Creative Education, 2020, 11, 1243-1260
https://www.scirp.org/journal/ce
ISSN Online: 2151-4771
ISSN Print: 2151-4755

The Historical Story behind the Discovery: How Does It Affect Students' Attitude towards the Scientific Endeavor?

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How to cite this paper: Kortam, N., Basheer, A., Drawshe, H., Drawshe, S., & Hugerat, M. (2020). The Historical Story behind the Discovery: How Does It Affect Students' Attitude towards the Scientific Endeavor?. *Creative Education, 11,* 1243-1260.
https://doi.org/10.4236/ce.2020.118093

Received: December 22, 2019
Accepted: August 9, 2020
Published: August 12, 2020

Abstract

This study examined changes in students' attitudes towards the scientific endeavor by exploring the impact of introducing historical stories and rationales into the science curriculum. The stories referred to discoveries by four scientists: Galvani (the discovery of the electrical current), Fleming (the discovery of penicillin), Archimedes (the discovery of the floating principle), and Kekulé (the discovery of the structure of the benzene ring). The participants comprised 542 Arab students from northern Israel between the ages of 12 and 16. Out of the 542 students, 270 studied a curriculum that included historical stories approach (the experimental group), and 272 studied a curriculum without historical stories approach (the control group). A questionnaire was used to examine the students' attitudes towards the scientific endeavor. The results provide evidence for the view that relating the story behind the discovery significantly improves students' attitudes towards science in comparison with those who study according to a traditional approach. The students noticed that certain circumstances must be present in order to enable a scientist to make his discovery. The main conclusion is that the scientific curriculum should include adequate scientific subject matter, integrating historical stories in order to encourage students to develop positive attitudes towards and perceptions of science.

Keywords

Approach towards the Scientific Endeavor, Historical Stories, History of Science, Science Education

1. Introduction and Theoretical Background

The prevalent approach to teaching, both generally and specifically in the

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sciences, focuses on presenting facts and results without taking the scientific process itself into account. This traditional approach does not promote students' active participation in scientific activity because it is based only on results; it also engenders unfavorable views of science and alienates students by leading them to believe that only scientists can make discoveries. In the traditional approach, elements of the history of science either are absent or introduced in a fragmentary way. However, another approach to teaching the sciences exists, despite not being very prevalent in schools: the historical stories approach, which emphasizes the process and not only the results in teaching scientific content. In this approach, students are exposed to scientific facts as well as to the story behind the discovery, and a discussion is held on the way the scientist used his intuition to make the discovery.

1.1. Traditional and Historical Stories Approaches to Science Education

Traditional teaching is content-based and teacher-focused (Mamlok-Naaman, 2011). The knowledge imparted to the students is regarded as new and foreign to them, but it is absorbed and becomes integrated into their pre-existing knowledge structure built by previous learning and serves as a basis for absorbing new external knowledge. The teacher serves as the students' source of knowledge (Brooks & Brooks, 1993). However, the traditional method is an economical and structured way of transmitting human cultural heritage and knowledge in an optimally organized manner and finished form. Regarding the assessment and measurement of how effectively the studied material is absorbed, the traditional method allows teachers to obtain feedback from their students in real time, through verbal communication in the form of questions and answers and through students' non-verbal responses.

The use of elements in the history of science teaching is related to, among other things, how it is integrated into teaching the epistemological distinction between the framework within which scientific knowledge is born and developed and the framework within which scientific knowledge is an already organized body of issues, contents, and theories (Kuhn, 1962). History of Science (HOS) is a way to provide students with a medium to interact with the culture of science. In the literature, several studies have used scientists' life stories (Wieder, 2006) or their works (Solomon, Duveen, & Scot, 1992) in order to investigate students' understanding of the nature of science.

