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Integrating historical cases in middle school science curriculum: Copernican revolution and the solar system

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ABSTRACT

Research shows that middle school science teachers in the United States rarely integrate history of science or historical cases in their lessons (Hottecke & Allchin, 2020). History of science plays a great role in building robust foundational knowledge in science disciplines, especially in the hearts of middle school students. This article describes a step-by-step teaching technique on how to integrate historical cases in middle school science lessons. In this paper, the author used a historical case of Copernican revolution and the solar system as an illustration to demonstrate how middle school science teachers could effectively explain scientific concepts to their students through historical perspectives.

Keywords: history of science, historical cases, middle school science, Copernican revolution, solar system, Copernicus, geocentric universe, heliocentric universe, Galileo's telescope

INTRODUCTION

Science teachers at middle school level in the United States employ various teaching methods to create impactful knowledge and solid foundational student learning experiences in science classrooms. The teachers could employ teaching methods such as inquiry-based approach, project-based learning, constructivist approach, teacher-centered approach, student-centered approach, flipped classroom, cooperative learning, among others (Longo, 2016). A large body of research has been published on how middle school science teachers could adopt these teaching methods, but only few research has been published on how middle school science teachers could adopt historical cases teaching method in their classrooms (Hottecke & Allchin, 2020). Science teachers at middle school should not only be competent in creating science curriculum adopting those mentioned popular teaching methods, but also should be capable of designing science "curriculum and organize lessons informed by historical, philosophical, sociological, and cognitive perspectives" (Hottecke & Allchin, 2020, p. 660).

History of science plays a great role in building robust foundational knowledge in science disciplines, especially in the hearts of middle school students. In addition, knowledge of history of science exposes students to the attributes of the nature of science (NOS), which help them to understand how science and its enterprises are carried out (Burbules & Linn, 1991). According to National Research Council (1996), "historical examples are used to help students understand scientific inquiry, the nature of scientific knowledge, and the interactions between science and society" (p. 170). Students gain in-depth knowledge on historical accounts of how science has been progressed through many centuries. This knowledge makes students appreciate the work and discoveries of the past and present scientists.

Purpose of the Study

This paper focuses on the importance of using historical perspectives as a teaching method in middle school science classrooms. Middle school science teachers would learn how to integrate historical cases in middle school science curriculum. The paper explores an 8th grade science topic (The solar system) as an illustration of how to present a science lesson using historical perspectives in a middle school science class. For example, in this paper, Copernican revolution is presented as historical cases to describe past and existing theories that explain the solar system and characteristics of the nature of science found in the historical cases. According to Kuhn (1985), Copernican revolution, which stemmed from the Copernicus' heliocentric theory of the universe has proved to be an important historic event in the history of science and the beginning of scientific revolutions.

The Copernicus' heliocentric theory refuted and replaced the earlier Aristotle's and Ptolemy's geocentric theory of the universe. Kuhn (1985) argued that "many of modern astronomy's principal achievements depend upon this transposition [that occurred from geocentric to heliocentric

Figure 1. Solar system (https://in.pinterest.com/pin/735775657875389379/?mt=login)

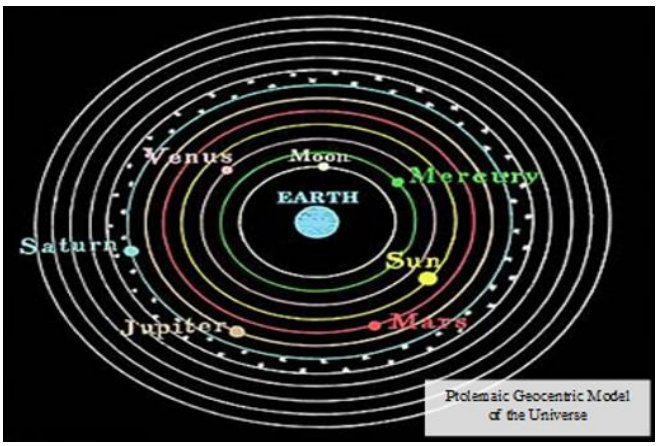

Figure 2. Ptolemaic geocentric model of the universe (https://fineartamerica.com/featured/ptolemaic-cosmology-sheila-terryscience-photo-library.html?product=poster)

theory]" (p. 1). Based on the crucial role Copernican revolution played and still playing in the advancement of science, middle school students need to be taught about the histories behind the evolution of the two important theories of the universe and their relevance to our present world astronomic and scientific events.

