Historical models and science instruction: A cross-cultural analysis based on students' views

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Abstract

The paper is an extended work from a previous study on Taiwanese and German students' conceptions of the universe (Liu, 2005). The study revealed that students discuss astronomical events and entities based on a mental model of universe and their models of the universe seem to have similar underlying principles with historical ones. In present paper, the author seeks to further analyze historical models of the two

different cultural contexts, and elaborate the instructional use of these historical material based on students' views.

Introduction

There have been various reasons proposed in the past for including history and philosophy of science in science teaching and learning (Matthews et al., 2001). Apart from a large amount of literature focusing on its relation to teaching nature of science, in the following are some convincing arguments:

1. History of science may harbor keys to science learning for there seems to be a parallelism between students' and historical ideas.

The eminent historian of science, Thomas S. Kuhn, explicitly mentioned that the research on children's cognitive development, in particular done by Piaget, had made a contribution to his thoughts on the historical development of science. He recalled a meeting with a colleague in his speech:

> I said to him that it was Piaget's children from whom I had learned to understand Aristotle's physics. His response -- that it was Aristotle's physics that had taught him to understand Piaget's children -- only confirmed my impression of the importance of what I had learned (1977, p.21).

He followed to tell the audience: "Part of what I know about how to ask questions of dead scientists has been learned by examining Piaget's interrogations of living children." Interestingly, Piaget had a similar view, but in reverse: As for him, the history of science has shed the light on the problems of children's cognitive development (Piaget & Garcia, 1989). From Kuhn's point of view, if there is a parallelism between the child's cognitive development and the history of science, as Piaget argued based upon his comprehensive investigations, this should be of interest both to psychologists and historians. As a matter of fact, it has drawn much attention from science educators, in particular in the 1970s and 1980s, while the intriguing analogous features between the historical and individual knowledge acquisition were considered to have much instructional implication. As Wandersee et al. (1994) cited, among the best available evidence in the field of preconception research is that alternative conceptions often parallel explanations of natural phenomena offered by previous generations of scientists and philosophers. Thus, the development of scientific knowledge may shed some light on the ways in which students come to understand it.

2. History of science can offer more "plausible" accounts of science.

We should bear in mind that science teaching is not successful often because more attention is paid to the precision and comprehensiveness of the subject matter than to making it comprehensible. It is often forgotten that science teaching is aimed at young people, who do not have the same "conceptual tools" as adults. The need for a more plausible presentation of science has led us to look at history. Before technology started to vastly accelerate scientific progress in the seventeenth century, early scientists inquired into nature based on personal experience and observations with naked eyes. Thus, they provided relatively naïve accounts in describing and explaining natural phenomena as opposed to modern science. For the conceptual tools used to derive these accounts seem to be at a level closer to the students', these accounts would likely appear to be more plausible for them than the intended scientific knowledge.

3. Historical thinking is needed for a "continuous experience" in science learning.

Education is essentially experiential, as John Dewey (1997) contended. Young people come to school and acquire various experiences, some may be defective and negative while others fruitful and positive. These experiences are all of significance insomuch as they are connected to further experiences: No matter a defective or a fruitful experience, it lives on in further experiences. Thus, as Dewey continued to argue, the central problem of education is "to select the kind of present experiences that live fruitfully and creatively in subsequent experiences". In doing so, education will provide students with meaningful experiences which "have their roots on what has gone before" and lead to better qualities of future experiences. Along this line, Dewey argued for the necessity of historical thinking in teaching and learning. While learning science, students need to anchor and extend their experience with the aid of historical thinking so that scientific knowledge is not learned as merely an "end" product. It is history which can provide the student with sequences involving genuine figures and thereby assist in the continuous advancement of thoughts.