The historical method is a pedagogical approach to teaching in which teachers use the chronological story of scientific discoveries and the evolution of scientific ideas in order to render students' perceptions of the conceptual aspects of science, its processes and contexts more accurately (Wang & Marsh, 2002). This approach is unique in that it provides a background and defines the characteristics of scientists (Losee, 1993). The use of the historical approach in teaching science has been studied for many years. Some scholars (e.g., Irwin, 2000; Monk & Osborne, 1997) argue that the historical approach has numerous advantages and benefits. They claim that this approach has the power to improve students' understanding of the nature of science (NOS) by emphasizing not only the products of science but also the evolution of its ideas. One approach to teaching and learning about the NOS is the exploration and interpretation of cases from the HOS (Abd-El-Khalick, 2013); NOS refers primarily to "the values and assumptions inherent to the development of scientific knowledge" (Lederman, 1992: p. 331). Likewise, Paraskevopoulou and Koliopoulos (2011) found a significant improvement in students' understanding of several NOS aspects after a five-lesson teaching intervention in which students learned about a historical scientific dispute by reading four short stories and answering accompanying questions focusing on different NOS aspects. In addition, this approach, which integrates explanations of scientific developments with historical analyses of scientific events, may help students gain a better understanding of the essence of science and the work of scientists (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Cachepot & Paisa (2005) pointed out that the historical approach involves using more verbiage in scientific explanations and may therefore cause learners to confuse historical and current information. An approach that combines teaching scientific content with a historical analysis of scientific events can help improve students' understanding of the essence of science and the scientific method (Abd-El-Khalick, 2002; Elkanah, 2000; Erduran, 2001). Hugerat, Kortam & Zidane (2011) investigated the effect of teaching science using the historical stories approach, using the discovery of Archimedes' principle as an example. They found that adding the historical stories approach improved students' attitudes towards the sciences. Exposing students to the historical contexts of scientific discoveries can help them gain a more profound understanding of the scientific subject matter; this can be determined by assessing their attitudes towards science. Eshach (2009) argued that the history and philosophy of science can serve as tools for teaching about science and that they are comparable to teaching science itself. This kind of teaching applies the principles of case-based teaching, which builds on how people naturally think, learn, and remember. Concerning cognitive levels, some scholars (e.g., Erduran, 2001) claim that students' initial knowledge in the sciences can be compared to the knowledge early scientists had, since it is based on arriving at conclusions intuitively through observation. Just as scientists in the past tended to personify objects and describe natural processes and phenomena using emotional concepts, today's students also construct their own conceptual world, which is adapted to their personal world of knowledge and emotions. Children understand what they feel or see and tend not to believe in anything that lies outside the range of their senses (Mamlok-Naaman et al., 2005). Despite studies that advocate for integrating historical aspects into science curricula, it appears that teachers are not well prepared for teaching by this approach and may avoid these parts of the curriculum (Erduran, Aduriz-Bravo, & Mamlok-Naaman, 2007). Wang & March (2002) examined science teachers' attitudes towards the educational contribution of adding the historical approach to science teaching. They found that in science lessons teachers emphasize understanding the content rather than the process itself. Wang & Cox-Petersen (2002) found that most of the secondary school teachers they investigated used historical elements in their science teaching in order to improve students' understanding of the content studied and the nature of scientific knowledge, as well as to develop their processing skills. Hacieminoglu, Ertepinar, & Yilmaz-Tuzun (2012) found that teacher trainees who used the historical approach during the science lessons they taught as part of their practical training tended to stress all aspects, but that after the trainees had become actual teachers they began to stress only the conceptual aspects and tended to attach less importance to context and the scientific process in their lessons. The emphatic conclusion of various studies is that the science curriculum must develop a historical approach to the teaching of science (Abd-El-Khalick, 2002). For example, the National Science Education Standards (NRC, 1996) emphasize that in studying science, students need to understand that science reflects its history and is an ongoing, changing enterprise. The standards for teaching 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 developing various cultures. Wolfensberger & Canella (2015) reported a classroom study on cooperative learning about the NOS using a case from the HOS. The purpose of the research was to gain insight into how students worked with the historical case study during cooperative group work, how students and teachers assessed the teaching unit, and in what ways students' ideas about selected aspects of the NOS changed as a result of the teaching unit. The results show that both the topic and the instructional design of the unit were judged very positively, and that students had more informed views of selected NOS aspects after the teaching unit was completed. Stinner, MacMillan, Metz, Jilek, & Klassen (2003) suggested that teachers of all grades use a methodological approach for creating historical material that may take the form of short excerpts from historical texts (vignettes) or case studies in which a unifying central idea is used to create a story based on the authentic historical material.