HOW SOLAR SYSTEM LESSON CAN BE TAUGHT THROUGH HISTORICAL PERSPECTIVES

Solar system is one of the notable science lessons in middle schools in the United States; normally, it is taught in 8th grade science class. I was a former middle school teacher and taught middle schoolers for more than ten years, I have vast experience about middle school curriculum and effective teaching methods. Middle school science teachers can integrate historical cases teaching method in their science classrooms by adopting the following teaching techniques.

Introduction

1. Teachers should introduce the lesson "The solar system" by displaying an image of solar system on the chalkboard in front of the class (**Figure 1**).
2. Teacher should ask the students to study the image carefully for about two or three minutes. Then call on two or three students, one at a time, to describe what the image stands for and where it can be found in our universe.
3. Teacher should inform the students that the word "solar" is a Latin word for "sun." At the center of the solar system is the sun surrounded by eight planets (mercury, venus, earth, mars, jupiter, saturn, uranus, and neptune), which revolve around it. Moreover, the earth rotates daily on its own axis (once in 24 hours), and it revolves around the sun once in a year (365 days) (Kuhn, 1985; Pinterest, n.d.; Rosenberg, 2005).
4. Teacher should tell the students brief history of how ancient philosophers and astronomers were interested in cosmic bodies and posited theories about the positions and motions of the celestial bodies. At this stage, teacher should briefly inform students about a 16th century astronomer called Copernicus and his sun-centered theory of the universe (Kuhn, 1985).
5. Teacher should point out some concepts of NOS from the historical case:
   a. Copernicus watched planetary motions through naked eye (scientists observe objects or events using their human senses (eyesight, smell, touch, taste, and hearing) (Yager & Akcay, 2010).
   b. Copernicus supported his argument of the sun-centered theory of the universe based on the findings from his astronomical observations through watching cosmic bodies and mathematical calculations (scientific theories must be provable by evidence) (Yager & Akcay, 2010).
6. Teacher should divide the students into groups and ask them to spend four or five minutes discussing possible answers to the following questions:
   a. How many planets orbit the sun? Name them.
   b. How did Copernicus observe the sun and the other planets?
   c. How long does the earth take to revolve around the sun?

Geocentric Theory of the Universe

1. Teacher should introduce the next section of the lesson "Geocentric theory of the universe" by displaying an image of Ptolemaic geocentric model of the universe (**Figure 2**) on the chalkboard in front of the class.
2. Teacher should ask the students to study the image carefully for about two or three minutes. Then call on two or three students, one at a time, to describe how this image is different from that of the Copernicus' model of the universe, which is called the solar system.
3. Teacher should inform the students that the word "geo" is a Greek word for earth, and "centric" means center, so geocentric means earth at the center (Kuhn, 1985; Terry, n.d.).
4. Teacher should tell the students brief histories about the origins of the geocentric theory of the universe, and

the ancient astronomers (from Eudoxus to Aristotle to Ptolemy) who played important roles in theorizing the idea of immovable earth at the center of the universe where all other planets revolve around it. Aristotle built upon Eudoxus' geocentric theory, and Ptolemy built upon Aristotle's geocentric theory (Kuhn, 1985; Rosenberg, 2005). Ptolemy was a 2nd century Greek astronomer and mathematician, through his astronomical observations and mathematical calculations he created a cosmological model that explained how the sun, moon, stars, and planets orbit around the unmoving earth. Ptolemaic geocentric theory of universe was widely accepted among astronomers and scientists and prevailed for about 1,400 years (Kuhn, 1985).

