A Facilitator Model for the Use of History of Science in Science Teaching

Hayati ŞEKER

Assist.Prof.Dr., Marmara University, Atatürk Faculty of Education, İstanbul-TURKEY

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ABSTRACT

This paper proposes a theoretical model for science educators to promote science teachers’ use of the history of science in science teaching. The practical perspective of the research on the use of history of science does not provide consistent evidence to support a model to explain why and how history of science is influential in science education. In this paper, a theoretical model is discussed relying on empirical findings of the research and educational theories. The facilitator model was developed through a review of the literature that discusses the relationship between history of science and science education and a previous study that used history of science in eighth grade science lessons. The model defines four different levels: Interest Level, which includes information about stories of scientists’ lives to humanize science and scientists and to catch students’ interest in science lesson; Sociocultural Level, which includes information about how science interacts with society to improve students’ attitudes towards science and to humanize science; Epistemological Level, which includes information about scientific methods followed by scientists in the history to introduce some concepts of scientific inquiry; and Conceptual Level, which includes information about historical development of the concepts to help students understand scientific concepts. This model may serve to yield theory-based discussions on the relationship between history of science and science education.

Keywords: Science Teaching; History of Science; Science Education.

INTRODUCTION

Science educators have been emphasizing using history of science in science teaching because of the potential advantages of understanding nature of science, interest in science, and science learning (Becker, 2000; Irwin, 2000; Seker & Welsh, 2006; Seroglou, Koumaras & Tselfes, 1998; Solomon et al., 1992). However, the practical perspective of the research on the use of history of science does not provide consistent evidence to support a model to explain why and how history of science can be influential in science education. In this paper,
A theoretical model is presented, relying on empirical findings of the research and educational theories.

A well-known model for using history of science in science teaching is based on the similarities between student learning of concepts and the development of scientific knowledge throughout history (Galili & Hazan, 2001; Seroglou et al., 1998; Song, Cho & Chung, 1997; Stinner & Williams, 1993; Wandersee, 1985). The ‘assimilation’ and ‘accommodation’ processes in learning scientific concepts are considered analogous to the ‘normal sciences’ and ‘revolutionary sciences’ in the development of scientific concepts, mapping normal science onto assimilation and revolutionary science onto accommodation (Kuhn, 1970; Piaget & Garcia, 1989 cited in Gruber & Bödeker, 2005). Seroglou et al. (1998) criticized this approach, “Scientific models were developed in a context quite different from the current one where pupils live and learn” (p.262). Another model for the use of history of science in science teaching is the story form (Egan, 1989). Stinner and Williams (1993), and Roach and Wandersee (1995) used Egan’s story form which is about seeing a scientific content as a story to be told, a story involving a dramatic conflict created by using binary opposites, engaging students to resolve the conflict, helping them make sense of the learning experiences (Egan, 1989). Employing Egan’s (1989) story form, Roach and Wandersee (1995) introduced Interactive Historical Vignettes to help science teachers use science stories within the existing curriculum, which may help students organize their cognitive structure (Lauritzen & Jaeger, 1997) and connect ideas in the learning material (Carson, 1997; Stinner & Williams, 1993). As another approach to the use of history of science, Stinner suggests using the storyline approach within the Large Context Problems. (Stinner, 1994; Stinner, 1996; Stinner & Williams, 1993). Storyline involves interesting discoveries, which may attract student attention and imagination. Stinner (1994) explains the story of force from Aristotle to Einstein in a story line. In the development of a scientific concept, scientists have rejected the ideas of previous scientists and have developed new ones. Sometimes they interpret phenomena differently and extend or modify previous theories. This scientific process goes on as concepts develop throughout history. Every stage of the development of scientific knowledge throughout history can be constructed as a story line. Roach and Wandersee (1995) observed and later Monk and Osborne (1997) pointed out that science teachers found it joyful to use interactive historical vignettes and proposed that the stories would be more effective in science teaching if science teachers created their own vignettes. However, in general, teachers’ joy does not necessarily make them eligible to create and tell stories; to be able to successfully create and tell stories, teachers require additional training in using drama in science lessons, by training or by taking additional courses they could get in a self-taught manner (Galili, 2001). Similarly, science teachers would need to learn more about the development of scientific knowledge throughout history, again requiring additional training either in a self-taught way or through taking additional courses (Galili, 2001; Matthews, 2004). Furthermore, the use of history of science in science teaching is not only a matter of how knowledgeable science teachers are in history of science but also how well they can employ instructional strategies appropriate to subject matter. Teachers’ knowledge of subject matter is different from a scientists’ knowledge of the same subject. On the other hand, teachers’ knowledge of history of science is supposed to be different from knowledge of a historian of science. As Shulman (1986, 1987) considers pedagogy and content knowledge into the Pedagogical Content Knowledge, there is a need for an approach to bring historical knowledge, pedagogy, and content for the use of history of science in science teaching (Galili, 2011; Monk & Osborne, 1996).
The Facilitator Model

