneering studies on the nature and use of thought experiments have been made (Mach,1905/1976). Popper (1959/1999) and Kuhn (1977), the most important names in the philosophy of science, have discussed how thought experiments are used while generating ideas on the methodology of science, and the structure and rationale of scientific revolutions. According to Bernstein (2006), thoughts experiments are experiments which we do in our minds and which are real experiments that impossible to do in laboratory. Thought experiments were used a lot in the development of science (especially physics). It can be said that the thought experiments are quite beneficial in solving the problems of important fields of science (Heisnberg, 1964/2000). For example, about Galileo's thought experiment on the free fall experiment, Popper says that this is one of the most important thought experiments in the philosophy of science because it reveals one of the simplest and skillfully executed approaches of rational thinking about our universe. In this thought experiment, Galileo refutes Aristotle's theory that a heavy object's natural speed is faster than a light one (Popper, 1935/2005). He did this experiment through a thought experiment that he generated in his mind. Some thought experiments in the history of science have been shown on Table 1 (Karakuyu & Tortop, 2009).

Table 1. Examples for important thought experiments in the history of science

	**Stevin Chain Thought Experiment** Simon Stevin (1548-1620) made an explanation about motion on inclined plane with thought experiments. On a triangular section of a block, he designed a thought experiment about how a piece of chain would move sideways if he would ignore friction between the chain and the block (Stevin, 1955; Georgiou, 2005)
	**Galileo Free Fall Thought Experiment** Galileo Galilei's (1564-1642) most famous thought experiment is about falling objects. Aristotle's idea that heavy objects would fall faster was destroyed by this thought experiment.
	**Maxwell's Demon Thought Experiment** It is a thought experiment that James Clerk Maxwell put forward in 1867 to question the validity of the second law of thermodynamics. In Maxwell's thought experiment, he imagines a demon that chooses gas molecules in the two chambers A and B completely isolated from the outside, except for a small door between them. He critizes in this way (Maxwell, 1871/2001).
	**Schrödinger's Cat Thought Experiment** Erwin Schrödinger put forth a thought experiment. He questions the condition of the cat he has placed in a virtual device working according to the quantum mechanics rules. He wanted others to explain the situation of the cat of being alive and dead (Bilim ve Teknik Dergisi, 2000).
	**Gamma Ray Microscopy Thought Experiment** In 1927, Heisenberg set up a Gama-Ray microscopic thought experiment, which will gain as much as the principle it supports at least, to defend the uncertainty principle. *It also explains the uncertainty when a gamma-ray microscope, which works with beams smaller than the wavelength of the atom, is made (Heisnberg, 1964/2000,s.24).*
	**Newton's Bucket Thought Experiment** Newton tried to explain the notion of a mere space by imagining a world in which no planet or celestial body existed except for a bucket full of water (Newton, 1686/1999).



Einstein's Thought Experiment of a Stationary Box and a Photon

It was Einstein's thought experiment which he put forth in 1930 at the Solvay Conference to destroy the uncertainty principle. Einstein tried to show that the uncertainty relation between energy and time is wrong (İpekoğlu, 2000).

Galileo's Ship Thought Experiment

After Einstein revealed the general theory of relativity, a thought experiment put forth by Galileo came to the agenda again. In fact, it is possible to see the preliminary traces of the general relativity theory (Galieo, 1632/2008).

Types of Thought Experiment

Many classifications have been made related to thought experiments. But Popper (1966/2005) has grouped it briefly. *Criticizing an existing theory (Critical Use), for example Galilei's thought experiment, Promoting an invention (Intuitive Use), for example the fragmentation of a substance to the point where it will not eventually break apart, Einstein's accelerated elevator thought experiment, (Defensive use), Experiments used in discussions on quantum theory, for example Heisenberg's photon-light microscope play an important role (Popper, 1966/2005).* Another categorization was made by Brown (1991). According to Brown, thought experiments can be grouped as follows.

i. Disruptive Thought Experiments: They destroy a theory or attack it with many scientific problems. Schröndinger's cat is an example of such experiments,

ii. Constructive Thought Experiments: These are intended to reveal positive results and divided into three sub-groups.

iii. Mediator Thought Experiments: They facilitate the resulting outcome of a definite, clear theory. Maxwell's demon is an instance of such experiments.

