Students' Considerations of Archimedes Law – Use of Historic Introduction in Science Teaching

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Abstract

One of the most significant features of science is the formulation of appropriate hypotheses and their testing. This particular feature of science requires the researcher to use imagination, creativity and skills in order to formulate a hypothesis that is new - funny sometimes and strange at other times. Such hypotheses may be reached as a result of a dream, intuition or accident. The aim of this study was to explore students' attitudes toward the scientific exploration not as a result of systematic method, but through the use of the historical introduction. This study used the story of Archimedes and the golden crown and Archimedes' discovery of the law of density as a concrete illustration of classroom implementation. The findings of this study provide evidence that students changed their view of Archimedes after their knowledge of the story of his discovery. This study demonstrates that teaching science through historical accounts of scientific discoveries can increase students' understanding of the significance of scientific imagination and intuition for scientific discoveries.

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Introduction

There are numerous approaches to science teaching such as the traditional (Beardsley, 1992), detective or problem-solving (Bowden & Beeman, 1998), and historic approaches (Brush, 1989; Crowther, 1969). The historic approach refers to the pedagogical style used by science teachers to reveal the historic development of specific scientific subjects in an effort to improve one's perception of the meaning, image, knowledge and nature of science. This approach is distinguished from other methods of presentation because it provides background and distinguishing features of scientists (Losee, 1993).

Some science educators suggest that an historical approach tends to give room to wordiness and allows old information to become confused with modern knowledge (Cachapuz & Paixao, 2005), while other science educators consider the incorporation of contents from the history and philosophy of science (HPS) in science instruction as powerful and beneficial (Brush, 1989; Matthews, 1994). Yet, others advocate the introduction of HPS into science education as a possible way of highlighting its concern not only with the products, but also with the processes of the development of science ideas (Irwin, 2000; Monk & Osborne, 1997).

Advantages of using an historical approach in teaching physics are discussed, focusing on the questioning techniques that a teacher can adopt in analyzing a particular episode or concept in the history of physics (Brouwer & Singh, 1983). Incorporating the philosophical and historical aspects of science enables teaching about science as well as teaching science itself, and that such instruction implements case-based teaching principles, which is how humans naturally think, learn, and remember (Eshach, 2009).

The idea underlying the strategy is that it may attract and motivate high school students to open-up to scientific topics and thus be spurred to pursue science.

One of the aspects science education should focus on is learning about how science works as a discipline. Achieving a good understanding of this aspect requires, among other things, the use of the history of science. There is some evidence that teachers rely heavily on textbooks to select the historical content they include in their physical science lessons (Laurinda, 2004). Many educators share this conviction, whereas others decisively reject HPS on the grounds of inadequacy of the old knowledge subsequently discharged in science, its misleading potential for the students aimed at mastering the ‘‘accurate’’ theory, and its appearance for the contemporary student as strange or unusual (Galili & Hazan, 2000). At the same time, the arguments in favor of HPS use in science instruction have been strengthened, expanding on cognitive aspects (Matthews, 1994).

A close look at scientific treatises at the dawn of science (Aristotle, Euclid, and Archimedes) may provide additional clues regarding scheme-facets organization of non-mature knowledge. Namely, one can recognize cases when a number of claims and accounts about regularities, observed in specific situations (as facets are) were later represented by one inclusive proposition (law, or principle, in science) (Galili & Hazan, 2000). This study was conducted using the Science, Technology and Society (STS) approach which presents the image of the science’s nature as part of curriculum (Driver, Leach, Miller & Scott, 1996; Solomon & Aikenhead, 1994). According to the STS approach, the image of the science nature and the scientists' contribution is vital for curriculum development. The goals of curriculum developers in this approach is to describe science as part of science content (as a discipline) and technology (as influenced by science), to describe the influence of these two on the society, as well as, to describe science as influenced by social beliefs and perceptions (Driver et al., 1996). During the middle of last century, a number of studies were published that are relevant to the scientist's image. Most of them were carried out among school children, few were done among teaching trainees, and most took place in western populations and only few in eastern populations. These studies examined mainly the physical (dress and workplace) and social image of the scientist. In some instances, they examined the scientist's personal characteristics. Literature review relevant to scientist's image shows that examining different views of such image (e.g. physical and social views and examining the default model) requires the use of different means. DAST Test (Draw a Scientist) shows the scientist's appearance, dress, gender, workplace, the equipments he/she uses and the activities he/she performs. Statement questionnaires emphasize more the personal and social characteristics of the scientist: diligent, intelligent and isolated (Aikenhead, 1987).