Hofstein & Mamlok-Naaman (2011) and Hugerat et al. (2011) consider the historical approach suitable for providing students with a profound learning experience and tools for better understanding the way scientific knowledge is built and discoveries are made. Solomon et al. (1992) emphasized that adding the historical approach to science teaching has the following advantages: better effective learning of scientific concepts, improved student interest and motivation, acquaintance with the philosophy of science, and improved student attitudes towards science. Seker & Welsh (2006) noted that the effect of using the historical approach on the level of the understanding of science content is still debatable. Oh and Yager (2004) stated that while students' negative attitudes toward science are related to a traditional approach to teaching science, their positive feelings are associated with constructivist science teaching.

1.2. Students' Attitudes towards the Scientific Endeavor

Attitudes can be defined as "feelings, beliefs and values held about the enterprise of school science, school science and the impact of the science on society" (Osborne, Simon, & Collins, 2003: p. 1050). The concept of attitudes towards science involves curiosity and interest in science, the expression of opinions, desires, and beliefs associated with science, the desire and motivation to study science, as well as achievements and satisfaction derived from studying science (Osborne, Simon, & Colluns, 2003; Koballa & Glynn, 2007). The development of positive attitudes towards science in general, and towards studying science in particular, is one of the aims of science teaching and learning. Since the beginning of the twenty-first century, this topic has attracted international attention after a period of decline during the previous twenty years (Hofstein & Lunetta, 2004; Koballa & Glynn, 2007). Arons (1984) argued that many science teachers do not devote enough time to discussing the nature of the scientific process with their students, and therefore miss opportunities to teach them creative, inventive, and critical thinking skills.

Osborne et al. (2003) drew a dark picture of students' attitudes towards science, their interest in science in general, in studying science, and regarding the number of graduates who choose a science-related career. Furthermore, in the wake of poor results in international science assessment exams (TIMSS since 1995 and PISA since 2000), many countries in the West have experienced an upswing in thinking and research aimed at reassessing the aims, contents, and methods of science teaching (Bybee, Fensham, & Laurie, 2009). It was found that the contents of science taught in schools and the methods of science teaching do not fit the needs, interests, and motivational characteristics of most students (Graber, 2002; Jenkins, 2005).

Studies have shown that the way students perceive knowledge is very important for their learning process (Bloom, 1976). Fairbrother (2000) noted that students would study science if they are intrinsically interested in it, and that they develop more positive attitudes towards it if they are familiar with science contents and concepts. Osborne & Dillon (2008) stated that no significant correlation exists between students' achievements and their attitudes towards science. In other words, students' attitudes towards science can be influenced as part of the process of teaching science but not as part of the results of this process. It has been shown that the most important factor for students' success when studying science is their interest in the field (Hugerat et al., 2011). Students who show an interest in science and who have a better understanding of science content and scientific concepts will be more highly motivated and will have a more positive attitude towards science than students who experience difficulties in the discipline (Mamlok-Naaman et al., 2005). In order to further improve students' understanding of scientific concepts and their attitudes towards science, they should be taught less content but be encouraged to achieve a deeper understanding of how scientific knowledge is discovered and accumulated and how scientific theories are constructed (O'Neill & Polman, 2004).

The purpose of the present study was to examine changes in students' attitudes towards the scientific endeavor by exploring the impact of introducing historical stories and rationales into the science curriculum. The study's basic hypothesis was that adding a historical dimension when teaching science can improve students' attitudes towards science, which in turn may encourage more students to study it. The historical stories approach was implemented using the stories behind Galvani's discovery of the electric current (the galvanic cell), Archimedes' discovery of the principle of floating bodies (the golden crown), the discovery of penicillin by Fleming, and Kekulé's discovery of the structure of the benzene ring. Based on the above, the research question was:

What is the students' attitude towards the scientific endeavor after teaching *scientific content using historical stories approach*?

2. Methods

2.1. Research Design

The present study was carried out using a quantitative method, triangulated with statements made by students from elementary, middle, and high schools. We examined students' attitudes towards the scientific endeavor after studying the curriculum (see following). Two groups of students were compared: students who studied science through historical stories approach and rationales (the experimental group), and those who studied science using a traditional approach (the control group). The same science teacher taught the material to both groups.