Assumptive Thought Experiments: Their main idea is to present a set of facts and hypotheses to explain the outcome, establish some thought experiments and phenomena. Newton's bucket is an assumptive thought experiment,

Guiding Thought Experiments: They do not start from a well-defined theory, but they end with such a theory. Stevin's chain is a sample guiding thought experiment,

Platonic Thought Experiments: These are both destructive and constructive-guiding thought experiments. Galileo's free fall thought experiment is an example of Platonic thought experiment.

Use of Thought Experiments in Gifted Education

Thought experiments are cognitive tools commonly used by students as well as experts (philosophers, scientists) for purposive scientific problem solving (Clement 2006, 2008; Reiner, 2006). There are a lot of studies in the literature about how thought experiments revealed students' many traits such as imagination, creativity and problem solving skills (Reiner, 1998, Reiner and Burko, 2003, Reiner and Gilbert, 2000, Stephens and Clement, 2006, Matthews 1994, Helm et al., 1985; Lattery, 2001). Obviously, the development of creativity, imagination and problem-solving skills in the differentiated education of gifted students is also an important goal (Tortop, 2015a).

Instead of using thought experiments just as an individualistic tool, it can be suggested to be used with gifted students as a group (Reiner, 1998) to contribute to improving the socio-emotional properties of gifted students. Because, like the Osborn's brainstorming, one of the creative thinking techniques of the use of thought experiments in a collaborative environment, each student's putting forward different ideas can create environments that contribute to the development of ideas and thinking in cases in which the thought experiment made by one of them is not sufficient by integrating this experiment with the others. Meanwhile, students may produce false thought experiments, but these errors are crucial in the ongoing conceptual refinement process for students (Reiner ve Burko, 2003).

Findings show that the use of thought experiments as instructional tools increases students' level of logical thinking skills and conceptual understanding of Newtonian laws (Karakuyu and Tortop, 2009). In addition to this, an effective learning environment can be established in the science education by creating problem sets containing different types of thought experiments in terms of understanding the information and of making reasonings (Dönertaş, 2011). There are other studies that criticize the negative aspects of the use of thought experiments as well as their positive aspects. In their study, Reiner and Burko (2003) analyzed Landau, Eddington and Einstein's thought experiments on star formation and general relativity. They brought evidence that their thought experiments were more prone to errors than laboratory experiments. This finding may also be related to the -in terms of information depth- group who learned. This finding may be different for students with high level knowledge (Dönertaş, 2011).

The importance of using thought experiments in the previous science program has been emphasized in Turkey. Likewise, the 2013 physics program included the outcome "Students will be able to discuss thought experiments in the history of science ". The Turkish Academy of Sciences (TUBA) also has positive opinions about the use of thought experiments in teaching programs.

> *"... experiments that the student will do on his own even in simple environments … On the other hand, revealing the problem, forming and solving it,*

> *experiment design, thought experiments (for example, asking "how can I understand if a proposal is correct or not?") should come to the fore in learning, assessment and evaluation (TUBA, 2008; Akt: Karakuyu ve Tortop; 2009).*

According to Maker (2001) giftedness is defined as an individual who solves a problem (Tortop, 2015a). Problem-solving skill has been re-conceptualized as *creative problem-solving skill* in Tortop's (2015b) Education Program for Gifted Students Bridge with University (EPGBU) by going through a transformation in the light of the concept of Parnes, in the training of gifted students. Thought experiments are essential educational tools for developing gifted students' creativity, intuition, and problem-solving skills (Reiner & Gilbert, 2000). An important issue here is that gifted students also know what gifted people are using as the thinking tools. In this respect, like in many gifted education models, in EPGBU program as well, Tortop (2015a) considers that the processes undergone by the gifted scientists in the components history and philosophy of science curriculum must be known by the gifted students.