4. History of science can assist in enhancing students' conceptual development through contextual alternative representations

It should be especially noted that the recent years have witnessed a shift of emphasis from "conceptual change" to "conceptual differentiation" and "conceptual appreciation" in the research of science teaching and learning (Caravita & Hallden, 1994; Linder, 1993). It is argued that students' preconceptions can prove to be useful and adequate in dealing with their everyday situations and, therefore, it is not always necessary to remove these ideas. Consequently, science instruction should not focus on how to change students' ideas, albeit the change may still emerge as a result of the instruction, but instead on how to help students differentiate their ideas from those presented in the science lesson according to the context they apply to. Also, students should learn to appreciate different perspectives or points of view, as they could be all "correct" in their own particular situations. This move in science education research seems to have opened a gateway for the historical approach in science instruction. Pre-scientific ideas can be operated as "alternative representations" in the science classroom for two reasons: first, they can exemplify the argument that concepts may be appropriate in their particular settings; secondly, they may illustrate a third perspective to the two - often very different - ones in the classroom, one from students and the other from science textbooks or the teacher. To provide students an alternative perspective should be meaningful to their learning because, as we may agree, it is easier to gain insight into something when we see its alternative (Marton & Tsui, 2003).

Objectives

The present work is inspired by a previous cross-cultural study (Liu, 2005) on young students' descriptions and explanations of the Earth, the sky, and familiar heavenly events, such as phases of the Moon. In the study, both Taiwanese and German students presented their knowledge based on a mental model of the universe. A number of previous studies on different topics have also provided evidence on the structural feature of students' knowledge (Greca & Moreira, 2000; Vosniadou & Brewer, 1992; Wandersee et al., 1994). Another worth-noting finding of Liu's study is that there seems to be similarities between students' and historical ideas which lie in their organized pattern and perceptual basis, and these similarities can be located in the both cultural settings. In other words, students' perception-based arguments and models have their analogies in conceptual history of the both (and perhaps more) cultures. It therefore draws a meaningful point to extend the cross-cultural analysis from students' conceptions to the historical ones from an instructional perspective.

The paper seeks to analyze the historical ideas and models regarding the sky and Earth in the Western and Chinese world and to explicitly locate their common place with student' ideas and models. Furthermore, their meanings to science instruction are elaborated. The paper will thus arrive at some instructional suggestions of using historical material based on the similar underlying principles between students' and early scientists' view.

Conceptions of the universe in early China and Europe

Before the seventeenth century, astronomy had developed differently in China and in Europe. The similarities of these two lines of scientific development are that, first, both focused on the study of the heavens (the order of the heavens as a major preoccupation), and that, second, both dealt with the calendar, cosmography (sometimes along with the study of the movements of the planets), and what we call today "astrology". The scientists in the two early worlds paid great attention to the sky and believed the heavens to be organized in order. Regulating the calendar, drawing the sky map, and investigating omens, are the same tasks they undertook.

As Lloyd (1999) cited, the subject matter of the both enquiries in early Chinese and Greek antiquity was the same, yet they developed and presented very different theories and concepts, which are associated with the questions they chose to study and, consequently, the answers they chose to give to them. Their fundamental conceptual differences can be summarized as follows:

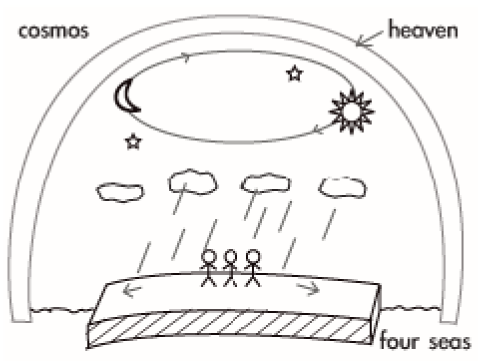
1. Greek astronomy highlighted planetary motions (the apparent irregularities threatened the very notion of celestial order itself, so the Greeks sought to geometrize them and in doing so turn irregularities into regularities). In contrast, the Chinese were more confident in the inherent order of the heavens and more open minded about its possible messages for the Earth. Chinese theories seem to have "imposed far less rigid patterns on the order they expected" (Lloyd, 1999).