2.2. Participants

The participants comprised 542 students, 52% female and 48% male, from 16 classes (**Table 1**) selected from among the primary, middle, and high schools of the Arab sector of northern Israel. All students studied in public schools, while differing in their socio-economic status. The classrooms for the experimental and control classes at each school were assigned randomly. The teachers were science graduates, with 10 - 18 years of teaching experience.

Table 1. Student samples and teaching approaches.

Classes	Approach	N
5th (primary school, 4 classes)	Traditional	67
	Historical	70
8th (middle school, 4 classes)	Traditional	68
	Historical	64
9th (middle school, 4 classes)	Traditional	72
	Historical	67
10th (secondary school, 4 classes)	Traditional	65
	Historical	69

2.3. Data Sources

The data sources consisted of 1) a questionnaire on "students' attitudes towards the scientific endeavor," which was distributed to the students after studying the curriculum, and 2) statements made by students from the experimental group, collected by the teachers after first author of this paper, after studying the chosen curriculum. The questionnaire used was a Likert scale with a five-choice model (scale of five) consisted of 13 closed items. Answer categories 1) strongly agree, 2) agree, 3) not sure, 4) Disagree, 5) strongly disagree. The questionnaire items were adapted from previously published instruments (Hugerat et al., 2011) (see **Appendix A**). The questionnaire was content validated by five science education experts. The items $\left(\propto_{\text{Cronbach}} = 0.742\right)$ were divided into four indices: 1) requirements, conditions, and favorable circumstances for making discoveries (statements 1, 4, 7, 10, and 13, and to a certain extent, also statement 3); 2) attitudes towards the scientists (statements 2, 6, and 8); 3) attitudes towards the discovery itself (statement 5); 4) implications for students and their perceptions of their own ability to make discoveries (statements 9, 11, and 12).

2.4. Curriculum

We chose topics in science that are appropriate for primary, middle, and secondary school students and that are consistent with the curriculum. Wang & Cox-Petersen (2002) claimed that teachers gave importance to HOS activities if they were related to the curriculum. The following topics were chosen and integrated into the teaching units: the discovery of the electrical current, the basis for the galvanic cell, by Galvani, for the 5th grade; the discovery of penicillin and its effects by Fleming, for the 7th grade; the discovery of Archimedes' principle of floating, for the 8th grade; and the discovery of the structure of the benzene ring by Kekulé, for the 10th grade. According to the Israeli curriculum, primary school students (5th graders in our research) study science and technology (without separating the subject matter into different disciplines) for about 3 hours per week. The students learn about the discovery of the electrical current when studying the unit "the production and utilization of electrical energy." This curriculum is interdisciplinary, in accordance with the ("Science, Technology and Society" (STS) approach in which the teacher has to emphasize scientific, technological, and socio-ethical aspects. According to the Israeli curriculum, middle-school students (7th and 8th graders) study science for 5 hours per week (usually 3 hours of biology and 2 hours of chemistry or physics). Archimedes' law was taught as part of the unit "the mass and volume of bodies" (measuring the volume of solids of a non-geometrical form that are immersed in water). Only in high school (10th grade) does the situation change and the 3 disciplines of biology, chemistry, and physics are taught separately.

The traditional group studied the curriculum according to the instructions given to teachers in the guidebooks. The experimental group was exposed to details about the life and professional development of each of the four discoverers as well as the context and process they lived through when making their discoveries. The story was told using a narrative text, but it also included photographs, drawings, YouTube videos, and charts relating to the other two dimensions of scientific knowledge: the conceptual and the methodological aspects. The teacher then distributed a handout giving a brief description of the discoverer and the process of research and discovery:

1) Galvani's discovery of the electrical current (5^{th} grade): The teacher stressed that Galvani was a pioneer in the study of electricity. He focused on anatomy and physiology, specifically the connection between electricity and the nervous system. The teacher told the students the story of how in 1780 Galvani conducted an experiment in which he cut off a frog's leg and by chance, a steel scalpel touched the brass hook holding it. To Galvani's great surprise, the leg contracted. Galvani himself did not realize the significance of his observation and thought that the contraction was due to electricity in the muscle. He repeated the experiment a number of times and eventually concluded that he had discovered a special, "vital" form of electricity that flows continuously and is created by the organisms of living creatures and generated by them. In 1791, he published a paper in which he reported his discovery of this "vital" electricity. The teacher discussed Galvani's discovery of what we today call the electric current, which became the basis for the electrical battery, and highlighted the dispute between Galvani and Volta.