The facilitator model was developed through a review of the literature that discusses the relationship between history of science and science education and a previous study by Seker and Welsh (2003, 2006) that used history of science in eighth grade science lessons. For the previous study (2006), four different curricula were developed considering (a) traditional science curriculum, (b) development of scientific knowledge throughout the history, (c) scientific methods followed by scientists in the history, and (d) stories about scientists’ personal lives. Comparing the curricula integrated with history of science to the traditional curriculum resulted with the support of existence of different class contexts with regard to the use of history of science (Seker & Welsh, 2003). Therefore, the facilitator model is based on contextual differences on construction and development of the scientific knowledge in using history of science in classroom environments.

The distinction between contexts has been emphasized in the literature of history and philosophy of science and science education. The well-known distinction is between scientists’ actual thinking processes or the actual process of research (context of discovery) and the presentation of a theory before a public or the accounts by which the results of that research are exposed and defended as valid (context of justification). Reichenbach (1938) was credited with Carnap’s distinction (1928 cited in Matthews 2004), and his argument is widely accepted (Matthews, 2004). Schickore (2008) stressed the context of discovery and the context of justification with Reichenbach’s emphasis on the mismatch between what scientists do and the presentation of results in scientific publications. Duschl (1990), pointed that, with regard to Reichenbach’s distinction, using history of science knowledge in science education studies constructs different education contexts. In first context, context of discovery, which is about what we know, scientific ideas are presented as tentative, interpretative and figurative. In the second context, context of justification, which is about how we know, the situation in which knowledge claims are systematically presented in relation to the data and termed by Duschl as final form science (Duschl et al., 1992). Duschl puts more emphasis on the context of development rather than the context of justification or context of discovery since science is recognized because of improvement and refinement (Grandy & Duschl, 2008). Stinner (2003) also emphasized an inquiry approach with three levels of historical and conceptual development: a foundation level, a research level, and a pedagogical level. The foundation level is defined as thinking and activities when scientific theory is constructed. The research level is defined as working out of the consequences of that theory. The pedagogical level is defined as presentation of that theory as a content knowledge. Stinner emphasized the importance of the connection between pedagogical level and other two levels. He suggested using inquiry approach to connect pedagogical level with foundation and research levels.

Consequently, the facilitator model discussed in this paper was developed with the Pedagogical Content Knowledge Approach (Shulman 1986, 1987), Duschl’s emphasis on contextual differences (Duschl et al., 1992), and competency level of Self Determination (Deci & Ryan, 2000) for teachers to use history of science in science teaching. In the facilitator model, four levels were used to connect history of science with science teaching: Interest Level, Sociocultural Level, Epistemological Level, and Conceptual Level. These levels are gradually arranged by competency level of teachers in the use of history of science in science teaching. First level includes information that teachers integrate short science stories into their lessons easily whereas the fourth level includes information that teachers tailor pedagogical knowledge and history of science to content knowledge.
**The Interest Level**