2. The early Chinese and Greeks developed very different models of the universe: the former primarily with a flat Earth, round heaven, free heavenly bodies and infinite cosmos, and the latter with a round Earth centered by layers of round heavens, bound heavenly bodies and finite cosmos/heavens. The motions of heavenly bodies were, for the Greeks, the consequence of the rotation of the concentric celestial spheres on a common axis, and, for the Chinese, generated by vapor with each having its own path around the Earth (Chen, 1996).
3. The Chinese concentrated on the polar star (based on their keen observation to the sky) as opposed to the Greeks on the Earth and, much later on, the Sun (Needham, 1959).
4. The Chinese were focused on an arithmetic approach, the Greeks on a geometrical one.

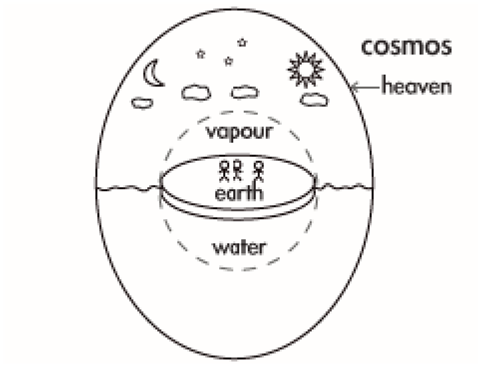
In ancient China, three main theories of cosmology can be distinguished. These theories do not give detailed descriptions of the movement of the heavenly bodies, which draws a contrasting point to the European cosmology of the time. The Greek tradition persisted in using homocentric spheres to construct the picture of the universe and placed the Earth or, at the end, the Sun at the center, probably for the reason that such conceptions (celestial spheres with uniform motion) were regarded as the "perfect form". For the ancient Greek scientists, their aim was to provide a tempo-spatial model of the universe for explaining the apparent motions of the heavenly bodies – the Sun, Moon, planets and stars - as seen from the Earth (Sun, 2000). It is worth noting that the shape of Earth had not been a problem for either of the Chinese and Greeks before the seventeenth century when missionaries arrived in China. For the Chinese the Earth had been always flat, whereas the Greeks had taken for granted the Earth was spherical. These two very different ideas seem to both be rooted in what people considered as ideal shape in their own cultural context. The Chinese term of "flat" or "square" also means the highly respected moral quality of being righteous and strong-minded; in contrast, the spherical shape was repetitively regarded by ancient Greeks as perfect form. Nevertheless, the Greeks went further to seek evidence by conducting experiments unlike the Chinese who for centuries simply premised the flat Earth in their astronomy (Chu, 1999).

Three early Chinese models

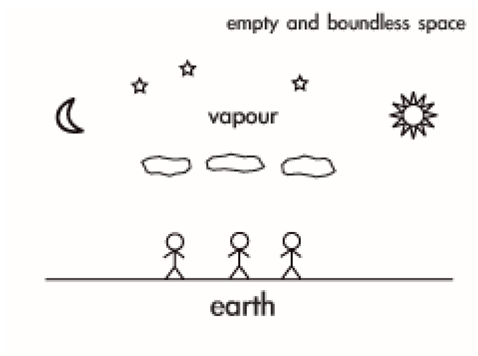
The early Chinese drew up their pictures of the universe with a focus on the relations between Heaven and Earth. Three cosmological models (see Figure 1) were advocated by different schools and held true for a long time. These models were once highly advanced in human history, but as a whole, because of the lack of systematic theories, failed to move forward and eventually were replaced in the seventeenth century by the Western theories.



The *Gai Tian* Model (Hemispherical Dome)



Hun Tian Model (Celestial Sphere)



Shuen Ye Theory (Infinity)

Figure 1. Three early Chinese models of the universe.

The great emphasis on ethics of the most dominant philosophical school, Confucianism, had much to do with how Chinese people conceived the world. It is also often considered as one of the major obstacles to eliminate their childish beliefs from scientific theory (Jin et al., 1996). The Chinese science developed along with an endeavor of active participation in the real world and consequently an emphasis on technology. Most of the experiments were conducted for practical purposes, and few for verifying scientific theories. Jin et al. (1996) pointed out that the Confucian doctrine rests upon a particular conception of the world which they term "man in nature". The spirit of this doctrine is that "mankind is meant to maintain the universal harmony by following the natural rules" and there is a de-emphasis of reasons for natural phenomena because they are beyond human intellectual comprehension.