5. Teacher should point out some concepts of NOS from the historical case:
   a. Ancient astronomers determined to investigate the planetary motions and positions in the outer space or the sky (i.e., scientists always strive to study and explain how our natural world works) (Burbles & Linn, 1991; Rosenberg, 2005).
   b. The geocentric theory of the universe experienced modifications among astronomers, as it started from Eudoxus to Aristotle, then to Ptolemy (this means, while scientific theories are durable because they can last for hundreds of years, they are also tentative because they can be modified when new convincing evidence surface) (Burbles & Linn, 1991; Rosenberg, 2005).
6. Teacher should ask students to spend four or five minutes in their groups discussing possible answers to the following questions:
   a. How do you explain geocentric theory of the universe?
   b. Describe the roles the earth plays in the geocentric theory of the universe.
   c. What were the skills Ptolemy used in creating his model of geocentric universe?

Heliocentric Theory of the Universe (Copernican Revolution)

1. Teacher should introduce the next section of the lesson "Heliocentric theory of the universe (Copernican revolution)" by displaying an image of Copernicus with his heliocentric model of the universe (**Figure 3**) on the chalkboard in front of the class.
2. Teacher should ask the students to study the image carefully for about two or three minutes. Then call on two or three students, one at a time, to describe what they noticed from the picture.
3. Teachers should inform the students that the word "helio" is a Greek word for sun, and centric means center, so, heliocentric means sun at the center. Copernicus' heliocentric theory describes how the sun lies at the center of the universe and the eight planets, including our earth, revolve around it (Famous Scientists, n.d.; Kuhn, 1985). This model is contrary to Aristotle's and Ptolemy's geocentric model where unmoving earth lies at the center of the universe and other cosmic bodies in the universe revolve around it.

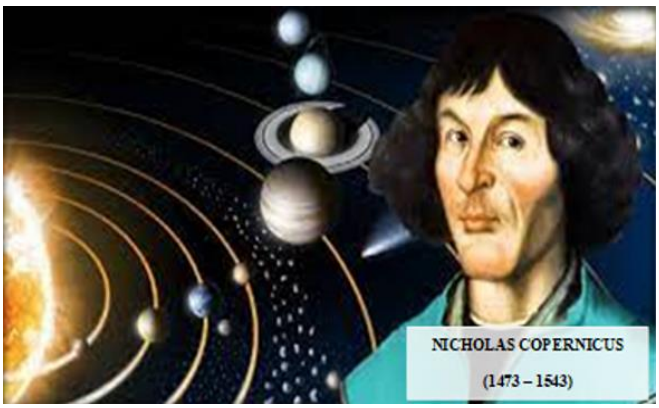

Figure 3. Nicholas Copernicus & his heliocentric model of the universe (https://www.famousscientists.org/nicolaus-copernicus/)

4. Teacher should tell the students a brief history about Copernicus and how his heliocentric theory revolutionized our knowledge about cosmic bodies and the universe. Copernicus was a 16th century Polish astronomer and mathematician who wrote extensively how the eight planets in the solar system revolve around the sun based on his astronomical observations and mathematical calculations. Copernicus insisted in his writings that the earth moves, contrary to the Aristotle's and Ptolemy's egocentric theory, and it revolves around the sun like other planets in the solar system. This is known as Copernican revolution, and the beginning of a wider scientific revolution (Famous Scientists, n.d.; Kuhn, 1985). Copernicus' theory faced stiff resistance from antagonists and the Roman Catholic Church authorities who supported egocentric theory. Later, Copernicus' theory gained ground, and today, it is widely accepted among modern-day astronomers because the theory presents more convincing evidence (logical and mathematical) about our solar system. Copernicus wrote all his findings about the heliocentric theory of the universe in a book, which was finally published in 1543, the same year he passed away (Famous Scientists, n.d.; Kuhn, 1985).
5. Teacher should point out some concepts of NOS from the historical case:
   a. Copernicus rejected Ptolemaic geocentric theory of the universe and suggested a new theory (heliocentric theory) with more convincing evidence in replacement (this is an example that demonstrates the fact that scientific theories are tentative, although durable, they can be rejected in the face of new theories, which have more convincing evidence) (Kuhn, 1985).
   b. Copernicus' heliocentric theory of the universe with comprehensive explanations were published in a book (scientists publish their findings in journals, books, and through conference presentations to