The Interest Level covers information about stories of scientists’ lives. Interest Level aimed at two main educational objectives; first, to humanize science and scientists; the, second, to catch students’ interest in science lesson. Teachers are expected to use short stories about scientists’ personal lives without connection to the concepts of science or nature of science at the Interest Level. For example, telling students Sir Isaac Newton was raised in his grandmother’s home after his father’s death and his mother abandoned him to remarry. Such kind of stories has a potential to humanize the scientist by focusing students’ attention on scientist’s experience as a person rather than as a scientist (Matthews, 1994; Hadzigeorgiou, 2006). Presenting human aspects of scientist can help for what Mitchell (1993) described catch component of interest as short-term interest for a period of lesson. Continual use of these stories may help students generate individual interest in science (Person-Object Theory of Interest, Krapp, 2002; Welsh & Seker, 2003). This level may consist of three main sublevels: The lives of scientists, which is about scientists’ personal lives affecting their studies in direct or indirect ways; scientists as human beings, which is about emphasizing scientists had a life beside their scientific studies, and magazines, which is about interesting points in scientists’ lives (Table 1).

**The Sociocultural Level**

The Sociocultural Level covers information about how science interacts with society. Society in this approach is twofold as scientific society that brings together scientist and the authorities of science; and people who live in the era that scientific developments arise. For example, Jewish scientists escaped from Germany to the U.S., and their inventions played an important role in changing the direction of World War II (Wandersee & Roach, 1998). Educational objectives of this type of information are to improve students’ attitudes towards science and to humanize science by showing that scientific information is not product of an individual scientist but the product of a society; so science is in interaction with society direct or indirect ways (Becker, 2000; Matthews, 1994). Besides, historical information at this level can hold student interest in science by showing how the subject matter is meaningful and valuable which is in accordance with Mitchell’s (1993) description of hold component of interest as meaningfulness and value of the material. This level may consist of three main sublevels: Scientific society, which is about how scientists interact with scientific society; science and people, which is about how scientists and their discoveries interact with people; and the history of technology, which is about the technological outcomes of the scientific discoveries (Table 1).
Table 1. Examples for the levels of the facilitator model

<table>
<thead>
<tr>
<th>Levels</th>
<th>Sub-Levels</th>
<th>History of Science</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest Level</td>
<td>Lives of scientists</td>
<td>Scientists’ personal lives affecting their studies directly or indirectly</td>
<td>Galileo’s father was a musician and he used to play instruments, and that is why he could use little bells in his inclined plane experiment.</td>
</tr>
<tr>
<td></td>
<td>Scientists as human beings</td>
<td>Scientists’ lives besides their scientific studies</td>
<td>When Newton was a schoolboy he fought with a boy and punched him on the stomach.</td>
</tr>
<tr>
<td></td>
<td>Magazines</td>
<td><em>Interesting</em> points in scientists’ lives</td>
<td>Volta wanted to marry with a singer but it was impossible in his era, so he had to marry to another woman.</td>
</tr>
<tr>
<td>Sociocultural Level</td>
<td>Scientific society</td>
<td>The relationship between scientist and the scientific community</td>
<td>Newton headed Royal Society for 24 years.</td>
</tr>
<tr>
<td></td>
<td>Science and people</td>
<td>How scientists and their discoveries interact with people</td>
<td>Discovery of electric current, telegraph came into use with Atlantic Cable so people started to communicate easier than before.</td>
</tr>
<tr>
<td></td>
<td>History of technology</td>
<td>Technological outcomes of the scientific discoveries</td>
<td>Lightening conductor is invented after Benjamin Franklin’s studies on electric charges.</td>
</tr>
<tr>
<td>Epistemological Level</td>
<td>Scientific methods</td>
<td>Information about the scientific methods scientists followed in their research</td>
<td>Galileo designed experiments, defined and controlled variables in order to have accurate data.</td>
</tr>
<tr>
<td>Conceptual Level</td>
<td>Historical development of concepts</td>
<td>How a concept was developed throughout the history</td>
<td>For the historical development of electric current; Stephen Gray is the first scientist who discovered that the electricity can transfer and then Du Fay and Franklin proposed their fluid theories. Faraday rejected these theories and proposed a wave-like motion for the electric charges.</td>
</tr>
<tr>
<td></td>
<td>Discovery of concepts</td>
<td>How a specific concept was discovered</td>
<td>Before the discovery of law of friction, concept of friction was already known by Leonardo da Vinci. Studying on perpetual motion, his experiments put the first principles of the friction.</td>
</tr>
<tr>
<td></td>
<td>Controversies and opposing ideas</td>
<td>Controversies between scientists with opposing theories or paradigms</td>
<td>Galvani thinks that animals are the source of the electricity but Volta thinks that it is because of the contact potential.</td>
</tr>
</tbody>
</table>
The Epistemological Level