Therefore, the Chinese scientists took for granted that their tasks are to "discover" and "follow" the natural rules, rather than to "reason". This view did not demolish even as late as in the nineteenth century, when the eminent scholar Ruan Yuan still complained about the changing theories in Western astronomy: "The laws are always changing…I don't know where the real reason lies." He went on to argue that "heavenly laws are so profound and subtle that they lie beyond human ability". It is therefore prevailing in Chinese history of science that theories are intended to express certainties rather than search for reasons. Only in this way can theories "last forever without error" (Jin et al., 1996).

To point out again, the lack of reasoning is regarded as a hindrance to revise their scientific theories. The three dominant cosmological models in early China started in slightly different times, but all remained to have their voices until the seventeenth century when missionaries came to China and transmitted the Western view of science. It is worth noting that two of the models (Hun Tian and Gai Tian) maintained a flat Earth, either like a disk or a square, and the round heavens, either spherical or hemispherical, whilst the third (Shuen Ye) did not give descriptions of the shapes. The main characteristics of the ancient Chinese models of the universe include:

1. The models did not address what we know as "universe", but instead "Heaven and Earth"- a "researchable" universe -. Precisely, "Heaven and Earth" denotes a space to be observed from the Earth and to be home of all visible heavenly entities. It was believed that beyond this space there is unknown infinite cosmos.
2. The Earth was flat.

3. The heavens were round; the heavenly bodies were moving freely.

These features are remarkably distinguished from those of the Greek cosmological models in which the universe was finite, Earth was round (spherical) in its center, and the heavens were layers of solid spheres; the heavenly bodies were attached to the layers respectively.

The Greek "sphere making"

One of the key elements of the history of Western astronomy, as Albanese et al. (1997) summarized, is the construction of an Earth model and its place in the universe; as a whole, the Earth had been a central object for the early scientists.

The general picture of the universe for most Greek astronomers and philosophers from the fourth century on was the Earth being a tiny sphere suspended without movement at the center of a much bigger rotating sphere which carried the stars. The Sun moved in the ample space between these two spheres. There was absolutely nothing outside of the outer sphere. This was the ancient version of the cosmological model which developed through time into the medieval and modern world. This two-sphere framework worked very well in the Greek astronomy, for it sufficiently explained the observations of the heavens (Kuhn, 1985). Eudoxo of Cnido (408-355 B.C.), for example, proposed a cosmological model with concentric spheres centered at a fixed and static Earth, using 27 spheres to account for all the motions of heavenly bodies known to the time. This was later improved by Aristotle (4th Century B.C.) in order to explain the brightness of the planets; the spheres became 55 in number. Aristotle's "onion" universe was again revised by Ptolemy (87-150 A.D.), who added in more artifacts known as epicycles, and was turned into the "wheels-within-wheels" universe (Koestler, 1959).

From the Ptolemaic to Copernican universe

The Ptolemaic universe had been the basis of astronomical thought in Europe for many centuries, in line with the Greek sphere-making tradition in constructing cosmological models. In this system, every planet is treated as an exclusive fact, being independent of all others, and having its own motion and its own parameters. The theory was made flexible: it could be "stretched, compressed, cut, almost everything" (Bechler, 1991, p. 83).

Copernicus (1473-1543 A.D.) is probably the first in the Western history of science to give statements that distinguish the form of a theory (logical structure) from the content (Bechler, 1991). Indeed there had been criticisms on Ptolemaic astronomy before Copernicus, but they concentrated on its opposition to Aristotle's principle of uniform planetary motion. Their concern had been only upon the contents. It is Copernicus who started to look at the structure and to argue for a systematic, harmonic and logically coherent astronomy. He made his point that traditional astronomy is "fundamentally hypothetical"- nothing is certain, all in pieces, and thus one can freely add, delete and correct any parts to match new empirical data. He thus proposed a revolutionary model of the universe in which the central position of the Earth was replaced by the Sun and contended thoroughly how this model achieved a systematic, harmonic and logically coherent structure in explaining the heavenly phenomena.

