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The Instructional Model for Using History of Science

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Abstract

This paper discusses the levels of The Instructional Model for Using History of Science (UHOS) to explain the relationship between the history of science and science teaching. The UHOS model proposes four levels: Conceptual Level, Epistemological Level, Sociocultural Level, and Interest Level. Each Level has sublevels with regards to types of historical knowledge, pedagogical approach and educational objectives. The UHOS model purports to help educator and researchers to explain their findings with an overarching theoretical framework.

Key Words

History of Science, Science Education, Instructional Model.

The history of science has an important role in science education (Matthews, 1994). The use of history of science in science teaching has positive influence on student understanding nature of science, interest in science, and science learning (Brush, 1989; Irwin, 2000; Klopfer & Cooley, 1961; Seker & Welsh, 2006; Seroglou, Koumaras, & Tselfes, 1998; Solbes & Traver, 2003; Solomon, Duveen, & Scot, 1992; Stinner & Williams 1993). Studies showing significant contributions to the field have not convinced science teachers and educators why and how history of science can be influential in science education because of the weak connection with educational approaches. The use of the history of science in science teaching requires to be considered an instructional approach based on educational approaches to disseminate research results to educators. For this purpose, this paper presents an instructional model, which is continuation of previous models discussed in authors' recent papers (Seker, 2007, 2011).

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Early initiatives; such as, Harvard Case Histories in Experimental Science (Conant, 1957), the Harvard Project Physics Course (Holton, Rutherford, & Watson, 1970), Science Cases for Schools (Klopfer, 1964-1966) and Teachers' Handbook for the BSCS Curriculum (Schwab, 1963) have not convinced follow up studies in science education (Russell, 1981; Welch, 1973). These initial efforts did not contribute an explanatory model of instruction to the following studies. After 1970's, Egan's Story Form (1986) became primary instructional approach for science educators to use the history of science in science education. Wandersee (1992) and Roach and Wandersee (1995) proposed Interactive Historical Vignettes, Interrupted Story Form, and Binary Opposites and Stinner (1994; Stinner & Williams, 1993) proposed Story Line and Large Context Problems (1995) to incorporate the history of science into science lessons. The Story Form provides a context to help students organize their cognitive structure and connects ideas in the story (Carson, 1997). Studies introduce history of science in Story Form often emphasize that storytelling requires teacher talent even some consider teachers as natural storytellers.

To explain the effects of the use of the history of science on student learning, science educators debate parallelism between students' cognitive development and the development of scientific knowledge throughout history. Even though the parallelism is still obscure, the similarity between scientists' ideas and students' alternative ideas may help students learn meaningfully (Monk & Osborne, 1997; Piaget & Garcia, 1989; Wandersee, Mintzes, & Novak, 1994). The parallelism between student cognition and the development of scientific concepts emphasizes that the 'assimilation' and 'accommodation' processes in learning scientific concepts are analogous to the 'normal sciences' and 'revolutionary sciences' in the development of scientific knowledge. However, there are arguments against using this analogy.

Most studies on the use of the history of science in science education have not concerned with teachers' competencies and curriculum restraints. It is assumed that science teachers found stories joyful to use the history of science (Monk & Osborne, 1997). However, in general, the teachers' joy does not necessarily make them eligible to create and tell stories. Science teachers don't use them unless they are interested in personally. Teachers are persistent in using the traditional curriculum and do not want to change it (Rutherford, 2001). Teachers used most pragmatic ways in their experiences (Cohen & Ball, 1990; Gallagher, 1991). Even pragmatic approaches to the use of the history of science in science lessons lead to a discussion on pseudoscience and pseudohistory (Allchin, 2004; Brush, 1974). Teachers' knowledge of subject matter is different than a historian's knowledge on the same subject. As it is in Shulman's (1986, 1987) the idea of pedagogical content knowledge, a science teacher is expected to have pedagogical knowledge for history of science (Galili & Hazan, 2001; Monk & Osborne).

