Humanizing the teaching of physics through storytelling: the case of current electricity

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Abstract

The main purpose of this article is to discuss the potential role of storytelling in the teaching and learning of physics. I first present the main historical events concerning the discovery of current electricity by focusing on the Galvani–Volta controversy and the work of Michael Faraday. Then I outline a planning framework for teaching through storytelling. This framework consists of the following components: Idea(s) to incite wonder, main plot of the story, ideas to be learned by the pupils, content knowledge, human values and the moral of the story.

Introduction

The academic, dogmatic, authoritarian and generally sterile approach to teaching science has been widely criticized. The reason is that students have come to view science as just a collection of facts and laws with no relevance to their own life. Over the past two decades the various reform efforts have addressed the need to abandon that academic tradition and to link school science education with citizenship (see Jenkins 1999, 2002, OECD 2000, UNESCO 2000). It is evident that these reforms aim at humanizing science education by taking into account the human element of science. However, they promote a social orientation of science education, and a utilitarian view of scientific knowledge. They also appear to downplay or ignore the cultural and the personal/aesthetic elements of science (see Tauber 1996, Miller 2004).

Helping pupils, especially those in the early grades of secondary school, to experience the excitement and the 'romance' of science is very important. If an instrumentalist view of scientific knowledge becomes dominant, there are questions to be raised in regard to intellectual curiosity (Hadzigeorgiou 1999) and generally in regard to the involvement with science as a human endeavour, which incites wonder, reveals beauty and inspires interests (Hadzigeorgiou 2005). Moreover, humanizing the teaching and learning of science means helping pupils appreciate science as a human activity, and hence scientific knowledge as something that cannot be isolated from the people who created it. Thus pupils come to appreciate science as a value-laden activity (Stevenson and Byerly 2000), to which values such as objectivity, curiosity, pursuit of truth, intellectual honesty, humility and commitment to human welfare are central.

Storytelling can be considered a way to humanize the teaching and learning of science, and physics in particular. The ideas to be learned can be incorporated into the plot of a story. The narrative form of the presentation of these ideas has the potential not only to create anticipation, to pique pupils' curiosity, and even to develop a

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sense of wonder, but also to help pupils remember more and understand better (see Bruner 1990, Egan 2005, Nash 1990, Stinner 1995). In short, storytelling has the potential to both motivate and facilitate learning. In regard to the understanding of ideas (e.g., Galilean relativity, the Bohr model of the atom, the concept of heat), the historical context is crucially important since it helps pupils understand the problem situation from which those ideas arose (Hadzigeorgiou 1999).

In this article I will present in a narrative form a summary of the main historical events concerning the discovery of current electricity, as these appear in the relevant literature (see Burns 2003, Gooding 1985, Hamilton 2002, Meyer, 1971, Pera 1992), by focusing on the Galvani–Volta controversy and the work of the pioneer Michael Faraday. I will then proceed to the task of outlining a planning framework for teaching ideas concerning current electricity to early grade secondary school pupils.

A story for current electricity: the main historical events

The discovery of current electricity is quite interesting for a number of reasons. Perhaps the most obvious, and perhaps the most important from a societal point of view, is the production of electricity by mechanical means. A not so obvious reason is that the contribution of research came from at least three different countries: Italy, Denmark and England. Although it was in England, in the first week of September 1821, that a series of experiments performed by Michael Faraday in the basement of the Royal Institution culminated in the discovery of electromagnetic induction, the history of current electricity has its beginning in Italy in the late 1700s. At that time two Italian scientists, Luigi Galvani, a medical doctor, and Alessandro Giuseppe Volta, a physicist, became involved in a great debate about the nature of current electricity.

As the story goes, Galvani made his discovery by observing that the legs of a frog twitched while he was dissecting it. Galvani was startled since the frog was dead: what made the frog's legs twitch? Quite accidentally Galvani also observed that the twitching took place both during electrical storms and when the frog was placed next to a static electricity machine that gave off sparks. This was a significant discovery since Galvani made the following inference: the twitching must be connected in some way to electricity.