As Kuhn (1996) argued, the Copernican model is in fact not more informative than Ptolemaic astronomy, yet it is for the first time in history not only informative but also harmonic. It is the essence of the Copernican Revolution that there is a drive for harmony in addition to mere information. In order to compare these two structures, Nowak and Thagard (1992) took out their propositions and further identified the "explanatory relations" between these propositions. They constructed an elaborate model of the explanatory structures of both Ptolemy and Copernicus, and showed that from Copernicus's perspective, his astronomical system gave a more coherent account of the observable features of the heavens. Furthermore, they arrived at following conclusions:

1. The Copernican system had greater simplicity as it needed fewer hypotheses than the Ptolemaic. In the representation of Copernicus, far fewer propositions were used to describe the motions of the planets;
2. Most of the evidence is common for both systems, and therefore the main issue is simply which provides a better explanation;
3. It took a hundred years for Copernicus's theory to be generally accepted, even though it explains more with fewer hypotheses, because the Ptolemaic system of astronomy was consistent with the authoritative principles of Aristotelian physics.

Apart from revising the system in terms of harmony, the shift from a geocentric model to a heliocentric model can be viewed as a change of "reference system" for the understanding of the universe. We naturally use a geocentric reference when we watch the sky from the Earth; we see apparently the heavenly objects move around the Earth. Only when we are not constrained by the Earth's surface can we come to realize that the daily observation of the Sun going up one side of the horizon and going down the other side is not the evidence of the Sun moving around Earth. That is, the Sun moving up on the horizon would have the same effect as the horizon moving down to the Sun as observed on the Earth. This is a crucial point in scientific progress: The awareness of reference systems affects physical time and space magnitudes. The Copernican universe put forward a new reference system in which relative motions between the Sun and Earth were first brought into light. The model is revolutionary because it is not based upon direct sensorial observation, but rather a complex relation between what we see and cannot.

In the following, we turn to students' views before the instructional meanings of these historical accounts can be further analyzed. The discussion of students' ideas and models is taken along with a consideration of their linkage to the historical aspect of science.

Students' models of the universe

In attempt to discover students' alternative conceptions of the universe, Liu (2005) conducted an investigation with third to sixth graders (8-13 years old) in Taiwan (n=32) and in Germany (n=32) by means of interviewing in a story form. These students were randomly selected from a primary school (for Grade 1-6) in Taiwan and a Grundschule (for Grade 1-4) and a Gesamtschule (similar to comprehensive school; for Grade 5-12 or 5-13) in Germany; all of the schools are typical in terms of school size and student population and located in middle-sized cities. The age range was chosen for the fact that formal instruction on this subject is not given yet, and students may likely harbor a different view from the scientific one. They probably received previously related information from various sources, such as media and adults, these information may however be "internalized" based on their personal knowledge and thus given a different meaning. Consequently, these students may present a view that is not yet re-shaped by formal instruction and should be taken into consideration upon instructional design.

The interview was conducted individually and took for each 30-40 minutes. The participant was asked at the beginning of the interview to play the role of an Earth child and to have a conversation with an alien child (played by the interviewer) who by chance falls onto the Earth. A number of questions were presented in the interview, concerning the Earth (its shape, motion, relative positions to the obvious celestial bodies, etc.) and the heavens (its meaning, characteristics of the heavenly bodies and reasons for day/night cycle and the Moon phases). They were intended to reveal not only verbal responses but also students' drawing, clay model making and demonstration using clay. The data were analyzed using a similar technique documented in several studies on students' mental models (Nussbaum, 1985; Vosniadou & Brewer, 1992, 1994). The main results of the study are summarized as follows (for a detailed discussion of theoretical and methodological issues, see Liu, 2005):