Some researchers claim that students' initial scientific knowledge is analogous to the knowledge of scientists in the ancient world, and it is made up of observations and conclusions that were often intuitive (Erduran, 2001; Irwin, 1997; Thagard, 1992). Just as these scientists tended to personify objects, or describe processes and natural phenomena in emotional terms, so do children build a conceptual world that is adjusted to their own world of knowledge and emotions. Children believe in what they sense and tend not to believe in what is out of the scope of their senses. STS, which integrates scientific development and historical analysis of scientific events, may help to achieve a better understanding of the essence of science and the methods of scientists (Abd-El-Khalick, 2002). Moreover, science should be presented in a way that will be understood by the students, and provide an atmosphere of learning environment in which students will learn to understand phenomena and link between them without the complications of formulas (Ben-Zvi, 1999). We believe, that if students study a challenging curriculum, situated and encored within a certain context (a historical one in this case), their perceptions, beliefs, and attitudes towards science and science learning will be positive (Blumenfield, et al., 2000) leading students to be creative.

Creativity is a valuable asset to people of science (Holton, Chang & Jurkowitz, 1996; Mancini, 2006). It allows scientists to detect similarities among differing items. Since a scientist does not have an automatic knowledge of how to proceed from hypothesis to conclusion, finding a suitable research path is enhanced by observation and intuition (Beardsley, 1992; Brush, 1989).

The obvious conclusion of various studies is that the science curriculum must develop a historical approach to the teaching of science (Abd-El-Khalick, 2002). As a case in point, the National Science Education Standards (NRC, 1996) emphasize learning science through a historical approach because students need to understand that science reflects its history and is an ongoing, changing enterprise. The standards for the history and nature of science recommend the use of history in school science programs to clarify different aspects of scientific inquiry, the human aspects of science, and the role that science has played in the development of various cultures (NRC, 1996).

Methods

In this study, we examined our students' attitudes toward the discovery of the Archimedes law. One objective of this study is to examine the students' considerations of Archimedes Law before and after the discussion of his intuition as he made his discovery. A second objective is to determine the qualities students give to scientists and their discoveries based on the method that led to their discoveries.

Participants

The study involved tenth graders in high school who usually learn Archimedes Law and how to find the volume of non-geometric shapes. Ninety-two students from three heterogenic classes participated in the study. The first, second and third classes have 32, 29 and 31 students, respectively. About half (45) of the students were females. We expected no gender difference; therefore, no gender comparison was made in the study. Based on the students' achievements at school, the academic ability of the three groups was similar. All groups were taught by the same science teacher.

Data Collection

Table I
The findings following the traditional teaching method (Situation 1) and the historic introduction in science teaching (Situation 2)

Statement	Situation 1		Situation 2		Alpha*
	Agree	Disagree	Agree	Disagree	
1. Archimedes discovered his law using his intelligence	92 100%	00 00.0%	72 78.3%	20 21.7%	<0.001
2. He worked hard toward his discovery.	64 69.6%	28 30.4%	24 26.1%	68 73.9%	<0.001
3. I believe that Archimedes is a great scientist	68 73.9%	24 26.1%	64 69.6%	28 30.4%	NS
4. Archimedes law was a great discovery	88 95.7%	4 4.3%	88 95.7%	4 4.3%	NS
5. There could be no law without Archimedes	80 87.0%	12 13.0%	56 60.9%	36 39.1%	<0.001
6. His presence in the bathroom helped him in his discovery	28 30.4%	64 69.6%	92 100%	00 00.0%	<0.001
7. Everyone in science can discover what Archimedes had done	12 13.0%	80 87.0%	40 43.5%	52 56.5%	<0.001

* *Based on McNemar test of significance of change*

We used a questionnaire (Table I) that was prepared for the study purposes. It was administered in two different situations for the same group of students. The first was after students had been taught using a traditional method which did not include an historic introduction; the second followed the historic introduction of how Archimedes discovered his law. After students learned the Archimedes Law by the traditional method of teaching, they were asked to respond to the questionnaire. On the second day, the same law was introduced to the groups along with the narration of the debased crown and the swimming pool stories; and the role of intuition and inspiration in the discovery. This was followed by distribution of the same questionnaires among the study students. The two methods were introduced to the three classes, because we wanted to show the significance of using the two methods together starting with the traditional and followed by the historic methods. The emphasis of this study was not on comparing the two methods. For the purposes of our study, the physics teacher in the school chosen for the study was trained on both methods of teaching:

The traditional method. The teacher presents an experiment showing that bodies appear to have less weight when they are submerged in a liquid. If one has ever tried to carry someone in a swimming pool, it would have been obvious that much less force was needed to carry the person than what is needed to carry the person outside the pool. Similarly, the carrying force is less when an object is submerged in water. Apparently, water affects the object by a specific force upward. This is called the floating force. The liquids law that describes the floating force is known as the law that Archimedes discovered in the public bath.