The Instructional Model for Using History of Science

The Instructional Model for Using History of Science (UHOS) is based on the differentiation of contexts provided by history of science (Seker & Welsh, 2003). The contexts provided by scientific knowledge were classified with distinction between the context of discovery and the context of justification (Carnap 1928 cited in Matthews, 2004; Reichenbach, 1938; Duschl, 1990). Stinner (2003) constructed three levels of historical and conceptual development, a foundation level, a research level, and a pedagogical level. The UHOS Model has four levels and their sublevels to connect historical knowledge, pedagogical approach and educational objectives: Conceptual Level (Similar Ideas, Binary Opposites, Chronology, Context of Discovery), Epistemological Level (Method, Methodology), Sociocultural Level (Science and Public, Scientific Society, History of Technology), Interest Level (Scientist as Person, Image of Scientist, Magazines). The order of levels of the UHOS model is based on the teachers' competencies in using instructional techniques proposed at each level. The levels are ordered from difficult to easy one: Conceptual, Epistemological, Sociocultural, Interest Level (Seker, 2007). The line of order is not required to be the same for every field, but the assumption of UHOS model is the existence of various levels of teacher competency regarding the use of historical knowledge in science teaching.

Conceptual Level

The Conceptual Level is concerned with learning objectives and related educational approaches in science education. At this level, the parallelism between student cognitive process and the development of scientific knowledge is used to explain positive influence on student learning (Campanario, 2002; Clement, 1982; Galili & Hazan, 2000; Sequeira & Leite, 1991; Seroglou et al., 1998; Wandersee, 1985, 1992). Meaningful learning (Ausubel, 1968), conceptual change theory (Posner, Strike, Hewson, & Gertzog, 1982), cognitive conflict (Mason, 2001), argumentation activities (De Hosson & Kaminski, 2007) are used to develop instructional techniques to use the history of science for cognitive objectives. This level has four sublevels based on the differences in types of historical knowledge, instructional approaches, and objectives: Similar Ideas, Binary Opposites, Chronology, and Context of Discovery.

Similar Ideas: Similar Ideas sublevel is constructed for the use of historical information about the scientists' ideas similar to students' alternative ideas. Ausubel's Meaningful Learning Theory emphasizes on the importance of the similarity between students' prior knowledge and instructional materials for advancing cognitive structure. For example; the concept of impetus is similar to students' pre-concepts of force. Instructional techniques based on inquiry approach is expected to use develop a class context in which students question their prior knowledge on motion of objects. As a learning objective, students may recognize the similarity between their prior knowledge and ideas on impetus.

Binary Opposites: Binary Opposites sublevel is constructed for the use of historical information about opposing ideas in the same era or in different eras throughout history of science. Egan emphasized the importance of 'binary opposites' in learning because students learn meanings with opposites (Egan, 1986). Argumentation activities may be used since students need to justify their claims (Cho & Jonassen, 2002; Driver, Newton, & Osborne, 2000; Gürel, 2008). At this sublevel, justifications of claims are more important than resolutions of dilemma to develop students' reasoning ability. For example, Galvani and Volta, who were contemporary scholars at their times, had different ideas on the source of electricity. Galvani believed that animal was the source of electricity and Volta disproved his idea by showing that it was because of the contact potential. Teachers can use the disparity between these two scientists and their ideas for argumentation activities.

Chronology: Chronology sublevel is constructed for the use of historical information about the development of a scientific concept throughout a timeline. In the development progress, scientists rejected the ideas of previous scientists and developed new ones. Sometimes, they interpreted phenomena differently and extended or modified 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 and interrupted form is proposed as an instructional technique at the Chronology sublevel. The power of storytelling on organizing cognitive schema (Carson, 1997; Egan, 1986; Lauritzen & Jaeger, 1992, 1997) and Ausubel's meaningful learning (1968) is the motive of Story Line approach. For example, the development of force concept through history constructs a story line: Natural force, violent force, impressed force, impetus, momentum, inertia, force and motion. The causal link between each stage may help students understand force concept in a conceptual map from the history of science.