1. In accord with the previous studies in conceptual change research (to name a few examples: Carey, 1987, 1988; Vosniadou, 1991, 1994; Coll & Treagust, 2003), the elicited knowledge of Liu's students exhibits a structural form. Their ideas about the Earth and the sky seem to be rooted in a model of the universe, which is to various extents different from the accepted scientific one. A limited number of such models are identified. For example, Yu-Ting, a sixth grade girl in Taiwan, holding a model (see Figure 2) in which the Sun and Moon move in two parallel vertical orbits aside the Earth with their common focal point on the line of the Earth's rotation axis. In her model, the Earth rotates with an imaginary horizontal axis. There are clouds situated above it. Many cosmic bodies scatter in space. The Sun and Moon are those close to the Earth in the heavens, yet none of them is a cosmic body – they are something different from other things in the sky-, according to Yu-Ting. Although she knows that people can live at the bottom of the Earth, without falling down to the space, thanks to gravity, she believes that gravity is a force produced by the atmosphere and a property unique to the Earth. Her view indeed shows an emphasis on what one sees and where one locates. This is not novel among students, nor in history of science.

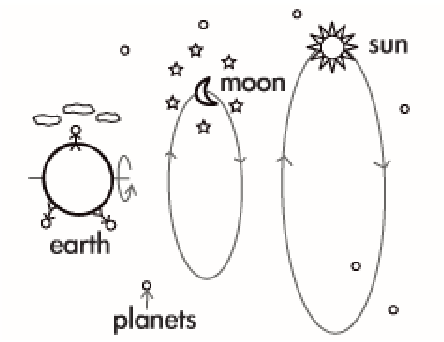


Figure 2. A model presented by Yu-Ting (Taiwanese 6th-grader).

2. Virtually all students know that the universe is infinite. However, further interrogations disclose a tendency that the students confine the basic astronomical objects – the Sun, Moon, Earth, planets and sometimes stars - to an observable (or imaginary) space and thus there is often a center of either the Sun or Earth. The described relative distances among the Earth, Sun, Moon, stars, and the "remote" stars indicate a separation of an observable space, where most, if not all, objects are situated, and the remote outside vastness, which seems to be beyond discussion. This approach to viewing the sky seems practical and plausible in that it is derived from a sensory experience of sky watching. The early Chinese scientists had inquired into the sky in a similar manner.
3. There are a limited number of models presented by the students; they can be grouped into Earth-centered and Sun-centered views. This finding is not surprising as children's egocentric view is well recognized among educational and psychological researchers. The most popular model of Earth-centered group is illustrated in Figure 3, in which the Sun and Moon, and sometimes even stars, revolve the Earth. In contrast, students with a Sun-centered view most frequently entertain a model in which the static Sun is located in the center (Figure 4). These two views can immediately draw our attention to history of science; to consider either the Earth or Sun in the center of the universe, as well documented, has been a crucial point in scientific thinking in the Western world.

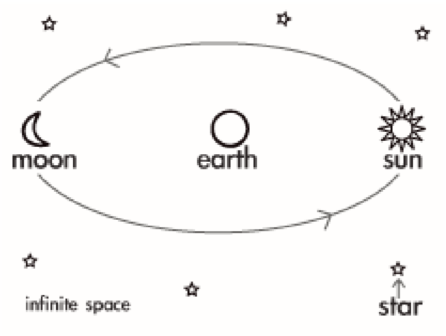


Figure 3. Earth-rotating heavens.

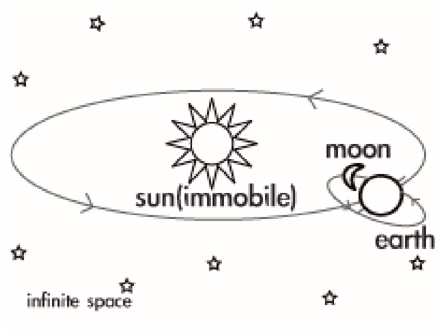


Figure 4. A model with static Sun in its center.

4. Similar to results of previous studies (Nussbaum, 1979, 1985; Vosniadou, 1991, 1994), some students, in particular those with Earth-centered view, have difficulty in relating the flat Earth as viewed on the surface of the Earth to the spherical Earth as explained by other people. The difficulty gives rise to statements like "clouds are located (only) above the Earth", and "people cannot live at the bottom of the Earth". As well acknowledged, the idea of a flat Earth had been common among people in the ancient world.
5. Comparing the data from the two countries, it is found that the Taiwanese students appear to have less intention, and sometimes even do not see the need, of reasoning celestial phenomena. When asked to explain the causes of day/night cycle and phases of the Moon, they often appear as if these questions were unusual or simply never came to their mind, while their German counterparts seemed to be prepared to answer these questions, correctly or not. Especially worth-noting is the comment from several Taiwanese children that there is no reason for the phenomenon in question: These events act as the way they are. While these Taiwanese children constructed relatively primitive models compared to the others,

it can be argued that the position of "reasoning" plays a role in refining their models. This connection can be also traced in history of science.

