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Philosophically Correct Science Stories? Examining the Implications of Heroic Science Stories for School Science

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Abstract: Some people think that science is a set of facts that can be presented in plain and unadorned language. This fosters a belief that science has few stories. Actually, stories are very important in school science. In an examination of science textbooks, I have identified four different types of science stories which I call (a) heroic, (b) discovery, (c) declarative, and (d) politically correct. Each of these types of story promotes a particular set of philosophical assumptions about science. These assumptions are presented implicitly within the framework of the story as truths of science. This article specifically examines the philosophical assumptions that underpin heroic science stories and the implications of these stories in the discursive practices of the school science classroom. As teachers, we need to be critically aware of these assumptions, since they may be at odds with our beliefs about knowledge and our preferred teaching practices. © 1998 John Wiley & Sons, Inc. J Res Sci Teach **35:** 175–187, 1998.

I am interested in examining the implicit notions of science that are embedded in particular types of science story told in school science. I argue that these stories help to frame the discourses of the school science classroom and that different types of science stories told in science textbooks present implicit notions about the nature of science to teachers and students. The types of stories that I have analyzed are not exhaustive or inclusive, but I have identified the following: the heroic science story, the discovery science story, the declarative science story, and the politically correct science story.

Heroic science stories focus on a hero of science who single-handedly contributed to the development of science. In discovery science stories, scientific knowledge is presented as having occurred as the result of an accident (Milne, 1996a). In declarative science stories, processes or scientific concepts become objects and are represented as open to observation in nature by anyone (Milne, 1996c). These particular stories present concepts such as food chains, acid, gravity, genes and temperature as secure and timeless, and as a consequence, any sense of the construction of these concepts is lost. Politically correct science stories are a relatively recent development in school science as some teachers and texts attempt to represent more fairly the contribution of people from different cultures, genders, religions, and countries to the development of science and to examine critically the interaction between science and society as they construct each other. I argue that as teachers, we need to be aware of both the power of story and of the philosophical assumptions underpinning them, especially those which may be at odds with our emerging views on the constructed nature of scientific knowledge (Milne, 1996b). In

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this article, I specifically wish to examine critically the representation of heroes, both men and women, in science stories and the implications for teaching practice and learning that can be drawn from these representations.

Stories in Science?

Already I can hear some readers exclaim, "How can she say that? How can she talk as though science is all about stories?" These readers might argue that science is mainly about facts. It is facts and theories that are taught in school science, while stories are used by the teacher or the text purely as anecdotes to make science more interesting for students. They might continue the argument and say that stories are not an integral part of science because they are about fiction, not facts. Some readers might think that they can accept the importance of accounts in school science in which facts are linked together within a time frame to help us make sense of a concept or process. For example, the life cycle of a gnat could constitute an account or a description because it combines all the facts about the life of a gnat into a temporal frame, but it would never be a story. However, I wonder if it is possible in our account to include all the facts about a gnat's life that are available to us at that time. If it is not, who decides which facts to include and which to leave out? What implications does the selection of facts have for the meaning that we impose on the account? I argue that once ideas are presented selectively in science no longer are we telling the facts. We are instead telling a story. In the following sections of this article I describe the theoretical underpinnings of the notion of story that I use to make sense of textbook accounts of heroic science stories.

My notion of story is informed by writings from literary theory and educational research. According to Connelly and Clandinin (1990), we all tell "storied lives," and the major roles of the researcher is to collect these stories, write stories about them, develop a narrative of experience based on these stories, and make these stories available to other interested people. Thus, for Connelly and Clandinin narrative is both a method of research and a focus of research—that is, both process and product. But what is a narrative and how is that related to a story? According to semiotician Barthes (1978), narrative is a feature of all cultures and it is used in a culture as a mechanism for promoting learning: a way, argued historian White (1981), of translating knowing into telling. White argued that story is a metacode because there is a meaning in the story that allows stories to be understood across cultures.

Semiotician Scholes (1981) described a narrative as a "symbolic presentation of a sequence of events that are connected by subject matter and related by time" (p. 205). Without continuity of content or connectivity of time, we would have a list of events rather than a narrative. Thus, any spoken or written account that sequences and relates events is a narrative. In science, narratives can include the procedure for lighting a Bunsen burner, and the life cycle of a gnat or the activity of an earthquake. Because a narrative refers to a set of events that occur outside of itself and that are presented as having happened, the narrative is presented in past tense.