2) Fleming's discovery of penicillin (7^{th} grades): The teacher described Fleming's major discovery, made on September 15, 1928, when Fleming returned to London after a two-week vacation at his brother's house. Upon his arrival, he discovered that he had accidentally left some Petri dishes out on his laboratory table. The teacher asked the students what they would have done in such a situation. He then told them that Fleming did not throw them away after observing that in some of the dishes, which had contained cultures of the bacteria *Staphylococcus aureus*, a mold had developed. This contamination in itself was not remarkable, but he noticed that the bacteria cultures near the mold were small and sickly compared to the cultures located farther away from the mold. Fleming became interested in this phenomenon and performed the experiment again, by placing both fungi and bacteria in the same dish. After replicating the result, he hypothesized that the mold excreted a substance that was fatal to the bacteria. He later discovered that the mold was a fungus of the *Penicillum* family, specifically of the species *Penicillium chrysogenum* (previously called *Penicillium notatum*). Fleming named the antibacterial substance produced by the mold "penicillin." The experiments he conducted showed that penicillin killed many types of bacteria; however, the substance was not toxic to humans and did not harm healthy tissues. However, Fleming did not succeed at isolating penicillin or producing large amounts of it.

3) Archimedes' principle of floating objects (8^{th} grade): The teacher taught the same contents as in the control class, and then posed his students the same challenge that Hieron, the king of Syracuse, had presented to Archimedes: to test whether his crown was made of pure gold. The teacher added drama to the challenge by telling the students that Archimedes was threatened by the king with having his head cut off if he did not come up with an acceptable solution without damaging the crown. In addition to telling the story, the teacher also explained Archimedes' reasoning and how he arrived at his insight in a glorious moment of discovery. The students were exposed to the story's scientific content and to Archimedes' realization of how he could measure the crown's volume after he noticed that the water level in his bath rose as he entered the water. The teacher stressed the close connection between entering the bath, Archimedes' realization, and the conclusions that he had reached. The teacher and the students discussed the differences in the crown's weight in and out of the water in relation to the weight and volume of the water that had been displaced when the crown was submerged.

4) Kekulé's discovery of the structure of the benzene ring (10th grade): The teacher emphasized the context in which the discovery was made and its accidental nature, while at the same time illustrating the importance of perseverance and deep thinking for scientific discovery. The teacher explained the unique nature of the method used by Kekulé, a scientist who liked to work alone and saw atoms and molecules in his dreams. It was not easy for Kekulé to find the solution to the structure of the benzene molecule; however, his firm beliefs and assertiveness remained with him: in a dream, he once saw a snake swallowing its own tail. This immediately led him to the right solution; thus, he discovered the hexagonal structure of the benzene ring.

3. Results

We first present the findings obtained from the analysis of the quantitative data, followed by the triangulation with statements made by students in the experimental group as collected by the first author of this paper (Tobin, 1995).

I) The analysis of the quantitative data is discussed by referring to pre- and post-test results for each of the four discoveries, examining the influence of the historical vs. the traditional teaching approach on the students' attitude towards the scientific endeavor.

3.1. Galvani's Discovery

The findings in **Table 2** indicate a significant difference (t = 2.258, $p < 0.05$): The average score for students' attitudes towards the scientific endeavor in the experimental group, which learned about the discovery of electric current by Galvani together with the story behind this discovery (M = 0.66, SD = 0.14), was significantly higher than that for students in the control group, who studied the subject without the story (M = 0.61, SD = 0.12).

3.2. Fleming's Discovery

The findings in **Table 3** indicate a non-significant difference (t = 1.325, $p > 0.05$):

Table 2. Students' attitudes towards the scientific endeavor after learning the story behind Galvani's discovery of the electrical current (5^{th} grades).

Approach	M	SD	t-value
historical	0.66	0.14	*2.258
traditional	0.61	0.12	

***$p < 0.05$.

Table 3. Students' attitudes towards the scientific endeavor after learning the story behind Fleming's discovery of the penicillin (7^{th} grades).