Instructional use of historical material

Through the previous discussion of historical and students' knowledge regarding the Earth and the sky, some common underlying principles between them can be brought to light:

1. Their structural form: Not only early scientists but also today's students construct a model of the universe through which they describe and explain astronomical objects and events. These models may exhibit various degrees of precision and coherence, yet in general maintain a self-sufficient structure before new questions or evidence come forth.
2. Essentially based on perception: To let either the Earth or Sun place in the middle of their models, and be the dominant power over the movements of other celestial bodies is a perspective relying on sensorial evidence. So is the idea of the Earth being flat as well as the view to confine all the visible objects in the sky to an imaginary space. These are found evident in both students and history.
3. Cognitive progress as a function of reasoning: The move from merely describing to reasoning natural phenomena seems to be an essential step for model modification. Students who do not intend to explain causal connections within the model seem to consequently hold a relatively primitive model. Similarly, Chinese models underwent hardly any progress as their scientists did not seek to go beyond facts and look for reasons.

These common features may act as an indicator for us to transform historical material into a form for instructional use. Their presence calls for an examination of the ways in which pre-scientific models are generated and revised, so that we can further reflect on teaching strategies that can help our students to recognize and rethink about their models. It should be noted that in studying cross-culturally the significant points of conceptual development in science, some essence of science itself comes to the surface as well as underlying principles of the particular concept and model. Some instructional suggestions of using historical material are thus evolved based on the present analysis of students' and historical ideas regarding the universe:

Historical models for students' understanding of the perspective beyond the surface of the Earth

Liu's investigation shows that students' elicited models of the universe fall into two groups: Earth-centered and Sun-centered views, similar to the geocentric and heliocentric models which characterized the astronomical development in Europe. As the essential difference between the geocentric and heliocentric views is the perspective taken on the surface of the Earth and beyond, it should be therefore a high point for instruction to use the historical models. To be more precise, the geocentric and heliocentric perspectives of historical models can be introduced to students in relation to the understanding of the perspective on the surface of Earth and beyond; the former is constrained by the experience and observation based on the surface of the Earth, whereas the latter was regarded as the first step that man goes beyond the surface of the Earth to view the universe. Students do have similar difficulty to take a different perspective beyond where they are located. When they are able to move from the perspective on the Earth to that beyond, they are on the way towards understanding the intended scientific knowledge, and, moreover, the process this understanding is achieved.

In addition, students' difficulty in relating the flat Earth as viewed on the surface of Earth to the spherical Earth as explained by other people is similarly derived from the perspective students take from where they locate. To understand the spherical shape of Earth, the student must first realize there is a difference between what is seen on the Earth (while the observer is a tiny point as opposed to the whole Earth), and outside the Earth (while the Earth can be fully captured in the view). The historical models of the Earth can be therefore placed in the students' learning process for understanding this distinction. For example, the historical intuitive ideas about the shape of the Earth, such as Homer's shield-like Earth, Anaximander's cylindrical Earth, and the disk- or plate-like Earth held by early Chinese scientists for centuries, are those that can be understood as the perspective taken on the Earth's surface. In contrast, a spherical model of Earth was established in the Greek antiquity as early as in the sixth century B.C. along with several primary and convincing arguments, such as "the ships approaching the shore appear first with its mast" and "the shadow of the Earth cast on the Moon during an eclipse is always round" so that the Earth must be round. To illustrate these arguments may assist students in taking a different perspective beyond what one merely sees.