Topics covered in rhetoric and argumentation such as argumentation, argumentation tools, basic argumentation, and advanced instrumentation tools are among the important study fields of philosophy. Argumentation is the process of exposing what is right on two opposing states, but is not related to how argumentation is true (explanation). In this process, rebutting evidence is presented. Some tools need to be used to make an argumentation. These are basic and advanced argumentation tools. Basic argumentation tools are the followings: Truth, consistency, error, refutation, axiom, definition, certainty and possibility, tautology, contradiction and contradiction of self. These argumentation tools are given implicitly in our education system. For example, deductive and induction tools are used in teaching concept. Errors and refutations are among the basic argumentation tools that are used in a lot of lessons, but not explicitly. The advanced argumentation tools are the form of hypothesis, dialectics, analogy, anomaly, intuition, reduction, thought experiment, and transcendental argument. As it can be seen, thought experiments are among the advanced argumentation tools used by philosophers and physicists.

The skills related to the use of some of the argumentation tools mentioned above are included in science curricula (Science Curriculum of Ministry of Turkey, 2004). Among the skills mentioned as the Scientific Process Skills in the literature, the basic process skills (like observation, classification, prediction, deduction, measurement, and data recording) as well as advanced or operational process skills (like hypothesizing, variable identification, variable changing, designed experiment, and modelling) exist (Baggini & Fosl, 2003). Advanced scientific process skills are not emphasized in the new science curriculum. It is enough for the students with mental retardation to acquire the basic scientific process skills. However, it is necessary to study on advanced scientific process skills for gifted students (Tortop, 2015a; Maker & Schiever, 2005).

Scientific creativity, one of the curriculum components of EPGBU, can be conceptualized as the application of creativity to the field of science, which emphasizes new ideas, and the mental processes of producing solutions. Some of the researchers who have put forth the theoretical foundations of scientific creativity have pointed out that there are constructs such as inconsistencies, unknown fields, and discoveries (Colton & Steel, 1999), and others have to be structures such as processes and products like in creativity (Hu & Adey, 2002). Scientific creativity skills of the scientists underlie scientific progress. EPGBU curriculum model' the outcomes Scientific Creativity include the use of thought experiment (Tortop, 2013c; Tortop, 2015a) which is one of the advanced argumentation tools used by important scientists (such as Galilei, Newton, Einstein, and Maxwell). From this point of view, it can be said that EPGBU is the first and important program in the use of thought experiments to educate the gifted scientists in Turkey.

It is crucial to use thought experiments, which are advanced argumentation tools, to train highly skilled scientists. However, in order for something to become a thought experiment, it must be composed of the following parts. The components of the thought experiment are the statement of the problem and the hypothesis, the creation of an imaginary world, the design of the thought experiment, trigerring of the thought experiment, making the observations, and presenting of results in order (Reiner ve Gilbert, 2000). We can see the overlapping points between the processes of thought experiments, one of the tools of advanced argumentation with creativity.. The most important aspect of creativity and creative process is "Diagnosing the Problem or Finding It" (Csikszentmihalyi, 1994). Thought experiments are also based on the appearance of the problem in a scientific explanation. Another important stage of creativity is the redefinition of the problem (Sternberg & Grigorenka, 2000). The problem is redefined during the design of the thought experiment. The stage of discussion and argumentation in the thinking experiment is important for the use of critical thinking skills (Tortop, 2015b) that are desired to be developed in gifted learners.