The epistemological level addresses ways of doing science and the aspects of nature of science. Main educative objectives at this level are to show that there is no single way of doing science (McComas, 1996), and to introduce some concepts of scientific processes like controlled experiment, dependent and independent variables, direct and indirect observations, the use of mathematics and modeling, the role of evidence based scientific inferences. For example; Galileo is one of the first experimenters and he developed theories about motion, which were opposite to the accepted ideas of Aristotle (Table 1). This opposition may help students understand the empirical nature of scientific knowledge. Two scientists may perceive and respond to the same data in different ways since they have different backgrounds and minds. The role of different perceptions on producing scientific knowledge can be used in science teaching to demonstrate human aspect of science and subjective elements in the process of science (Kampourakis & McComas, 2010).

The Conceptual Level

The Conceptual Level addresses cognitive domain referring to conceptual learning (Klopfer & Cooley, 1961; Roach & Wandersee, 1995; Seroglou et al., 1998; Stinner & Williams, 1993; Wandersee & Roach, 1998). Educational objectives of this level are to help students understand scientific concepts and scientific knowledge taught in science lessons is not final form of science (Duschl, 1990). Students' prior knowledge is important when developing learning activities due to the similarity between students' naive ideas and scientists' ideas throughout the history (Roach & Wandersee, 1995; Stinner & Williams, 1993). With the historical information at this level, students can realize the similarity between their naive ideas and scientists' ideas. For example, the concept of impetus, used before Isaac Newton's ideas in physics, is often referenced to discuss similarity between students' alternative concepts and scientific concepts throughout the history (McCloskey, 1983). Historical information at the Conceptual Level are expected to promote students' awareness to facilitate construction of new knowledge on prior knowledge, this may help students discuss their own ideas by means of being aware of the similarities (Irwin, 2000; Roach & Wandersee, 1995; Seroglou, Koumaras & Tsiefs, 1998; Stinner & Williams, 1993; Wandersee, 1985). Awareness of prior knowledge may activate students' metacognitive skills (Campanario, 2002) and foster students' conceptual change (Seroglou et al, 1998). At this level, using history of science demands more teacher effort and teacher may face the occasion that students do not want to discuss their own ideas (Irwin, 2000). This level may consist of three main sublevels: Historical development of the concepts, which is about how concepts were developed throughout the history; discovery of the concepts, which is about how a specific concept was discovered; and controversies and opposing ideas, which is about controversies between scientists with opposing theories or paradigms (Table 1).

In Table 1, examples are provided to explain the levels and sublevels of Facilitator Model. The examples from different historical cases were given for each sublevel instead of giving them from the same historical case. Because, historical information on the same concept may not be available for each sublevel while it is possible for each level of the model. Differences between examples also reflect modular aspects of the facilitator model, which asserts that not all historical information across all sublevels were recommended to use in one or two class periods. Teachers may choose historical information at one or more sublevels of the model in which they feel efficient and competent at using them in their teachings.
CONCLUSION

The facilitator model discussed in this paper is intended to explain the relationship between history of science and science education. It is a pragmatic approach based on educational theories of cognition (assimilation, accommodation, conceptual change, metacognition), Person-Object Theory of Interest, Pedagogical Content Knowledge Approach, and sociocultural approaches (Science-Technology-Society). The modular approach may be in conflict with particular cases, but this model focuses on the integration of history of science into the enacted curriculum, which aims certain objectives for all students. As an educational approach in practice, the model may cover objectives other than targeted ones, historical information for each level may serve educational objectives other than the one the model targeted. The levels of the model are not independent of each other, one may overlap with another. Different contexts provided by different types of information meant to be levels of the facilitator model, which is based teacher’s competence level of using historical information. The model with levels and sublevels are being examined with a project in progress. Flexibility of the model may benefit to change the order or number of levels and sublevels. An optimized model may serve educators to explain findings of their research on the history of science in science education in an educational framework.
REFERENCES


