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Investigation of physics thought experiments' effects on students' logical problem solving skills

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Abstract. The purpose of this study, investigation of physics thought experiments' effects on students' logical problem-solving skills in collaborative groups. In this context, it was requested to undergraduate students who have taken General Physics I and General Physics II to develop thought experiments in order to solve daily life problems. At the next stage, students' thought experiments were classified according to common issues in cooperative groups and were asked to try to solve the problems by using thought experiments' process from each group. As a result of this study; students' thought experiments related to daily life were developed and problem solving processes have been presented in detail.

Keywords: Physics education; science education; thought experiments; logical problem solving skills

1 Introduction

Thought experiments are effective form in both teaching of physics and science and are performed in the mind. As known, during the scientific revolutions of the 17th and of the 20th century, thought experiments were used by famous scientists such as Galileo, Newton and Einstein. In physics education, thought experiments have had important role since they were used by leading scientists for the formulation of new theories, the representation of views, the variation of the existing theories which were designed and performed mentally by the scientists while investigating a new topic. In physicists community, Galileo's falling bodies, [4] Newton's bucket and cannon, [11], Einstein's elevator, [2] Maxwell's demon, [10] Heisenberg's γ-ray microscope, [7] Schrödinger's cat, [13] the E.P.R experiment, [3] are very popular thought experiments in this respect, [14].

Scientific studies defined that thought experiments have huge impact to student learning of scientific concepts, [5], [6], [9]. Gilbert and Reiner have shown that students configure imagines for problem solving, if they are encouraged to develop their own thought

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experiments, they can create new facts, new explanations, and alternative solves, [5]. In accordance with the findings of Matthews [9]; thought experiments process engages the students' mind, and reveals what a student believes. In another study, Reiner, [12] indicated that students' provide access to implicit knowledge while problem solving discussions were in the format of thought experiments.

Thought experiments implementation has significant role in physics. But the use of it requires that students imagine and predict situations that do not take place in everyday life and find results on the basis of existing or new hypotheses. Students may imagine the situation without help about concepts or processes in everyday life. In this context, thought experiments help them to use their imagination, develop their critical thinking, make hypotheses and exchange ideas, [9]. It is clear that thought experiment implementation has become a bridge students' everyday experience and the new concepts which have to be taught for students.

Thought experiments are usually determined a basic components by problem solving, hypothesis testing and constructing imaginary situations. If we examine the details of these components; we reach to similar founding of Reiner [12] and Brown [1] such as; proposing a problem or hypothesis; forming an imaginary situation, designing and setting an experiment as mentally using background knowledge, producing experiment as logic, drawing or reaching a result.

2 Methods

2.1 Purpose of the research

The purpose of this study, investigation of physics thought experiments' effects on students' logical problem-solving skills in collaborative groups. In this context, it was requested to undergraduate students who have taken General Physics I and General Physics II to develop thought experiments in order to solve daily life problems. At the next stage, students' thought experiments were classified according to common issues in cooperative groups and were asked to try to solve the problems by using thought experiments' process from each group. As a result of this study; students' thought experiments related to daily life were developed and problem solving processes have been presented in detail.

2.2 Participant

The participants of the study consists of 50 undergraduate students attending Istanbul University, Hasan Ali Yucel Education Faculty, Science Education Department at the first grade who received General Physics I and General Physics II courses. In these physics courses, undergraduate students learn the subjects of "The SI unit system, dimensional analysis, vectors, dynamic, gravitation, friction force, work, power, mechanical energy, impulse, linear momentum, rotational motion, angular momentum, mechanical properties of matter, Bernoulli's principle, simple harmonic movement kinematics, damped and forced oscillations and resonance, electric force and electric field, coulomb's law, gauss's law, potential difference, circuits, RL, RC and RLC circuits, magnetic force and magnetic field, biot- savart law, hall effect, magnetic properties of matter, faraday's law, lenz law, AC generators, electrical motors, transformers, thermodynamics, optic, waves, doppler effect, electromagnetic, nuclear physics (radioactivity, nuclear reactions fission, fusion, reactors), atomic structure (atomic models, energy levels, atomic and molecular spectra), relativity, photons(radiation, photoelectric and compton effect), quantum mechanics (de Broglie

waves, uncertainty principle, schrödinger's wave, semiconductors, superconductors, x-ray, Ultrasound, MR, Tomography, Scintillation, and scanning electron microscopes.

3 Instruments and findings

In the beginning of the this process; students were asked: "which problem do you know about world, life or universe?. And then students started to research the problem which they wanted to know how to solve the subject they chose. One week later students came into the course with their subjects. Then, the groups were determined according to their common subjects. Each group includes 7 or 8 students.

The subjects related to dark matter, expanding universe, time travel, Heisenberg uncertainty, relativity, sound waves, big bang theory, string theory. Students started to develop their thought experiments to solve the problem which was determined by them according to problem solving strategies. The procedure took 7 weeks and they produced their thought experiments with concrete models. Each week, students were directed by researchers.