Scholes (1981) and educator Carter (1993) argued that a narrative involves a selection of events for the telling. Thus, in a narrative not all the events in a situation are given equal significance, and some are left out altogether. When this selected sequence of events has a recognizable narrative structure and particular cultural and human values are embedded in the content, you have a story. According to Scholes (1981), "When we speak of narrative, we are usually speaking of story" (p. 206). He argued that a story is constructed in a semiotic circle of events, text, and interpretation, as shown in Figure 1.

This circle makes sense to me in the following way. A story consists of selected events which are presented as a sequence in time. In a story, these events are converted into text and

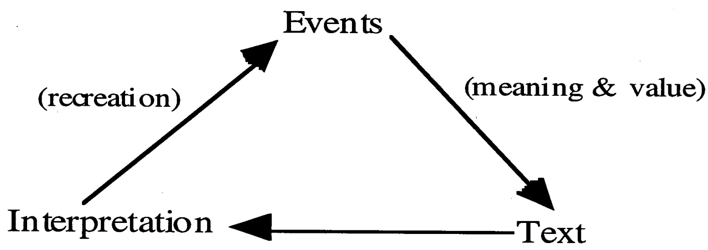

Figure 1. A semiotic circle of a story.

in the process are imbued with meanings and values. The text is a set of signs that refer to the selection of events. The text has its own internal structure, so the occurrence of events portrayed in the text might not reflect the actual occurrence of events. Once the text is written or spoken, it is interpreted by readers and listeners idiosyncratically. Often interpretation involves an attempt to restructure the natural occurrence of events based on the text. Scholes (1991) argued:

> Narrative is presented as if the events came first, the text second, and the interpretation third, so that the interpretation by striving toward a recreation of the events, in effect completes a semiotic circle. (pp. 206–207)

In the process of creating a story, the narrated events become saturated with values and meaning during both the development of the text and the interpretation stage. Thus, the most significant possible difference between story and narrative is the story's focus on the presentation of values and meaning, as well as content, in the presentation and interpretation of the events. However, often the terms *narrative* and *story* are used interchangeably by authors and readers.

Scholes (1981) used the semiotic circle to differentiate between historical and fictional narratives. For example, he argued that in historical narratives, the events represented in the narrative are presented as factual, as having occurred. Therefore, it is possible to criticize a historical narrative by introducing material external to the text and arguing that some facts were misrepresented or not given their due significance. However, in fictional narratives, even if the actor can create an environment in which events seem real, these events did not exist before the text. It is interesting to examine some science stories in which there exist accounts of events presented as historical fact, but which have doubtful authenticity: for example, Galileo dropping cannon balls from the Leaning Tower of Pisa; Galileo responding in undertones at the end of his Inquisition trial, "And yet it moves"; the president of the tribunal which tried Lavoisier saying, "The Revolution has no need of scholars"; Kekule's dream; and James Watt and the boiling kettle. Thus, it might be difficult in science stories to separate history from fiction. Perhaps these specific examples continue to be included in science texts because they tell a good story, not because of their factual significance.

Stories and School Science

All stories have in common their relation to culture via codes that are agreed-upon sets of rules or social norms or myths. We use these codes to make sense of events by ordering events into a narrative and by introducing causality into the interpretation of texts that have been presented as an account of the narrative. If teachers and students of science understand how stories and narratives are structured, if they understand the relationship between events, text, and interpretation, and if they appreciate that stories contain explicit or implicit messages about values and meaning, then they can develop an awareness of the possibility of multiple representations of events. Thus, if we wish to improve the quality of teaching and learning in science, it may be important to understand the influence of narrative structure on the representation of science because stories are an undeniable feature of the human condition. A critical awareness of the possibility of creating more than one set of meanings and values in a story is important because stories are significant in school science. Students are novices who are believed to lack knowledge about science—that is, situated knowledge—so textbooks and teachers use stories to help students make sense of the purported grand narrative of science.

Thus, stories are used to help students organize their knowledge into explanatory frameworks which serve them as interpretive lenses through which to comprehend their experiences in science. Even stories about the natural world reveal the author's values and attitudes (Pagano, 1991). Consequently, narrative structure in school science serves to assist in the construction and transmission of a particular notion of the culture of science. However, I hope that narrative can also assist in transforming school science. Because science stories reveal implicitly something about the nature of science, they serve to legitimate particular philosophical frameworks in science which may not be consistent with contemporary developments in philosophy of science or educational practice. What philosophical frameworks are legitimated in heroic science stories and Galileo's heroic science story in particular?