The historical method. In this lesson, the teacher discusses the subject again inserting the famous historic story and a brief description of Archimedes' life as in the following paragraph, which was distributed to students and recited in the classroom with the teacher. The traditional method describes the buoyant force. If one were to teach Archimedes' Principle, he/she would have to relate the weight/mass of the displaced water and the apparent weight/mass difference of the submerged object versus its out-of-water weight/mass. This study emphasizes the displacement of water, comparing pure gold with an impure sample.

The distributed text

"In the case of Archimedes, although he made many wonderful discoveries of diverse kinds, yet of them all, the following, which I shall relate, seems to have been the result of a boundless ingenuity. Hiero, after gaining the royal power in Syracuse, resolved, as a consequence of his successful exploits, to place in a certain temple a golden crown which he had vowed to the immortal gods. He contracted for its making at a fixed price, and weighed out a precise amount of gold to the contractor. At the appointed time the latter delivered to the king's satisfaction an exquisitely finished piece of handiwork, and it appeared that in weight the crown corresponded precisely to what the gold had weighed.

But afterwards a charge was made that gold had been abstracted and an equivalent weight of silver had been added in the manufacture of the crown. Hiero, thinking it an outrage that he had been tricked, and yet not knowing how to detect the theft, requested Archimedes to consider the matter. The latter, while the case was still on his mind, happened to go to the bath, and on getting into a tub observed that the more his body sank into it the more water ran out over the tub. As this pointed out the way to explain the case in question, without a moment's delay, and transported with joy, he jumped out of the tub and rushed home naked, crying with a loud voice that he had found what he was seeking; for as he ran he shouted repeatedly in Greek, Ευρηκα, ευρηκα."

Taking this as the beginning of his discovery, it is said that he made two masses of the same weight as the crown, one of gold and the other of silver. After making them, he filled a large vessel with water to the very brim, and dropped the mass of silver into it. As much water ran out as was equal in bulk to that of the silver sunk in the vessel. Then, taking out the mass, he poured back the lost quantity of water, using a pint measure, until it was level with the brim as it had been before. Thus he found the weight of silver corresponding to a definite quantity of water. After this experiment, he likewise dropped the mass of gold into the full vessel and, on taking it out and measuring as before, found that not so much water was lost, but a smaller quantity: namely, as much less as a mass of gold lacks in bulk compared to a mass of silver of the same weight. Finally, filling the vessel again and dropping the crown itself into the same quantity of water, he found that more water ran over for the crown than for the mass of gold of the same weight. Hence, reasoning from the fact that more water was lost in the case of the crown than in that of the mass, he detected the mixing of silver with the gold, and made the theft of the contractor perfectly clear." (Bogomolny, 2010)

Results and discussions

The analysis of the students' responses to the questionnaire distributed after traditional teaching shows that all students think that Archimedes discovered his law due to his intelligence (Table 1). In comparison, almost 22% of the students changed their mind after the historic introduction in science teaching (Situation2). A McNemar test of significance of change shows highly significant change with $\alpha<0.001$ (Conover, 1980). In addition, almost 70% of the students think that Archimedes worked hard toward his discovery, while 30% think that a scientist with his intelligence does not need a great effort to reach such discovery. Following the historic introduction, the response to this statement were almost reversed with highly significant change ($\alpha<0.001$). Nearly three-fourths of the students consider Archimedes a great scientist, while over 4% changed their mind after the historic introduction. The vast majority of the students (96%) think that Archimedes law was a great discovery with no change in the response in the post test, which reflects a high level of appreciation of scientists among students.

The students continued their responses with 87% of them thinking that the law could not be discovered without Archimedes. After the historic introduction, over 26% of the students changed their mind pulling the rate down to 60.9% ($\alpha<0.001$). This means that nearly 40% of the students think that other scientists could have discovered the law. In the pre test (situation 1), only 30% agreed that his presence in the public bath helped him in his discovery. This changed significantly ($\alpha<0.001$) after the historic introduction reaching 100% of them agreeing with the statement. The last statement in situation 1, only 13% of the students think that everyone in science can discover what

Archimedes had done. After the historic introduction, this percent went up to 44% with statistically significant change ($\alpha<0.001$).