Context of Discovery: Context of Discovery sublevel is constructed for the use of historical information about authentic ill-structured problems of scientists. Situated Cognition approach emphasized the importance of authentic problems for learning concepts (Brown, Collins, & Duguid, 1989; Mercan, 2012). Authentic school science emphasize on authentic inquiry as close to the environment in which scientists conduct their research (Roth, 1995). At this sublevel, authentic science is considered as the closeness to the environment in which scientific concept was discovered. The historical information about the discovery of the concept can be used for argumentation activities because of its ill-structured nature (Cho & Jonassen, 2002). For example, Kepler's problem with Brahe's data on Mars' orbit did not fit Aristotle's universe model. This problem can be an example to start a session in which students look for an answer to the question "How can Kepler solve this conflict?" Students' reasoning ability can be developed while they justify their answers.

Epistemological Level

Epistemological Level is concerned with understanding ways of doing science and nature of science. An explicit and reflective approach is proposed as an instructional technique to help students understand nature of science (Akerson, Abd-El-Khalick, & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002). Epistemological Level has two sublevels: Method and Methodology. At the Method sublevel, teachers are expected to facilitate students' repeating scientific methods (experiments, observation, modeling, etc.) followed in the origin of discovery. For example; Galileo is one of the great experimenters and he conducted inclined plane experiment which is a simple experiment to do in science lessons. While doing experiments, students are asked to question how many variables affect the results of the experiment. The teacher may initiate a discussion on the number of variables to be controlled in the inclined plane experiment. It is aimed that students become more aware of the role of control in doing experiments.

At the Methodological sublevel, teachers are expected to use inquiry based instruction technique to start with questions on the importance of methodology for conducting scientific research. For example, Volta was in instrumentalist perspective rather than a theorist one, and this is his inspiration for repeating experiments. At this sublevel, students are expected to be aware why Volta put emphasis on experiments, and to be informed about the co-existence of different perspectives on the same scientific case.

Sociocultural Level

Sociocultural Level is concerned with understanding the relationship between science and society. A goal in science education is to enhance scientific literacy, and because today's students are future citizens of the community their scientific literacy is critical. Historical information about the relationship between science and society may serve to achieve the curriculum objectives promoting scientific literacy. Society in this approach is twofold as formal and informal scientific societies; and people who live in the era of the discovery. At this level, historical information may stimulate students' feelings of meaningfulness (Mitchell, 1993), value-related expectancies (Schiefele, 1991), value beliefs (Wigfield & Eccles, 2000). Even if technology can be described as the interaction between science and society or scientific society, because definition of technology differs from science in terms of artificial interaction (Lawson, 2008), design and product oriented nature (Günay, 1988). History of Technology is constructed as a sublevel of Sociocultural Level. Therefore, this level has three sublevels: Science and Public, Scientific Society, History of Technology.

Science and Public: Science and Public sublevel is constructed for the use of historical information about the relationship between science and people in science teaching. The history of science includes cases in which scientific discoveries affect public life. To the ultimate goal of scientific literacy, future citizens are expected not to put distance to science. At this sublevel teachers may give examples of the interaction between science and public-life after finishing doing tasks in lesson. Such examples from the history of science provide socio-scientific issues to develop argumentation activities (Simon, Erduran, & Osborne, 2006). Teachers may give homework students to search how science interacts with today's public life. In the following lessons a discussion session can be started to compare examples from today and past.

Scientific Society: Scientific Society sublevel is constructed for the use of historical information about the interaction between scientists and scientific societies and structure of scientific societies. The studies on the nature of science emphasize the role of sociocultural context on the discovery of scientific concepts (Abd-El-Khalick, Bell, & Lederman, 1998). Sometimes scientific societies were supported on some scientists and sometimes they negatively influenced scientists and their research. At this sublevel Short Story Form is proposed as an instructional technique. Besides, students may compare today's scientific societies with earlier ones if teachers give them an assignment to search news related to the scientific societies. In the following lesson, students may discuss the differences between today's and earlier scientific societies.