Science Heroes

How does someone become a hero in science? What philosophical frameworks are legitimated in heroic science stories? In mythology, heroes such as Jason (of Jason and the Argonauts); Theseus, who slew the Monitor; and Odysseus attained hero status during their lifetimes, and numerous statues were erected in their honour (Graves, 1960). However, even in mythology not all heroes are recognized immediately by their society. It seems to me that heroic science stories, with the benefit of hindsight, represent scientific heroes and their work as transcending the limitations of their age and illuminating ages to come. Figure 2 is an example of the type of story I call a heroic, because it is based on the exploits of one of the heroes of science, Galileo Galilei. In his book *The hero with a thousand faces,* structuralist historian Campbell (1968) describes a hero as a man who travels on a big adventure into an unfamiliar world. He undergoes tests which, if he is triumphant, will ultimately bring him success and recognition once he returns home. According to Campbell, some heroic stories are much more complex than this, while other heroic stories isolate and emphasize one or two aspects of the story.

Science textbooks, if they discuss historical developments at all, often present controversies as simplistic heroic stories. Galileo believed that his knowledge of world systems based on observations and informed by his appreciation for theories such as the heliocentric theory was the true knowledge. Heroic science stories reinforce the notion that knowledge from science has an independent existence. Galileo's heroic status is due to his willingness to present this true knowledge to the world regardless of positive or negative consequences for his own wellbeing. Other scientists who have been portrayed as heroes include Aristotle, Democritus, Galileo Galilei, William Harvey, Antoine Lavoisier, James Hutton, Gregor Mendel and Benjamin Thompson (Count Rumford).

The representation of heroes in heroic science stories has implications for the discursive practices of school science classrooms because of the philosophical assumptions that underpin these stories. According to Campbell (1968), Daedalus, from Greek mythology, came to be represented as an exemplar of an artist-scientist. Campbell described Daedalus as:

> At that time [17th century], scientists began to realise that all physical events follow understandable laws. One of the first scientists to understand this was Galileo Galilei (1564-1642). While still attending the university, he challenged so called knowledge that was based on little, if any, observation or experimentation. He questioned the belief that the earth is the centre of the universe. . . . Galileo was dismissed from the university before he could complete his studies. However, he did not change his ideas. He knew that he could answer his critics only by showing them proof that could not be denied. To do this, he developed a systematic method of observation and analysis. . . . Galileo also found that all motion follows a simple set of laws. . . . He observed the heavens with a telescope. He confirmed the theory of Copernicus that the earth travels around the sun while spinning on its axis. This discovery did not agree with the religious belief of that day. As a result, Galileo was brought before the Inquisition. He was kept a prisoner for the rest of his life.
> (Murphy & Smoot, 1982, p. 19-20)

Figure 2. A heroic science story involving Galileo Galilei.

> [D]edicated to the morals not of his time but his art. He is the hero of the way of thought—single-hearted, courageous, and full of faith that the truth as he finds it, shall make us free. (1968, p. 24)

Campbell's statement about the characteristics of a hero-scientist illuminates a myth of science that represents heroes as courageous, determined uncoverers of the truth, not heroes of action but heroes of thought. The implication of this notion is that science finds out the truth about nature and presents the truth to the rest of society. This helps to free society from the constraints of ignorance. Clearly then, science is a special form of knowledge. In science, as in heroic stories elsewhere, the hero of the story is usually a male who has the strength of his courage and self-determination to stand against cultural forces to present the truth (Samuel & Thompson, 1990).

The Semiotic Circle and the Heroic Science Story

Creating the Text from Events

If we examine the heroic science story of Galileo from the perspective of a semiotic circle, we can acknowledge that there are many things known or believed about Galileo's life and his work. These constitute the *events* of Galileo's story. However, in their creation of a *text* about Galileo, Murphy and Smoot (1982) selected the events that they considered to be important. In the process of event selection and text construction, the story becomes imbued with specific meanings and values appropriate for an heroic science story. Figure 3 represents my attempt to use Scholes' (1981) semiotic circle of a story to demonstrate how selection of events by Murphy and Smoot in their story about Galileo imbued that story with specific meanings and values. Any story can be analyzed using the semiotic circle. First, it is possible to list the range of events that are available for selection in the construction of a story. Second, one can examine critically the events that are selected to tell a particular story to articulate the meanings and values imbued in the story; and third, one can reconstruct the story from another perspective.