Being a scientist, Galvani embarked upon a set of experiments and he was able to get the legs to twitch under good weather conditions and away from the static electricity generator. So he concluded that the source of the twitch must be something inside the frog, and he put forward his theory: the source of the twitch is a form of electricity, which is a kind of '*animal electricity*'.

Volta, however, challenged Galvani by proposing a different theory: the source of the twitch must be outside the frog! He performed experiments that showed that the twitch could be produced only when two dissimilar metals were used in the process of dissection. Therefore the twitch did not come from the legs but from the two metals that were touching the two legs. It must be a kind of '*contact electricity*'.

Galvani, following this challenge, undertook more experimental work and showed that the legs could twitch even when two similar metals were used for the dissection of the frog. But Volta was insistent that a dissimilarity in those obviously similar metals had to be involved. Galvani did more experimental work and produced startling evidence: the frog's legs could twitch in the absence of any metals (by just touching two nerve ends)! It was a clever counter-attack on the part of Galvani to experiment without the metals since his theory was based on the idea that the source of the twitch was inside the frog and not outside it. Who could object to such evidence? Apparently only Volta himself, who made a cleverer counter-attack. Galvani had got rid of the metal but he got rid of the whole frog!

Volta did experiments by using two different metals in a liquid. The simplest combination that could be used in those experiments was a piece of copper and a piece of zinc, both the size of a coin, and a cotton pad (that had been previously immersed in a solution of sodium chloride) in between them. Although the electricity that could be generated by such an element was small, a series of much bigger elements (e.g., a box filled with sulphuric acid in which a number of pairs of bigger pieces of metal were immersed) could produce a larger amount. So Volta managed to produce a much larger amount than that produced through the twitching of the frog's legs. Moreover, scientists and technicians could reproduce Volta's experimental work quite easily (without the surgical skills that Galvani's technique might have required).

Of course, one could think of many applications of such a discovery. But there were some problems. The apparatus comprising Volta's elements was quite heavy (so if it were to act as a source of energy for a bicycle, where it would be carried?) and even dangerous, since the acid could cause accidents and even prove fatal.

In the meantime Galvani had to admit his scientific defeat and he felt humiliated, disgraced. Less than a year later he died. In looking back on this debate, one can see its positive side, that is, the competitive force that drove scientific research in Italy. But in looking at the present and even into the future, one can also see that Galvani's death was an unfair consequence of his work. Today the idea that animal cells in general have their own electricity is well established and its applications—namely the electrocardiogram and electroencephalogram—are widely used in the medical profession. The irony of it all, of course, is that Volta and Galvani were both right.

But while this debate with its sad ending was taking place in Italy, and in France Charles-Augustin de Coulomb was discovering the repulsion between electric charges, in England another scientist was about to discover the production of current electricity by using moving magnets. His name was Michael Faraday. Originally a bookbinder, he was self-trained and at the age of 21 he was appointed assistant to Humphrey Davy in the laboratory of the Royal Institution in London. Between October 1813 and April 1815, Faraday accompanied Davy, as his assistant, on a scientific tour of Europe. In Italy they met the aged Volta.

However, it was a discovery made in 1820 by the Danish natural philosopher Hans Christian Oersted that must have played a crucial role in the thinking of Faraday and his subsequent experimental work. Oersted, while giving a lecture to his students at the university, noticed that the needle of a compass changed direction when an electric current passed through a nearby wire. Oersted had made a great discovery: an electric current produces a magnetic field. Faraday, in reading the paper that Oersted had published on his discovery, commented as follows: "I have very little to say on M Oersted's theory, for I must confess I do not quite understand it". However, on 3 and 4 September 1821, Faraday did try to duplicate Oersted's experiment in his basement laboratory at the Royal Institution.