History of Technology: History of Technology sublevel is constructed for the use of historical information about the technological outcomes of the scientific discoveries. Technological outcomes are also good examples for the interaction between science and society; particularly they show how scientific discoveries are useful for society utility value (Wigfield & Eccles, 2000). Teachers may give such technology examples in Short Story Form following class activities in the lesson. Students are asked to find similar examples from daily life as an assignment. In the following lesson teachers may encourage a discussion sessions on the influence of the technological innovations on society rather than technical details on how newer ones are more complex. For example, discovery of first batteries and the purpose of their use in their discovery era can be a good example to discuss the influence on society or scientific society. At the same time, students can find good examples to discuss differences between today's and earlier batteries.

Interest Level

Interest Level is concerned with objectives and approaches of affective domain (Krapp, 2002; Mitchell, 1993). Particularly salient themes are focus of the stories at this level (Schank, 1979). Short story form is proposed as an instructional strategy for teachers to stimulate student interest in science lesson. Continual use of these stories may help students generate individual interest in science (Krapp; Welsh & Seker, 2003). At this level, affective objectives; humanization of scientists and image of scientist support to split two separate sublevels: Scientist as Person and Image of Scientist. A third sublevel, Magazines is related to *seductive details* in the history of science.

Scientists as Person: Scientists as Person sublevel is constructed for the use of historical information about scientists' personal life stories. These stories particularly focus on regular and interesting activities of scientists as a person in society. Such stories may help humanize scientist and science (Hadzigeorgiou, 2006; Matthews, 1994, Wang & Marsh, 2002). Short story form is proposed as an instructional technique. Teacher may use stories for a short five or ten minutes, particularly when there is a need for a break in the lesson. The stories at this sublevel focus scientists' childhood, relationships with their parents, friendship, hobbies, marriage and death.

Image of Scientist: Image of Scientist sublevel is constructed for the use of historical information about personal life stories which affected scientists' scientific endeavors. The stories focus on social and cultural occasions in which scientists lived and how scientists faced difficulties in their life while continuing their studies. At this sublevel, teachers may use short story form as an instructional technique. These stories at this sublevel focus on scientists' experience in education, profession, institutes and events in places where scientists grew up.

Magazine: Magazine sublevel is constructed for the use of historical information about intriguing points in scientists' lives which are not necessarily related to content of science lesson. Highly interesting but irrelevant information is termed as seductive details in literature. Regarding inclusion of seductive details, studies do not provide consistent evidence of positive influence on cognitive interest and learning (Garner, Brown, Sanders, & Menke, 1992). At this level, seductive details in the history of science can be effective when students lose individual attention. The characteristics of these stories are away from educational objectives for teachers considering their limited time for attaining objectives of curriculum. For example, Kepler's aunt and his mother were sentenced to be burned because they were charged with being witch. Such intriguing stories may help teachers to get student attention but they are not directly related to objectives in education.

Discussion

In this article, The UHOS instructional model is presented with four levels (Conceptual, Epistemological, Sociocultural, and Interest) with sublevels. The UHOS model is based on a pragmatic approach which use several theories and approaches in education to connect historical knowledge with educational objectives. The levels of the UHOS model are modular, means that not all of them are needed to be used in practice. The levels are based on the assumption that there are different contexts provided by different types of historical knowledge, pedagogy, and objectives. Therefore, some objectives may overlap between levels. The elastic nature of the UHOS model may ease to use historical knowledge within the limits of the science curriculum. Most sources of the history of science are written without considering pedagogical benefits. The UHOS model can help transform the knowledge of the history of science into pedagogical content knowledge for the history of science, which composed of historical knowledge, pedagogical knowledge, and content knowledge.

The UHOS model has been used as a theoretical framework for a national project to promote the use of the history of science in science lessons. The instructional materials have been developed with the model discussed in this paper. Teachers have been interviewed to reflect their views on the utility of the historical materials. Teachers are using the materials on their teaching of biology, physics, and chemistry. Teachers' views on the use of historical materials are being analyzed by using categories developed with regards to levels and sublevels of the UHOS model. The model is still in progress and promising for further studies to develop theoretical framework for the use of the history of science in science teaching.

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