As students and teachers read text, they *interpret* it. However, interpretation is a complex interactive process, and often the readers can become captives of the text because the text is believed to be the expert and the reader the novice. Because students in particular are deemed, or believe themselves, to lack situated knowledge, they are more likely to accept science stories as truth and to accept uncritically the values and meanings that underpin the story. Unless we apply a critical eye to the text, we can continue to accept and promote a story which is under-

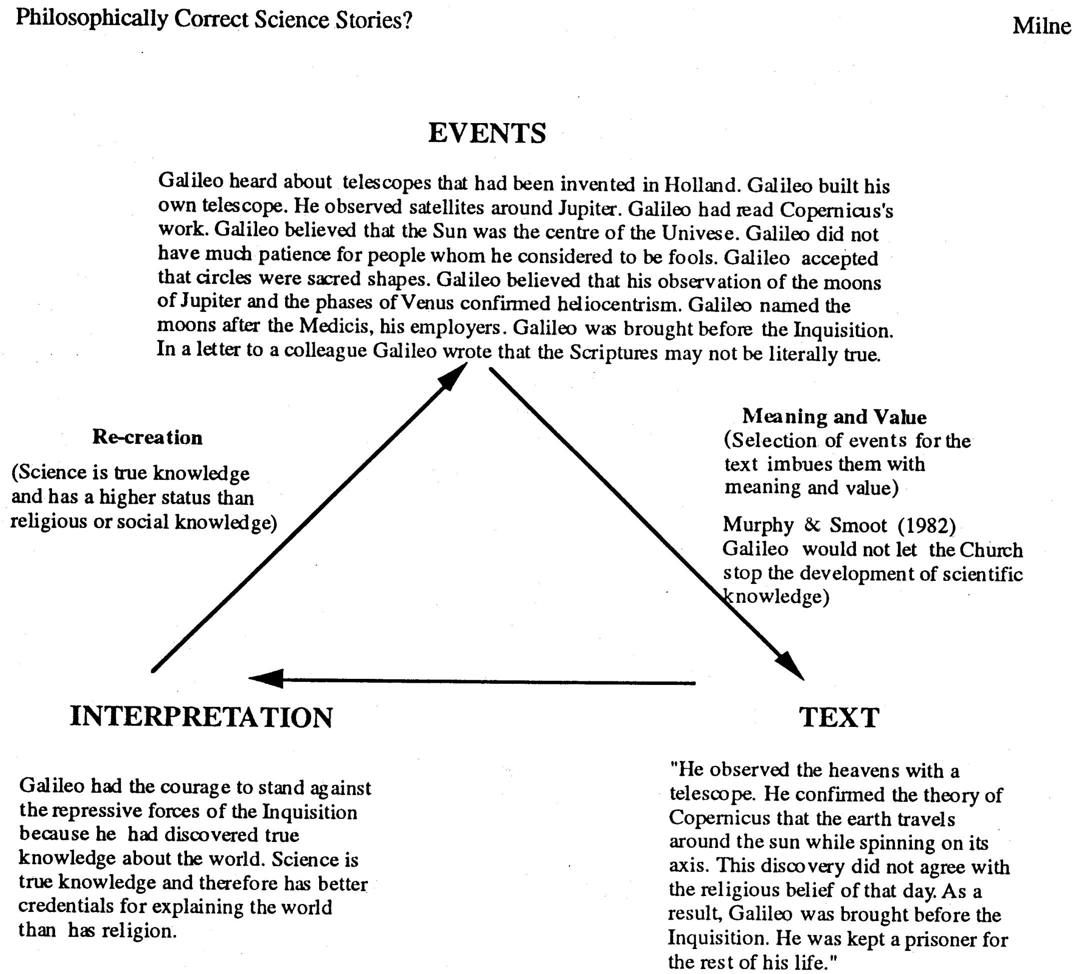

Figure 3. The semiotic circle applied to the story about Galileo, from Murphy and Smoot (1982).

pinned by meanings and values that we might not endorse if these meanings and values were presented explicitly.