Approach	M	SD	t-value
historical	0.68	0.15	1.325 (n.s)
traditional	0.65	0.17	

The average score for students' attitudes towards the scientific endeavor in the experimental group, which learned about the discovery of penicillin together with the story behind the discovery (M = 0.68, SD = 0.15), was higher, but not significantly higher, than that for students in the control group, who studied the subject without the story (M = 0.65, SD = 0.17).

3.3. Archimedes' Discovery

The findings in Table 4 indicate a significant difference (t = 4.063, $p < 0.001$): The average score for students' attitudes towards the scientific endeavor in the experimental group, which learned about the discovery of Archimedes' principle together with the story behind the discovery (M = 0.75, SD = 0.15), was significantly higher than the mean score for students in the control group, who studied the subject without the story (M = 0.64, SD = 0.19).

3.4. Kekulé's Discovery

The findings in Table 5 indicate a significant difference (t = 3.85431, $p < 0.001$): The average score for students' attitudes towards the scientific endeavor in the experimental group, which learned about Kekune's discovery of the structure of the benzene ring together with the story behind the discovery (M = 0.74, SD = 0.16), was significantly higher than that for the control group, which studied the subject without the story (M = 0.62, SD = 0.2).

II) Analysis of the statements made by students from the experimental group, collected by the teachers after teaching the curriculum.

The quotations in Table 6 show that most of the students were enthusiastic about the scientists' work and discoveries. The admiration for scientists increased with age. The high school students were more convinced of the capacity of any person to become a scientist than were the middle and elementary school students. Still, one of the elementary school students expressed his deep admiration for scientists: "I think all scientists are very smart people. This wisdom brought them to their discoveries."

Table 4. Students' attitudes towards the scientific endeavor after learning the story behind Archimedes' discovery of the principle of floating objects (8th grades).

Approach	M	SD	t-value
historical	0.75	0.15	***4.063
traditional	0.64	0.19	

***$p < 0.001$.

Table 5. Students' attitudes towards the scientific endeavor after learning the story behind Kekulé's discovery of the structure of the benzene ring (10th grades)

Approach	M	SD	t-value
historical	0.74	0.16	***3.854
traditional	0.62	0.20	

***$p < 0.001$.

Table 6. Statements made by students from the experimental group (primary, middle and high school), collected by the first author of this paper after studying the curriculum.

Primary School Students	I think all scientists are very smart people. This wisdom brought them to their discoveries.
	I myself would like to be a scientist because it brings tremendous pride.
	The discoveries of scientists must have brought improvement to humanity.
	To be a scientist you need wisdom, a lot of knowledge and a lot of luck.
	I do not appreciate discoveries made by accident.
	It intrigues me to learn about scientists and the way they acted to reach their discoveries. It makes me appreciate the science more.
	Scientists are the people who have contributed most to humanity.
	God loves scientists, so he wanted them to be among us to contribute to us.
	I do not always respect scientists because some of them bring bad discoveries to nature and humanity.
Middle School Students	To reach discoveries that will change the face of humanity requires a very wise scientist, consistency, and a lot of mental and physical investment from him.
	I appreciate scientists and I myself would like to be a scientist.
	Being a scientist brings personal, national and global pride.
	I cannot be a scientist because I do not have the wisdom and curiosity they have.
	I like to learn about the conditions of the discoveries and the stories of scientists, not just the rules and conclusions derived from the discoveries.
	I would appreciate it if fewer discoveries would happen by chance.
	Fleming or someone else could have made the same discoveries without the chance.
	I think that because of chance, not everyone can make the same discovery.

Continued

	Being a scientist is a gift from God and not everyone can be a scientist even if he is diligent and striving.
High School Students	A scientist is a very curious man and pursues the truth.
	Chance alone does not lead to discoveries. You need a scientist who has a great deal of knowledge and sharp senses to identify the chances that has come his way.
	All discoveries are very important, but there are discoveries that are more important and have made a tremendous contribution to humanity.
	I respect and admire scientists because they are special people.
	A scientist is a very creative man, clever, and he pays attention to the small details. Discoveries require creative thinking. Not everyone has these qualities.
	I know that discoveries have happened by chance. This is not enough to attain great achievements in science.
	I believe that if Kekulé had not come to his discovery someone else would have made the discovery.
	Not every science student can become a scientist. A scientist is a man with special qualities.
	I do not think I can be a scientist myself because I do not have the special qualities that scientists have, like sharp brains, special intellectual abilities, and lots of curiosity.
	A scientist must sacrifice his personal life in order to reach important discoveries.