Intercultural historical material for students' understanding of "the structural view of nature"

A structural view of nature is essential to science. It denotes the premise that nature can be described and explained through logically coherent theories. Without a structural view of nature, natural phenomena cannot be regulated into a whole and all bits in scientific theories cannot be summed up into certain rules or fundamental hypotheses, from which one can make logically consistent deductions by means of formal logic. This view highlights a search for reasons and evidence rather than a mere description of reality. It is claimed to be the driving force, by which European astronomy was moving towards a more coherent view, and in contrast, in absence of this view the early Chinese astronomers failed to progress their models.

The historical material from these two cultural contexts can be therefore operated to assist students in forming a structural view of nature. As discussed previously in the paper, it seems that the scientists in early China have never established the structural view of nature, which led to their theories being less logically structured than those in Greek antiquity. The ancient Chinese astronomers, unlike their Greek counterpart, did not give emphasis to efforts on regulating celestial phenomena, despite a different perspective they provide, and consequently on testing the derived regularities. As a consequence, their models of Heaven and Earth were prevailing without significant improvement for about two millenniums until the Western scientific concepts became known in the seventeenth century. This aspect indicates how significant it is to establish a structural view of nature and an understanding of the function of experiment in scientific theory that should have much implication to students' conceptual development.

The Copernican Revolution can serve as another example to teach about this, as Copernicus was the first in written history to single out the form of a theory, and to argue for a systematic, harmonic, and logically coherent astronomy. He criticized Ptolemaic astronomy as being "fundamentally hypothetical," within which everything is isolated and independent and thus can be freely changed whenever a need emerges. This historical chapter can not only tell students something about the nature of science but also help them to reflect upon their own views in terms of structure.

Historical material and hands-on experience

Historical concepts and models are intertwined with observations and experiments that early scientists carried out to seek for evidence. It is fundamentally through sky-gazing that the early astronomical models were constructed, as technological instruments were actually modern products, discovered as late as in the seventeenth century. It should thus be reasonable to expect that students may revise their concepts and models if watching the sky carefully. The child who, for example, described the Sun and Moon as orbiting the Earth and staying on two sides of it would soon realize that they sometimes appear together in the sky by means of regular observations. It is also relatively easy to remove some particularly naïve concepts such as the Moon phases resulted from clouds' obstruction, as indicated in several studies including Liu's, if a sky observation is carried out cautiously. Moreover, through the observation of the Sun, Moon and stars, from different angles, e.g., from the sea (horizon), students may develop a sense of spatial relations of heavenly bodies and the Earth.

Some more attention should be give to the role of early experiments in developing ideas and models. Students should learn about and can even re-do these experiments that brought about plausible pre-scientific arguments. One good example is the famous experiment done by Erathostenes (276-194 B.C.) of Alexandria; by measuring lengths of the stick shadow at the same time in different places with known distance, the concept of the spherical Earth was proven and its circumference was precisely calculated. It could be introduced and even replicated in the science classroom to lead the student to the understanding of the spherical shape of the Earth.

Educational research has pronounced the importance of hands-on experience in science learning processes. It is important to plan teaching and learning projects starting with direct observation and the contact with natural objects and events, and enhancing students' inquiry into nature by genuine personal experiences. As Vosniadou & Ioannides (1998) argued, "In order to persuade students to invest the substantial effort required to become science literate and to re-examine their initial explanations of physical phenomena, we need to provide them with additional meaningful experiences (in the form of systematic observations or the results of hands-on experiments), that prove to them that the explanations they have constructed are in need of revision" (p. 1224). It is therefore of significance to disclose the role and the value of the early activities involved in the development of scientific ideas and models in view of their connecting point to students' science learning.

Conclusion

Although science educators in general advocate the use of historical materials to enhance science teaching, the "what" and "how" questions are often considered to be problematic. Therefore this paper may make its contribution to the issue of introducing the historical aspect of science into science teaching and learning through suggesting a specific approach which brings together the students and historical views. The central point of this approach is to locate underlying principles of these views and to scrutinize the meanings of these principles to science teaching and learning. In this way, as the present work illustrated, particular examples - the heliocentric and geocentric view, the early flat Earth models, the structural view of nature, the early observations to sky and experiments on the Earth shape - from history of science and their linkage to students' conceptions can be identified and elaborated for use in the science classroom.

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