Interpreting the Text: The Implications of Heroic Science Stories

In Galileo's case, he is recognized as one of the first experimental philosophers. He is represented in the heroic science story presented in this article (Murphy & Smoot, 1982) as an individual who had the courage to stand against the dark forces of the Inquisition (Weingart, 1993). One implication of stories such as that of Murphy and Smoot is that Galileo's scientific arguments led to his persecution by the church of time. Consequently, his heroic status developed from his scientific arguments in which he promoted theories that were contrary to the accepted natural history theories of the late 16th and early 17th century. These theories were foundational to Christian theology, and any criticism could be construed as heresy.

Murphy and Smoot (1982) seemed to interpret the Galilean story so that as a hero, Galileo forms part of a larger myth which implies that scientific knowledge exists outside culture and society much like the mythology surrounding Daedalus. From this perspective, because science is describing nature, it has an independent existence. Thus, scientific knowledge cannot be suppressed because it exists independently of its discoverer, and therefore will prevail regardless of political or religious pressure. Acceptance of the independent existence of scientific knowledge implies that scientific knowledge lies around in nature waiting to be discovered. If science knowledge is always there, then it is not necessary to maintain a historical record of the development of scientific knowledge; but what is more important is that discoverers of this knowledge are recognized. For a discoverer to become a hero, that discoverer must stand up against outside forces and have the courage to present to the world the knowledge that he has discovered. Perhaps, also, science has to have heroes because scientific knowledge is often presented as eternal just as ancient mythological universes were eternal. On an eternal landscape, without a feeling for the history of scientific development, you have to have heroes who stand out on the featureless plain of timeless and secure scientific knowledge.

Heroic stories help to reinforce the notion of scientific knowledge as a privileged form of knowledge. According to sociologist of science Woolgar (1988), science has been presented as "something special and distinct from other forms of cultural and social activity" (p. 26), and this helps to reinforce the notion that scientific knowledge is determined by the nature of the external world and not of human struggle. This elevated status of science emerged in the 17th century, when it was believed that science was unlocking the secrets of nature, which was God's creation, rather than dabbling in the activities of human beings. If science is represented as timeless and privileged, then, according to science educator Duschl (1990), students are led to consider that scientific authority is unlimited and beyond reproach. A consequence of this notion is that students come to believe that if something looks and acts like science, it must be science. A contemporary example of this phenomenon are the arguments presented for equal time in school science for creationism.

A further consequence of the belief that scientific knowledge comes directly from nature is that the significance of social context in the generation of scientific knowledge is ignored. This often seems to be the case in heroic science stories where the discoveries become timeless and are presented without any reference to the context of the hero's life and work. For example, was Lavoisier executed because he was a scientist or because of his role as a tax collector? Other stories sometimes present experimenters as heroes without making any reference to their work. An example of a heroic science story in which the scientist's work is ignored is the story of James Prescott Joule, presented in Figure 4. A possible implication of this story is that it is enough for students to know that Joule was a hero (perhaps an antihero?), but it is not necessary to know why. Perhaps it could be argued that this type of story helps to reinforce the no-

> James Joule (1818-1889) was an unusual scientist because he was only an amateur. Science was his hobby. James was the son of a brewer, and could therefore afford to focus on his strong interest in heat. He had a reputation of being a fanatic as far as measurements were concerned. He even spent his honeymoon measuring the difference in temperature between the water at the top of the waterfall and the water at the bottom! At first his results were not taken seriously, but after Lord Kelvin supported him, he became famous and the unit of energy was named after him.
>
> (Lofts, Living with science and technology. Book 1, 1991, p.93)

Figure 4. James Joule presented in a heroic science story.

tion that scientists are a bit different from normal people. After all, he conducted experiments on his honeymoon!

Ignoring the social context allows storytellers to present the notion that science reveals God's creation, which exists externally of human interests. This approach privileges an experimental-observational methodology of science. Therefore, many heroes in science text books tend to be experimenters, or are represented as such. This might help to explain the elevated heroic status of experimenters and observers such as Galileo compared with theoreticians such as Copernicus. Also, as I scour science textbooks for heroic science stories involving women scientists, I realise that I scour in vain.

Women Heroes?