The other field that needs to be examined in terms of education of gifted students in their thought experiments is intuition. Our intuitions are the level of our consciousness and awareness. It is a quick comprehension and is being able to see the reality from a different aspect. However, intuitions are not worthy in education and western culture (Johnson, 2015). However, intuitive thinking in hypothesis production process in scientific creativity is used to expand and support the knowledge. Studies showed that intuitive knowledge was less (almost not present) in the group with higher knowledge level. Students with intermediate level of knowledge have more intuitive knowledge of thought experiments and physics problems. The level of using scientific concept is vice versa (Dönertaş, 2011).. This situation is similar in terms of producing ideas in creativity studies. Bu bulgu oldukça önemlidir. This finding is crucial. Einstein'ın Büyük Fikri belgeselinde de Faraday'ın Örsted'in yaptığı deney karşısında "Üzerinden elektrik akımı geçen tel belki göremediğimiz bir kuvvet yayıyor olabilir" şeklindeki açıklama karşısında diğer bilim insanlarının "Cambridge Üniversitesi'nde elektrik akımını telin içinden geçtiği öğretilir" şeklindeki kalıplaşmış düşünce Faraday gibi üniversite eğitimi görmemiş bir işçinin sezgisel ya da yaratıcı düşünmesinde yer edinmemektedir. In "Einstein's Big Ideas" documentary, the other scientists' stereotyped thought "At Cambridge University, it is taught that electric current passes through the wire" about Faraday's description of Oersted's experiment "The wire passing the electric current may be emitting a force that we are not able to see" did not have a place in the intuitive or creative thinking of a worker who did not have a college education like Faraday. Scientists like Faraday and Einstein have a strong imagistic simulation. In this respect, gifted students should be educated not only about the depth of knowledge, but also about developing the field of reasoning, as well as those that develop intuition and creativity (Johnson, 2015).

Results and Recommendations

The important experiential point of view that I have gained during my teaching career at schools and university is as follows. Theories are developed by taking into account the people who have made a difference with important behaviors and characteristics in any field. For example, in his first works on creativity, Wallas' (1926) model emerged as a result of observations and interviews with important creative people. The presentation of the scientific process skills has also been revealed in the same way. Project-based learning is nothing more than modeling the purposeful act of the people who have made significant inventions and developments in human history. The concept maps were created as a result of describing of the natural processes of the people who have the ability of creating good relationships between concepts. However, when we try to apply them in education, it is seen that there are problems such as being impracticable. Even project-based learning model appears with the case of not being implemented in the gifted students' education putting aside the normal students (Tortop, 2013a, 2013b; 2013c; Tortop, 2015a). There are a lot of studies that present good results about the effectiveness of concept maps, but this may not be remarkable when what level it is applied or practiced is checked. Marker and his colleagues (2015) have studies about the use of concept maps in the education of gifted learners. Many of these tools are the ideal tools for gifted students. Thought experiments are no simple argumentation tools, but they are actually advanced argumentation tools (Baggini & Fosl, 2003). Therefore, it may be more appropriate to apply this tool with gifted students instead of using it for educational purposes with normal students.

As a result, thought experiments are one of the most important educational tools suitable in terms of the development of the gifted students' (Tortop, 2015a) intuition, creativity, and problem-solving skills (Georgiou, 2005; Dönertaş, 2011; Karakuyu & Tortop, 2009). Therefore, doing activities including thought experiments in the education of gifted students can be recommended.

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Hasan Said Tortop has his masters and doctoral degrees on science and physics education. After working as a gifted learners' educator in the Ministry of National Education, he started working as assistan professor at Bulent Ecevit University in 2011. He established Special Education Services Application and Research Center (ÖZELMER) at Bulent Ecevit University. He has also established Education Program for Gifted Students Bridge with University (EPGBU) at ÖZELMER, and he is still running the program. He has received the title of associate professor in 2014. He has several articles about gifted learners and science education in many national and international academic journals. He is the editor and consultant for national and international journals. His research interests are gifted learners' education, science education, teacher training, higher education, and renewable energy education.

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Appendices

Appendix 1. Problem Examples Including Thought Experiments

Solar Chime Thought Experiment

The solar chim generates electricity by taking advantage of the air movement caused by the heat effect of the sun. The soil and air in a building covered with transparent material exposed to the sun are more heated than the ambient temperature. If the roof is sloped and the airflow is soared into a very high pit, air flow (wind) will occur in the chimney at a speed of 15 m/sec. Horizontal wind turbine to be placed at the entrance of the chimney will turn this wind into electricity.

