



## Good practice report

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# The story behind the discovery: integrating short historical stories in science teaching

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**Abstract:** The use of the historical approach in teaching science has been studied for many years. Many researchers claimed 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. In this paper we will deal with historical stories which were integrated into the science curriculum of primary, middle, and secondary school students *from Arab schools in the Israeli Galilee (270 students)*. Integrating short historical stories in science teaching is a pedagogical approach 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. The stories in this paper refer 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). At the completion of enacting this curriculum, the students were asked to write their reflections. By reading the students' reflections we found out that they noticed that certain circumstances must be present in order to enable a scientist to make his discovery.

**Keywords:** attitudes towards the scientific endeavor; history of science; historical stories; science teaching.

## Introduction and theoretical background

The common approach to teaching science is derived from the teaching model developed by Ausubel (1963). This model is based on information processing theory, which views learning as a process of absorbing, encoding, and storing information in long-term memory in an organized way so that it can be retrieved when necessary. 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 common 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 common 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.

Varying the classroom learning environment by implementing various types of instructional techniques (or pedagogical interventions) is suggested to have the potential to enhance also those students' situational interest and motivation in science that are regularly not triggered by the curriculum and pedagogy (Bolte, Streller, & Hofstein, 2013). Among these pedagogies, we should consider.

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The historical approach, which 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, as stated by Wang and 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 (1996), or Monk and 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 history of science (HOS), suggested by Abd-El-Khalick (2013). Lederman (1992) claimed that NOS refers primarily to "the values and assumptions inherent to the development of scientific knowledge". 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. Other researchers (e.g. Monk & Osborne, 1997) suggested that the historical stories approach might help students gain a better understanding of the essence of scientific phenomena, scientific methodology, and scientific thinking overall. 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 the nature of science.<sup>12</sup> Moreover, according to Ihde (1971), students should become familiar with various projects of scientists on a specific subject, and the effect of various cultures on scientific developments. Cachepot and 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. Abd-El-Khalick (2002), Elkana (2000), and Erduran (2001), proposed 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. Hugerat, Kortan, and Zidane (2011) investigated the effect of teaching science using the historical stories approach, e.g. the discovery of Archimedes' principle. They found that exposing students to the historical contexts of scientific discoveries may help them gain a more profound understanding of the scientific subject matter; this can be determined by asking them to reflect on this approach, or by assessing their attitudes towards science. 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, like Erduran (2001), claim that students' initial knowledge in the sciences can be compared to the knowledge early scientists had, since it is based on drawing 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 (Mamluk-Naaman, Ben-Zvi, Hofstein, Menis, & Erduran, 2005).

However, despite all the studies that advocate for integrating historical aspects into science curricula, Erduran, Aduriz-Bravo, and Mamluk-Naaman (2007) found out that teachers are not well prepared for teaching by this approach and may avoid these parts of the curriculum. Wang and Marsh (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. Teachers claim that they were forced to do so because the curriculum was too overloaded to permit them to spend time on the teaching scientific process or on adding a historical approach to their teaching. Based on their studies, Hacieminoglu, Ertepinar, and Yilmaz-Tuzun (2012) observed that teacher trainees who used the historical approach during the science lessons which they taught as part of their practical training, tended to stress all aspects, However, due to time constraints and overloaded science curriculum, when they became actual teachers, they referred only to the conceptual aspects, and tended to pay less attention to context and the scientific process in their lessons.

The emphatic conclusion of various studies is that the science curriculum should develop a historical approach to the teaching of science, and even make it compulsory. Actually, The National Science Education Standards (2012) also points out, 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 NOS 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 and Canella (2015) reported on a classroom study on cooperative learning about the NOS, using a case study from the HOS. The purpose of the study was to gain insights into the way in which 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 being exposed to the case study. The results showed that both the topic and the instructional design of the case study were regarded very positively by the students, and that they gained a broader view of the NOS.

The benefit of using historical case studies/stories can be found in many studies, as mentioned above. We may summarize the theoretical framework with what was said by Solomon, Duveen, Scot, and McCarthy (1992). They claimed 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. In addition, Stinner, MacMillan, Metz, Jilek, and 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. Research findings suggest that drama and storytelling activities might not necessarily improve factual recall, but can lead to deeper understanding of the topic learnt, and encourage even non-science oriented students to study science (Ødegaard, 2003). Both from the theoretical side and teachers' experiences telling stories can be considered as a supportive tool to enrich the pedagogy of inquiry learning (Peleg et al., 2017).

The purpose of the present paper is to focus and describe short *historical* stories, which were integrated in science lessons, and students' reflections to this approach. Thus, in order to improve student interest and motivation in the scientific endeavor, and in scientists' work.

## Examples of short historical stories integrated in science teaching

The stories were enacted with primary, middle, and secondary school students from Arab schools in the Israeli Galilee. The stories refer 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 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 h 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 h per week (usually 3 h of biology and 2 h 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 three disciplines of biology, chemistry, and physics are taught separately.

The stories consisted of narrative texts, photographs, drawings, YouTube videos, and charts relating to the other two dimensions of scientific knowledge: the conceptual and the methodological aspects. The researchers prepared detailed handouts about the scientists' biographies, as well as about the importance of the discoveries, and their impact on the development of scientific research and humanity. The scientists were chosen from a variety of topics in alignment with the curriculum. Galvani is mentioned in the curriculum in the context of teaching the unit on the history of electricity and electricity current; Fleming, during teaching the unit on the treatment of bacterial infectious diseases; Kekulé, while teaching the unit on carbon compounds; Archimedes, in the framework of teaching the unit on sedimentation and flooding.