Indeed, any cursory examination of indexes to general science textbooks often reveals few women scientists. I have observed in science textbooks what science historian Schiebinger (1987) describes as substituting women scientists for men in the "history of great men" form of biography. Her claim is that women are presented as exceptional, having defied convention to make it in a man's world. Usually the only woman presented in this way in school science textbooks is Marie Curie. However, often she is presented as someone who worked meticulously for years to build up scientific facts. In other words, she did boring work very well. Physicist and historian Brush (1985) calls this the "Marie Curie syndrome" in which the scientist, regardless of her abilities to be intuitive, imaginative, and creative, and a leader in her field, is presented as someone who painstakingly carried out tedious observational experimental work. An example of such a story which you might have heard before is presented in Figure 5.

The implication of such a story is that Marie Curie is not really a hero; she did not stand against outside forces. Instead, she happily slaved away in a dark laboratory, eventually extracting 1 g of radium from a ton of pitchblende. None of the textbooks that I examined mentioned that Marie Curie was a staunch communist. Did that have any influence on the recognition of her theories or discoveries? In the early part of the 20th century, representations of the Curies, Marie and Pierre, her husband, often placed Pierre in the preeminent position of conducting the work while Marie looked on (Meadows, 1987).

I cannot envisage that the presentation of a role-model woman scientist as one who slaved in relative isolation to meticulously collect data would do much to encourage girls to become involved in school science or to opt for careers in science. I do not wish to imply that science is not about being painstaking or that we should not admit that some activities in science can be tedious, but why is it largely women scientists who tend to be presented in this way? In Murphy and Smoot's heroic story, Galileo is not presented as having painstakingly spent hour upon

> Marie Curie (1867-1934) was the first person ever to win two Nobel prizes. She married the French chemist, Pierre Curie. In 1896 a French scientist noticed that uranium gave out strange rays, which when examined under an instrument like a microscope looked like tiny sparks. Nobody knew what caused these rays so the two Curies determined to find out.
>
> They set up their laboratory in an old shed. Pierre was busy with other research so Marie started to examine these rays. She found that pitchblende gave out stronger rays than uranium and so she obtained one tonne of pitchblende and began testing it gram by gram. This was slow, painstaking work and two long years later she had extracted a tiny quantity of a substance that sent out rays many hundreds of times stronger than uranium. To this substance the Curies gave the name 'radium'.

Figure 5. Marie Curie as a hero?

hour gazing through a telescope (which he probably had to do when you consider the quality of the equipment with which he worked), but as a defender of scientific knowledge.

Recreating a Heroic Science Story with Galileo

The simplistic nature of the heroic science story presented by Murphy and Smoot about Galileo's experimental philosophy leads me to imagine how we could tell Galileo's story differently and so assist students in developing some awareness of the times in which he lived and the people whose work helped him to construct his own investigations. If we want to imbue a story about Galileo with different meanings and values, we could select different events from Galileo's life and work and from the era in which he lived, and in the process emphasize meanings and values such as the constructed nature of scientific endeavor. Consequently, we present a different story about Galileo. It could be a story like the one presented in Figure 6, that was informed by sources such as Biagioli (1993), Schwartz (1992), and Westfall (1989). Applying the semiotic circle to the story in Figure 6 indicates the events that have been selected for the telling and the different meanings and values that underpin this Galilean story. For example, the contribution of Tycho Brahe is presented in this story to highlight the role of a number of scientists in the evolution of theories about the structure of the universe rather than celebrating the contribution of one hero scientist.

Murphy and Smoot (1982) presented Galileo as having stood against the might of the Roman Catholic church. However, Galileo's trial was characterized by a lack of common understanding between Galileo and the church. Perhaps a more complete story would recognize that the situation was complicated by the shared belief of both Galileo and the church that each was the arbiter of true knowledge. Galileo became a hero because he continued to publish his ideas although they opposed the claims of the church. According to Howard (1994) in his analysis of the significance of Galileo, Galileo was persecuted not for his scientific theories, but because he continued to promote Copernicanism, a theory that was both metaphysical and scientific because it removed the Earth as the center of the universe and therefore challenged the authority of the