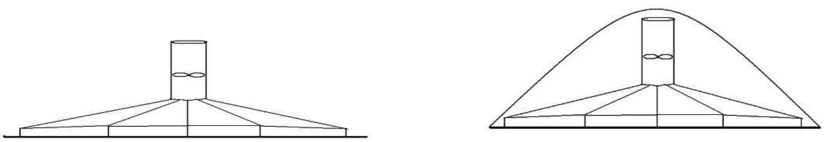

Figure 1. Solar Chime and Working Principle

"What happens if you put a jar on top of your sunshine as you can see above? Is the air flow still in this case? Will the solar energy turn into electricity?" (Williams, 2005; Akt: Karakuyu ve Tortop, 2009)

Fly in the Jar

A few flies were put into a jar. Which one of the following statements about the value of the scale is correct when this jar is placed on a delicate scale?

a) the most when all the flies perch on the bottom of the jar
b) the most while all the flies are flying in the jar
c) the value of the scale is the same in both situation(Georgiou, 2005).

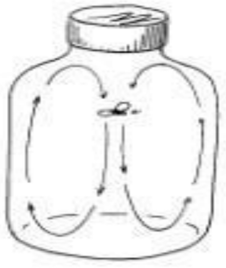

Figure 2. The Fly in the Jar Thought Experiment (Georgiou, 2005)

Magnetic Car

If a U shaped magnet is held to a car made of iron the as in the figure, which one of the following is true for its movement?

a) It moves

b) It moves if there is no friction force

c) It doesn't move (Georgiou, 2005).

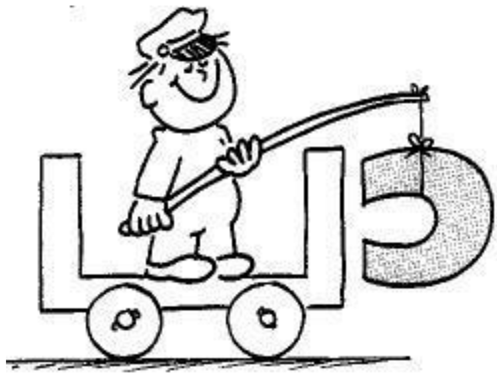

Figure 3. Magnetic Car Thought Experiment (Georgiou, 2005)

Strong Man

In the first case, when a strong man holds the rope, the tension on each arm of the rope is half the weight of the rope (5 N). If the strong man wants to haul the rope in the horizontal position as it is seen in the second picture, how many N would be the tension force in the case?

a) 0, b) Almost 10 N, c) 10 N, d) 20 N, e)More than 1 million N (Georgiou, 2005).

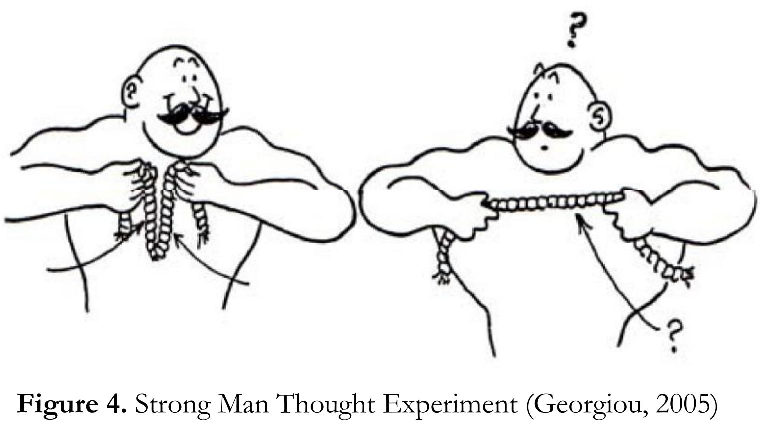

Figure 4. Strong Man Thought Experiment (Georgiou, 2005)