In conclusion, as the findings indicate, in three cases in which the science content was combined with the story behind the discoveries, we found that the students' attitudes towards the scientific endeavor were more positive compared with those of the control group; only in one case was the result not significant, even though it tended in the same direction. These findings seem to indicate that the historical stories approach improves students' attitude towards the scientific endeavor.

4. Discussion

The present study showed that an effective method that teachers could use in order to attract students' attention is to intuitively present the course of events leading to discoveries and the unique role that the scientists played. This is especially important in light of the fact that the science curriculum presents scientific discoveries and contents as facts; in other words, what is presented is the final product, without taking into account the process, causes, motives, circumstances, and supporting factors that contributed to making the discovery. By teaching how researchers made their discoveries and by stressing the role of intuition in the process, science teachers can make their students realize that errors, uncertainty, aptitude, and dreams are all part of the scientists' toolbox. This can clearly be seen in the students' answers as they were thinking about the role of the discovery's context. Furthermore, it is just as important that scientists be very good at correcting their mistakes, and at translating their dreams into an idea and the latter into an important discovery. Science teachers can also explain to students the reasons and motivations that drove scientists, such as those about whom they learned during the present study, in making their discoveries. Teachers can also mention the fact that scientists learn from even the simplest experiences and experiments. They should make their students aware of the importance of accuracy, precise observation, and critical thinking in science.

The results (**Tables 2-5**) show that using the historical stories approach to teaching science improves students' attitudes towards it. These results are consistent with other studies on the use of the historical stories approach in science teaching. Koliopoulos, Dossis, & Stamoulis (2007) claimed that introducing HOS elements, via short texts (vignettes), into the framework of the storyline approach seems to offer multiple benefits. Mamlok-Naaman (2011) and Mamlok-Naaman et al. (2005) showed that adding the historical stories approach to teaching science does indeed improve students' attitude towards the scientific endeavor. In line with Wang & Marsh (2002), we stressed the importance of presenting the history of scientific discoveries and the evolution of scientific subject matters in learning science. In addition, Osborne & Dillon (2008) showed that students' attitudes towards the scientific endeavor could be influenced in the course of teaching science, specifically by showing scientists' successes and achievements.

The improvement in students' attitudes towards the scientific endeavor means that they have a better understanding of and a greater familiarity with scientific concepts and principles, a greater interest in science, and a stronger desire to study it (Fairbrother, 2000); students have a better awareness of the role that scientists play in building models and theories as tools for better understanding nature (Hayes & Perez, 1997), as well as a deeper understanding of the research process, its characteristics and motivations, and also its occasional restrictions and even failures (O'Neill & Polman, 2004). This is especially true for students who are exposed to success stories of ground-breaking discoveries and who realize that scientists, like other human beings, cannot do everything on their own; they require the support and assistance of other researchers in order to complete their discoveries, as was the case with Galvani and Fleming. From this we can conclude that exposure to the historical stories approach in teaching the sciences and consequently, students' improved attitudes towards science, contribute to increasing their interest in science and motivation to study it (Mamlok-Naaman et al., 2005).

The use of the historical approach provides students with a profound learning experience and equips them with a tool for better understanding the NOS and the scientific method, that is, the way in which knowledge is created and discoveries are made (Abd-El-Khalick, 2002; Elkanah, 2000; Erduran, 2001; Hofstein & Mamlok-Naaman, 2011; Hugerat et al., 2011; Mamlok-Naaman et al., 2000). We wish to point out two advantages of adding the historical stories approach to science teaching. The first is that it provides students with theoretical access to the research process and helps them understand that the scientist is not some "unique superpower." Students are given a description of the research process, which presents it as a human activity involving continuous learning and intuition, temporary helplessness, uncertainties, and weaknesses. The second advantage is that this approach stresses the totality of qualities needed for making discoveries and, at the same time, imparts the message that discoveries can be made by anyone who possesses some of the required traits, such as intelligence, the willingness to work hard and make an intellectual effort, powers of observation, and, certainly, being exposed to the right conditions and opportunities, which a researcher can exploit and utilize using with a sharp intuition.