> Galileo Galilei is recognised as one of the first and perhaps greatest experimental philosophers of his time. Many of his observations of the natural world provided support for heliocentrism, a theory developed by Copernicus based on observational data provided by Tyco Brahe, that placed the sun at the centre of the universe. Galileo was born in Pisa in 1564 and was the eldest of seven children. In his youth, he dreamed of taking holy orders, a notion that was vetoed by his parents. However, he studied mathematics and in 1589 he achieved his ambition of a Chair in mathematics, first in Pisa and then in Padua where he stayed for 18 years.
>
> Galileo's father encouraged him to appreciate the value of experience when seeking answers to theoretical questions (Schwartz, 1992). This was unusual because at the time it was more acceptable to seek answers through debate, which was the way Galileo presented his classes at the University. Galileo's observations of Jupiter's four moons, using a telescope that he had constructed after learning about this invention from Holland, provided him with further evidence of the appropriateness of Copernicus' theory. When writing to a colleague, Galileo had written that parts of the Holy Scripture may not be literally true. A copy of the letter fell into the hands of the Inquisition and in 1615 Galileo agreed to abandon support for Copericanism. However, after a new wave of liberalism swept through the Vatican in 1623 Galileo believed that he could continue with his writing and experimentation. In 1632, Galileo published Dialogue on Two Chief World Systems in which he modelled one of the less sympathetic characters on a Church leader. Perhaps as a result of this approach, in the same year he was once again in front of the Inquisition. He agreed to recant and consequently was placed under house arrest until his death nine years later. It was during this time that he wrote his masterpiece on mechanics commonly called Two New Sciences in which he described the mathematics of uniform acceleration, proposed that heavy bodies behaved that way, proposed predictions and experiments that could be used to test these predictions.

Figure 6. A different heroic science story about Galileo.

church, and more particularly, the Pope, to interpret Holy Scripture. However, Galileo's letters to his contemporaries, in which he argued that parts of Holy Scripture may not be literally true, could be construed as an attack on the church's role as the arbiter of the status of Scripture. Perhaps it was Galileo's stand on a number of issues, and not just the status of scientific knowledge, that led to Galileo's persecution by the church.

The story presented in Figure 6 is my version or my text of Galileo's life and work. I am not arguing that my story about Galileo is the truth. Many other versions exist that are equally valid although they may be written for different purposes (Drake, 1990; Harvard Project Physics, 1973; Reston, 1994; Wertheim, 1995).

As I mentioned, science textbooks, if they discuss historical developments at all, often present controversies as simplistic heroic stories. Galileo believed that his knowledge of world systems, based on observations and informed by his appreciation for theories such as the heliocentric theory, was the true knowledge. Heroic science stories reinforce the notion that knowledge from science has an independent existence that is brought to our attention by a select number of male scientists who had the power of their convictions to stand against cultural forces and present the truth.

In summary, the characteristics of heroic science stories can be listed as follows:

- This person is a hero of science.
- Only male scientists have the courage and self-determination to stand against forces outside science, while female scientists are drudges who study minute things in great and uninspiring detail.
- Scientific knowledge cannot be suppressed because it exists independently of its discoverer and has a higher status than any other form of knowledge.

Implications for Science Teaching and Learning

Heroic stories help to reinforce the perception of the mythical status of heroes such as Galileo, and in the process, provide support for the notion that science is true knowledge because it describes nature. These stories imply that it is not possible to suppress true scientific knowledge and that the ideas of supporters of pseudo-science, such as that practiced by Aristotelians, or flat-earthers, or creationists ultimately will be shown to be false. However, Martin and Brouwer, in their 1991 paper on the use of narrative in science education, suggested that the elevated status of scientific knowledge leads students to imagine that they cannot achieve that level of understanding. Therefore, a focus on the struggles of scientists as well as on their successes might help students who have struggles in their own lives to identify more closely with the great scientists.

The tendency of heroic science stories to privilege an experimental-observational methodology in school science has other implications. It can lead to an emphasis in classrooms on students learning to be good observers and does not necessarily encourage students to be involved in predicting and theorising. Studies conducted by Friedler, Nachmias, and Linn and Linn and Songer (Eylon & Linn, 1988) indicated that students who were required to make predictions developed a more robust understanding of heating and cooling than students who were encouraged to be good observers. Not only did these students develop richer scientific concepts; they developed a richer notion of what constitutes science. An emphasis in school science on observations can lead also to the notion that facts, which are a scientist's representations of observations, are more valued than theories. Such an emphasis can lead to the acceptance of the myth that science is a process of fact accumulation. An approach to school science that examines predicting and theorizing as well as experimentation and observation might assist students to develop an appreciation for the process of revision and substitution of scientific knowledge claims involving many scientists as more representative of science (Milne & Taylor, 1995).