The use of intuitive sessions by the science teachers to introduce the biographies of discoverers and their distinguished role is considered one of the efficient methods teachers may use to attract the attention of their students. Science curriculum generally presents scientific discoveries as facts. In other words, it is presented in its final outcome without looking into its reasons, motives, circumstances and the assisting factors in its discovery. By teaching the way that Archimedes reached the floating body principle and the role of intuition, the science teachers can relay to their students that errors, oblivion sense and dreams are among the scientists' tools in discovering science. Situation 1 shows that 30% of the students consider Archimedes presence in the public bath helped him in his discovery. Following the historic introduction, 100% of them agreed with the statement. In addition to all these, it is necessary for the scientist to be able to correct the errors and translate the dream to a notion, and the notion to a potential, and the potential to a fact. Added to that, science teachers can clarify for their students the reasons and motives that had led scientists such as Archimedes to reach their scientific discoveries. Teacher can also point out that scientists learn from the simplest experiences. The teachers must call the students' attention to the necessity for accuracy and careful observation using critical thinking.

It is important that science teachers highlight the relevant aspect of scientists' lives. This leads students to develop greater respect and consideration for science and appreciation for the scientists' efforts in advancing science; this is obvious in the responses to questions 3 and 4. The human dimension relative to scientists and discoverers must be clarified in all scientific curricula by presenting the circumstances and social factors that helped scientists in their discoveries.

Coincidence does not happen to the discovering scientist easily; it requires a special mental orientation. In addition, scientists must be aware of any expected events. The scientists' awareness of coincidence may lead to important outcomes. He needs to train himself on observation, to promote his mental ability to seek unexpected things and to examine every initiative that coincidence brings. It appears that every individual observes the unusual phenomena and considers it factual when it is obvious and frequent. Nevertheless, scientists possess unique instinct to figure out the exceptional, even if the starting point was irrelevant to the subject of consideration.

Albert Einstein states that intuition is a factor of great value. The word intuition is used to explain an idea coming suddenly to one's mind. This takes place frequently when the individual is not consciously thinking about the subject, as in the case of Archimedes as he entered the public bath. The best opportunity for intuition is the period between the intensive work on the problem in an attempt to find a solution for it and leaving it aside for a while to concentrate on something else (Smith & Kounios, 1996). Intuition often makes one consider that the freshly-thought idea represents the truth most of the time. More often than not, this is accompanied with a feeling of joy as the case of Archimedes, or perhaps the excitement due to not thinking about the problem. The study indicates that students displayed a considerable appreciation for scientists. The response to question 4 before and after the historic introduction was highly positive. Questions 5 and 7 are reversed. The responses to them were similar but reversed. This shows that the students' opinions moved to believing that Archimedes was not the only person who could have developed this law.

This study suggests that the use of historic introduction in science teaching increases student's self-confidence. In response to question 7 after the historic introduction, 43.5% of the students seemed to support the idea that every scientist and possibly science students could reach the Archimedes discovery.

Conclusion

Science is usually presented in the classroom to students as a collection of facts; teachers present the specific facts to their students without questioning their development (Beardsley, 1992). Several authors introduce history of science into science education not only as a possible way of highlighting its concern with the products, but also with the processes of development of science ideas (Cachapuz & Paixao, 2005; Irwin, 2000). We have used this later method in the context of Archimedes discover story.

This study examined the students' consideration toward the discovery of Archimedes Law. We found that the most important factors contributing to scientific discoveries are observation and intuition. As perceived by students, this affects the students positively and promotes their sense of observation, and they might find the solution of a hard problem by observing an unexpected phenomenon.

The study suggests that almost all students think that Archimedes Law was a great discovery, regardless of the teaching method, but the narration of the story of his discovery led many students to change their opinion of several aspects of the discovery. We observed a significant rise ($\alpha<0.001$) in the number of agreements with the two statements: "Archimedes' presence in the public bath helped him in his discovery" and "Everyone in science can discover what Archimedes had done". The narration of the Archimedes story and others give the student the opportunity to learn the history and philosophy of science, as well as the stages of social and technological developments that may be called the "Humanities of science".

Based on the findings of this study, in teaching science, students should be encouraged to use their imagination. This may lead to the discovery of their skills in finding creative solutions. In addition, the utilization of the historic introduction and narration of the intuitive stories of famous scientists reinforces self-confidence among students and encourages them to make a sound scientific thinking.

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