In the course of his experiments, Faraday discovered that a suspended magnet would revolve around a current-bearing wire, leading him to propose that magnetism was a circular force. He undertook a set of experiments that culminated in his discovery of electromagnetic rotation—the principle behind the electric motor. But Faraday went even further. Since an electric current could cause a magnetic field—something that Oersted had discovered—a magnetic field should also be able to produce an electric current. This was the principle of induction that Faraday demonstrated about ten years later, i.e. in 1831. It was a landmark in applied science since it made possible the generator and the transformer, thus turning the production and the transference of current electricity from a mystery to a reality. Current electricity became a commodity at the service of humanity.

Bringing the story into the classroom: planning a teaching framework

There is no doubt that this narrative of real events provides the background for a story to be told to pupils. However, what should be borne in mind is that creating a story, especially an attractive and 'instructive' one, requires more than a sequence of historical events. The beginning of the story, its main part and its end are all crucial. They each serve a purpose. The beginning is crucial to capture the pupils' imagination, to incite wonder, and to provide a general background for the main plot of the story. The end is also important to provide a closure, and a moral (e.g., a significant idea). For the main part of the story, the ideas to be learned should be made clear in the plot. However, human values and the mental images that can be evoked by the pupils in connection with these values are also important in making a good story (see Egan 1997, 2005). It is important to stress here that humanizing the content of science means that human values are made implicit or explicit in the plot of the story. What follows are the component ideas that need to be considered in planning to teach about current electricity through storytelling. These component ideas are presented in the form of a planning framework, which can of course be used with other topics.

- *Central idea to incite wonder:* A chance discovery concerning the legs of a frog that changed the face of the whole world.
- *Human values:* ingenuity, insistence, persistence, curiosity, patience, commitment.
- *Protagonists:* Luigi Galvani, Alessandro Giuseppe Volta and Michael Faraday. Also featuring Hans Christian Oersted.
- *Mental images:* (*a*) Galvani and Volta in their labs to experiment with patience and persistence and to defend their ideas; (*b*) The happiness on Faraday's face when he was almost certain he had discovered a safer and easier way to produce electricity from magnets.
- *Plot of the story:* (*a*) The conflict and scientific debate between Galvani and Volta; (*b*) the significant discovery by Faraday about the relationship between electricity and magnetism (after turning on its head an accidental discovery by Oersted).
- *Ideas to be learned by the pupils:*
    1. **Physics content**: Production of current electricity (*a*) from animal cells, (*b*) from different metals immersed in an electrolyte, (*c*) from magnets; (*d*) the relationship between electricity and magnetism.
    2. **Nature of science**: (*a*) science is a social activity: the ideas put forward by one scientist open new avenues for other scientists, scientists think further about what other scientists have thought before them; (*b*) science is a human endeavour (i.e., it is tied to the scientists' struggle, to their anxieties, frustrations, hopes, fears of not being understood); (*c*) the accidental nature of scientific discovery; (*d*) the difficulties scientists sometimes experience in understanding what other scientists are saying; (*e*) the existence of conflict in the scientific community.
- *Moral:* (*a*) Galvani's discovery, despite the humiliating defeat that he suffered, was very significant since nowadays that discovery can save human lives (e.g., the use of electrocardiography); (*b*) The scientific community should not ridicule and reject scientific ideas, however strange or even crazy they may seem and sound at first.

Comments

The teachers who have trialled this general framework for teaching concepts of current electricity (and other topics) reported an increased interest in physics. This was documented through pupils questioning, discussing and bringing the ideas they were taught out of the classroom. This increase was particularly noteworthy in the case of girls, especially those from junior high school. Understanding of the fundamental ideas that were incorporated into the plot of the story was also assessed. Although the empirical (longitudinal) study of the effect of narrative on the understanding of physics is in progress[1], the initial results are encouraging.

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[1] The work reported here is part of a larger international project that aims to study the role of storytelling and imagination in learning various disciplines including science and mathematics. The project is directed by Kieran Egan, professor at Simon Fraser University in British Columbia and Canadian Chair of Education and Cognitive Development.

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