The researchers met the teachers, gave them the handouts, and together with them prepared the lesson plans (four lessons of 45 min), referring to each scientist out of the four:

- The students were asked to look for information (before the lessons), regarding each of the above scientists and their discoveries, in order to enrich the classroom discussion.
- The teachers then distributed a handout giving a brief description about the discovery of the scientist who was studied in a certain lesson, in line with the content of the curriculum, using also YouTube video clips. The students were asked to work in small groups (4 students in each group), fill in the handout together, and present it to the whole class. This activity was followed by a class discussion referring to the nature of the science discoveries.
- At the end of the lesson, each student filled in a reflection sheet about his/her attitudes towards integrating a short historical story in the chemistry studies.
- The assignment after each lesson was to choose a scientist whose discoveries were chemistry oriented (e.g. Lavoisier, Boyle, Mary Curie, etc.), and to write an essay, focusing on his discoveries. The title of the essay was "The Person behind the Scientific Endeavor". In order to help students in writing an essay, the teachers introduced them to the biographies of numerous eminent scientists from different periods. These scientists developed scientific theories that often contradicted those that had been previously accepted (Mamluk, Ben-Zvi, Menis, & Penick, 2000). The students were asked to describe in detail the lives of these scientists and the discoveries made by them. They also produced work characterizing "their" scientists: a picture of the scientist accompanying an article that the students had written. The students used internet resources, and the teachers helped them with references dealing with the HOS (Rayner-Canham & Rayner-Canham, 1998). Afterward, the class constructed a display along a time-line in order to place events, scientists, and theories in their appropriate historical perspective. Thus, all the students felt that each scientist represented by them had been given an honorable place in the HOS.

## Descriptions of the four stories

### Galvani's discovery of the electrical current (5th 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.

### **Fleming's discovery of penicillin (7th 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 *Penicillium* 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, including harmful ones; 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.

### **Archimedes' principle of floating objects (8th 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.

### **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.

## **Students' reflections**

The data collected refers to students' reflections, based on interviews with them. The interviewed students were selected randomly.

Table 1 presents students' reflections to the short historical stories, collected by the first author of this paper.

**Table 1:** Students' reflections (primary, middle and high school).

Primary school students	<p>I think all scientists are very smart people. This wisdom brought them to their discoveries.</p> <p>I myself would like to be a scientist because it brings tremendous pride.</p> <p>The discoveries of scientists must have brought improvement to humanity.</p> <p>To be a scientist you need wisdom, a lot of knowledge and a lot of luck.</p> <p>I do not appreciate discoveries made by accident.</p> <p>It intrigues me to learn about scientists and the way they acted to reach their discoveries. It makes me appreciate the science more.</p> <p>Scientists are the people who have contributed most to humanity.</p> <p>God loves scientists, so he wanted them to be among us to contribute to us.</p> <p>I do not always respect scientists because some of them bring bad discoveries to nature and humanity.</p>
Middle school students	<p>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.</p> <p>I appreciate scientists and I myself would like to be a scientist.</p> <p>Being a scientist brings personal, national and global pride.</p> <p>I cannot be a scientist because I do not have the wisdom and curiosity they have.</p> <p>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.</p> <p>I would appreciate it if fewer discoveries would happen by chance.</p> <p>Fleming or someone else could have made the same discoveries without the chance.</p> <p>I think that because of chance, not everyone can make the same discovery.</p> <p>Being a scientist is a gift from God and not everyone can be a scientist even if he is diligent and striving.</p>
High school students	<p>A scientist is a very curious man and pursues the truth.</p> <p>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.</p> <p>All discoveries are very important, but there are discoveries that are more important and have made a tremendous contribution to humanity.</p> <p>I respect and admire scientists because they are special people.</p> <p>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.</p> <p>I know that discoveries have happened by chance. This is not enough to attain great achievements in science.</p> <p>I believe that if Kekulé had not come to his discovery someone else would have made the discovery.</p> <p>Not every science student can become a scientist. A scientist is a man with special qualities.</p> <p>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.</p> <p>A scientist must sacrifice his personal life in order to reach important discoveries.</p>

Table 1 shows, 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." Another one claimed: "The discoveries of scientists must have brought improvement to humanity." It is not expected that all students will become scientists, but the reflections show that the students at least understood something about the scientific work.

## Discussion

In the present study we elaborated on a method that teachers may use in order to attract students' attention to events which lead to discoveries, and to 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 taught 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 developed 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. Furthermore, scientists are correcting their mistakes, and translating their dreams into ideas, and later on, into important discoveries. Science teachers can use these examples, and explain students the reasons and motivations that drove scientists. They should make their students aware of the importance of accuracy, precise observations, and critical thinking in science.

The subject of integrating short historical stories in science lessons was not surveyed in this paper, excluding a few students' reflections. However, based on literature, we believe that the improvement of students' attitudes towards the scientific endeavor leads to a better understanding, a greater familiarity with scientific concepts and principles, 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 (Blonder & Mamlok-Naaman, 2019; Hayes & Perez, 1997), as well the research process, its characteristics and motivations, and also its occasional restrictions and even failures (O'Neill & Polman, 2004). This is especially relevant for students who are exposed to success stories of discoveries. They might 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.

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. They demonstrated their ability to judge each topic critically and independently. 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 encouraged students to believe that they, too, will be able to make discoveries. Indeed, they demonstrated their ability to think about and judge each topic critically and independently.

In conclusion, integrating short stories into the chemistry lessons may also help to give chemistry a more humanistic flavor that can help overcome the big gap in studying science and diminish its nature. This would necessitate additional science teacher education and continuous professional development. Based on the current case study detailed here, it is suggested that it is worth enriching chemistry education by incorporating elements of short historical stories pedagogy. However, more research is needed to provide information regarding the best working and the most motivating elements of it in the context of chemistry education (Peleg et al., 2017).

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