As teachers, we need to be aware that heroic stories constitute only part of the narratives of science (I use the term “the narrative of science” to describe a text of events joined by subject matter and time). An alternative representation of scientific knowledge could be that it develops historically and involves many people in its construction. Therefore, rather than a simplistic focus, perhaps a greater emphasis in school science on the historical development of scientific knowledge would lead students to develop a greater awareness of the involvement of many people in the construction of scientific knowledge. For example, Isaac Newton is purported to have said, “If I have seen further it is because I have stood on the shoulders of giants.” From our lofty position of hindsight and from our immersion in a different context, we can recognize the veracity of his comment. However, an alternative explanation could be that it was the expectation of the times and not Newton’s natural modesty that required him to say something self-deprecating.

It might be appropriate to ask students, When does a scientist become a hero? Is the conception of a hero as presented in current heroic science stories too narrow? Pinch, in his lecture on science, technology and society (1992), suggested that there are three types of science heroes. The first type describes the experimenters who present their results with caution and who are deprecating about their achievements. He calls this “the ever so humble” approach to achieving hero status. Clearly, the proponents of cold fusion who published and were damned did not follow this strategy. Pinch identified the second type of hero as of the “blather, bluster, brilliance” style, which he claims is most common among theoretical scientists who attended the right institutions and who are central members of the science culture. He identified Richard Feyman as this type of scientific hero. Another hero of this ilk might be Isaac Newton, because although he was both an experimentalist and a theoretician, he attended a prestigious institution, Cambridge University; he belonged to the right institution, the Royal Society; and he surrounded himself with acolytes or disciples who were placed in significant institutions and who promoted Newton’s theories and laws.

The third type of hero that Pinch identified is the kind who “listen to the material” and who has developed a “feeling for the organism.” This style of hero does not work to impose order on nature but listens to what nature says to him. A noteworthy hero in this style is Barbara McClintock, and her feeling for the organism is described by Keller in her biography (1983). As Keller (1985) indicated, McClintock’s scientifically unfashionable approach to genetics marginalized her position (being a woman probably did not help either) in the science community, but there was still enough support from her peers to allow her to remain part of the scientific community and ultimately to be successful. If school science were to present heroes in these ways, then the plurality of the scientific community could be highlighted. However, Pinch’s suggestions about heroes are neither definitive nor complete. Students might be able to imagine other characteristics of people that are valued by both the scientific community and society.

Teachers can also use the semiotic circle as an organizer during science lessons, much as I have attempted to do in Figure 3. For example, the lesson focus may not necessarily be on heroes but on the development of a particular concept or theory in science. Stories such as Murphy and Smoot’s about Galileo (1982) can be examined by the class to extract the events that are highlighted by that story and the underlying messages about the nature of science that are presented in the story. Students could examine other stories about Galileo and write their own story about Galileo or mechanics or the heliocentric theory of the universe. This approach can be applied to an analysis of all types of science stories.

Conclusions

In this article I examined heroic science stories and their philosophical underpinnings and considered how we might select different events to produce different stories. The semiotic circle can be used to examine, first, how events are selected to create a text, and second, the meanings and values with which the story is imbued as a result. We can also use the circle to recreate the story so that different meanings and values are presented. Of course, there are other types of stories including discovery, declarative, and politically correct science stories, that also are significant in school science, but all science stories can be analyzed using critique based on the application of the semiotic circle.

Science stories are a particular reading of the narrative of science. If we accept White's description (1981) of stories as a metacode which allows them to be understood across cultures, then science stories can be used to tell about science across cultures. However, in the telling, science stories transmit both knowledge and values. Stories in school science have tended to emphasize the importance of objects of science over both the processes of science and the involvement of scientists in the construction of scientific knowledge. These values of science are presented implicitly. As teachers, we need to be mindful of these implicit messages. What sort of story about science do we want to present to our students? We need to be conscious of how we organize and interpret events in science and of the prominence that we give to particular science stories. What we tell and how we tell it are a revelation of what we believe about the nature of science. Perhaps if we wish to involve students more in thinking about the enterprise that we call science, we would do well to tell stories that emphasize the human aspects of the development of scientific knowledge, rather than being tokenistic about this involvement.

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