For example; it was presented thought experiments according to problem solving steps of "Dark Matter and Dark Energy" group as flowingly;

Proposing a problem or hypothesis:" Is there dark energy and dark matter at universe?"

Forming an imaginary situation: this group developed two thoughts together. After their investigations and discussions, they proposed that there are dark energy and dark matter and they affect the universe expanding.

Designing and setting an experiment as mentally using background knowledge: The group investigated dark energy, dark matter and universe expanding topics from books, papers and they also watched CERN experiments videos related to this content.

Producing experiment as logic: According to their researches they imagined that "There are dark matter and dark energy. While dark energy responsible for the rate of expansion of the universe, dark matter has a decelerator effect of the expansion rate of the universe. If there was not dark matter, the expansion rate of the universe would not be too much and universe collapse by expanding.

Drawing or reaching a result: They produced their thought experiments with concrete models and they presented their thought experiment in class.

Problem solving strategies were scored by researchers as 5 points for proposing a problem or hypothesis (problem question); 5 points for forming an imaginary situation(problem borders and relates), 5 points for designing and setting an experiment as mentally using background knowledge (sources and knowledge usage), 5 points for producing experiment as logic (comparing the hypothesis' result with the other results, 5 points for drawing or reaching a result (produced own products about thought experiments). Each group were scored according to their own thought experiments as determined problems by themselves. It was shown groups' thought experiments scores for each problem solving steps and topics (Table 1).

As shown in Table 1; the minimum and maximum scores of collaborative groups are computed as 17 and 25, respectively. It is clear that; students contribute their own thoughts, imaginations and models to solve their problems in collaborative groups and their problem solving skills are very high because of thought experiment implementation. It is interesting that; many students wonder structure of the universe topics instead of physics laws around them related to daily life.

Table 1. Groups' thought experiments scores for each problem solving steps as logically and topics.

Groups' Thought Experiments Topics	Proposing a problem or hypothesis	Forming an imaginary situation	Setting an experiment as mentally	Producing experiment as logic	Drawing or reaching a result	Total Score
Dark Matter and Dark Energy	5	5	5	5	5	25
Universe	3	4	3	3	5	18
Time Travel	3	4	4	5	5	21
Heisenberg Uncertainty	3	4	5	3	4	19
Relativity	4	3	5	5	3	20
Sound Waves	4	4	5	5	4	22
Big Bang Theory	5	5	5	5	5	25
String Theory	3	3	4	4	3	17

4 Conclusion

The results of this study showed that thought experiment implementation have high impact to understanding physics concepts and it seems to be very useful in teaching physics to undergraduate education. It was seen that students were able to think deeply, imagine situations beyond their everyday life experiences and try to use their scientific knowledge, [8]. Thought experiment implementation helped students both to overcome borders in understanding the laws of physics and to modify their ideas related to physics topics, especially on universe.

References

1. Brown, J., *The laboratory of the mind. thought experiments in the natural sciences*, Routledge, London, (1991).
2. Einstein, A. & Infeld, L., The *evolution of physics, simon and schuster*, New York, (1938).
3. Einstein, A., Podolsky B. & Rosen, N., Can quantum- mechanical description of physical reality be considered complete?, *Physical Review*, 47, 777-780, (1935).
4. Galileo, G., *Dialogue concerning two new sciences*, Dover, New York. (translated by Crew H., Salvio A, 1914), (1638).
5. Gilbert, J., J. Reiner, M., Epistemological resources for thought experimentation in science education., *International Journal of Science Education*, 22(5) , 489-506, (2000).
6. Helm, H, Gilbert, J. & Watts, D.M., Thought experiments and physics education-Part 2.*Physics Education*, 20, 211-17, (1985).
7. Heisenberg, W., *The principles of the quantum theory*, Dover, New York. (Translated by Eckart C., Hoyt F., 1949), (1930).
8. Kösem, Ş.D. & Özdemir, Ö.F., The nature and role of thought experiments in solving conceptual physics problems, *Science & Education, 23*, 865–895, (2014).
9. Matthews, M., *The role of history and philosophy of science*, Routledge, New York-London, (1994).
10. Maxwell, J., *Theory of Heat*, Dover, New York, (1871).
11. Newton, I., *Mathematical principles of natural philosophy and his system of the world,* Volume one: the motion of bodies, University of California press. (translated by Motte A., 1962a, 1962b), (1729).
12. Reiner, M., Thought experiments and collaborative learning in physics. *International Journal of Science Education, 20*(9), 1043-58, (1998).
13. Schrödinger, E., The present situation in quantum mechanics, *Wheeler and Zurek*, 1983, 152-67, (1935).

14. Velentzas, A., Halkia, K.. & Skordoulis, C. (2007). Thought Experiments in the Theory of Relativity and in Quantum Mechanics: Their Presence in Textbooks and in Popular Science Books. *Science & Education*, 6, 3-5; 353-370.