Furthermore, students are clearly capable of distinguishing between the different types of contents. They can deal with each topic separately and earnestly from a variety of different perspectives if they are provided with the right conditions, as was done in the present study. The topics we used presented students with scientific content including research and discoveries based on the scientist's intuition. We learned that adding the historical stories approach made students acquire a greater affinity for and a better understanding of science, research, and discovery. In addition, it gave students the courage to think that they, too, could make discoveries. Indeed, they demonstrated their ability to think about and judge each topic critically and independently.

5. Conclusion

In the course of the present study, we saw that students who studied science using the traditional approach concluded that scientists must be unusually smart and must also work very hard in order to make their discoveries. This trend became even more noticeable when we examined students' responses to various statements in the "students' attitude towards the scientific endeavor" questionnaires. We learned that students believed that scientists were unique individuals who were not influenced by context, and who were not affected by any outside factors as they performed their research and made their discoveries, which no other scientist could have made. The picture that emerges makes it very clear that the traditional teaching approach did not contribute to promoting creative and critical thinking among students, nor did it encourage them to dare to think that they, too, could make important discoveries.

On the other hand, the study showed that when the historical stories approach to teaching science was used, students' attitude towards the scientific endeavor improved. This study provides direct evidence of the change that took place in students' attitude towards the scientific endeavor, research, scientists, and discoveries following their exposure to the stories behind the discoveries. It can be seen that teaching science by portraying the stories behind the scientific discoveries can make students think more critically; this is evident from the varied attitudes of students toward the individual topics and scientists presented, who were not treated as an undifferentiated whole. Furthermore, students also exhibited a greater understanding of the importance of imagination and intuition in the course of scientific discovery. They learned that in order to make discoveries, intelligence was not enough and that good observation skills, deep thought, and hard work were necessary as well. When students are exposed to the contents of discoveries in their actual context, they begin to understand these contents better. They also develop better judgment and greater efficacy when studying, and come to realize that researchers may not be uniquely capable of making discoveries and that others could do so as well, even the student him- or herself. Moreover, the study shows that even after adding the historical stories approach, students do not yet have enough confidence in their own ability to make discoveries, as they still feel that a barrier prevents them from either making them or from becoming capable of doing so. This would seem to indicate that students ascribe greater importance to a researcher's personal attributes such as intelligence, wisdom, and fame than to external circumstances having to do with scientific content as well as working conditions and historical, scientific, and social contexts. We can conclude that using historical stories approach to teaching science brings students closer to science and discoveries and enables them to gain a better understanding of the contexts in which the discoveries were made and to realize that scientific discoveries are based on a great deal of intuition as well as a combination of conditions, contexts, and abilities, such as chance and overall circumstances, which go well beyond the personal and professional attributes of the researcher himself.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix A

The "students' attitudes towards the scientific endeavor" questionnaire, referring to Galvani's discovery of the electrical current*

(1 = strongly agree; 2 = agree; 3 = not sure; 4 = disagree; 5 = strongly disagree)

	Statement	1	2	3	4	5
1	Galvani discovered the electrical current thanks to his intelligence.					
2	I believe that Galvani was a great scientist.					
3	Galvani worked very hard and consistently in order to arrive at his discovery.					
4	Galvani invested much profound thinking to arrive at his discovery.					
5	Galvani's discovery is momentous.					
6	Without Galvani, the electrical current would never have been discovered.					
7	Experimenting with frog legs helped Galvani arrive at his discovery.					
8	Any scientist could have made Galvani's discovery.					
9	My exposure to the way Galvani made his discovery helped me better understand the subject.					
10	Galvani was led to his discovery by chance.					
11	I could make discoveries under the right conditions and with some luck.					
12	I could make discoveries if I gave it enough thought.					
13	Excellent powers of observation are the basis for discovery.					

*Similar questionnaires were given to the students referring to the other three discoveries.