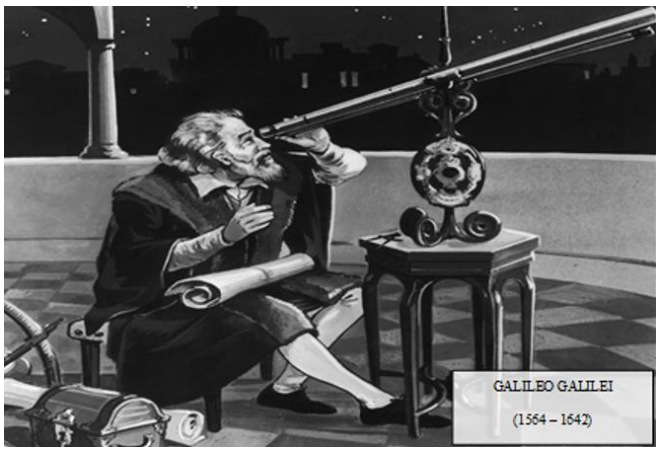

Figure 4. Galileo watching celestial bodies through his telescope (https://www.biography.com/news/galileo-discoveries-theories-modern-physics-astronomy)

reach a larger audience) (Hottecke & Allchin, 2020; Kuhn, 1985).

6. Teacher should ask students to spend four or five minutes in their groups discussing possible answers to the following questions:
   a. How do you explain Copernican revolution?
   b. What is the position of the sun in the Copernicus' heliocentric theory of the universe, and how do other planetary bodies relate to it?
   c. Give one reason why the Ptolemaic geocentric theory of the universe was rejected by contemporary astronomers but widely accepted Copernicus' heliocentric theory instead?

Galileo's Telescope and Copernicus' Heliocentric Theory

1. Teacher should introduce the next and last section of the lesson "Galileo's telescope and Copernicus' heliocentric theory" by displaying an image of Galileo watching celestial bodies through his telescope (**Figure 4**) on the chalkboard in front of the class.
2. Teacher should ask the students to study the image carefully for about two or three minutes. Then call on two or three students, one at a time, to describe what they noticed from the picture.
3. Teacher should tell the students a brief history about Galileo Galilei, a 17th century Italian astronomer and physicist who made a telescope to observe cosmic bodies in magnified forms. Galileo was intrigued by the planetary motions in the sky and even more fascinated by the theories that explain the motions–geocentric and heliocentric theories of the universe. He discovered that Jupiter, the largest planet in our solar system, has its own moons (Maranzani, 2020). The astronomer saw four moons revolving around Jupiter. This discovery nullified Aristotelian and Ptolemaic geocentric theory that stated that all cosmic bodies in the universe revolve around the earth. In addition, when the astronomer pointed his telescope at Venus, he discovered bright phases of the planet, which pointed to the fact that Venus must be revolving around the sun, not the earth as Aristotle and Ptolemy believed (Kuhn, 1985; Maranzani, 2020). These discoveries corroborated with Copernicus heliocentric theory, which affirmed that the sun lies at the center of the universe and all other cosmic bodies, including the earth, revolve around it. Galileo documented his astronomical observations in a book, which was published in 1632. Roman Catholic Church authorities arrested Galileo for professing heliocentric theory and was sentenced to house arrest for life. Galileo continued working with his telescope in his house; he eventually passed away in 1642 (Kuhn, 1985; Maranzani, 2020).
4. Teacher should point out some concepts of NOS from the historical case:
   a. Galileo used an instrument, a telescope, to carry out his astronomical investigations, and this made his findings considered as empirical evidence (scientists use tools in carrying out experiments, the outcomes are empirical evidence, which can be verified by anyone) (Burbules & Linn, 1991).
   b. Galileo's research supported Copernicus' heliocentric theory of the universe, but it refuted Aristotelian and Ptolemaic geocentric theory of the universe (a scientific theory corroborates, modifies, or refutes existing theories) (Burbules & Linn, 1991; Hottecke & Allchin, 2020).
5. Teacher should ask students to spend four or five minutes in their groups discussing possible answers to the following questions:
   a. Describe how Galileo's astronomical investigation approaches were different from that of Copernicus' investigation approaches.
   b. Why did the Roman Catholic Church authorities arrest Galileo?
   c. Do you think the Copernicus' and Galileo's heliocentric theory of the universe could be refuted by future research? Why, or why not?
6. Teacher should provide students extra resources for further reading on the lesson of the solar system and Copernican revolution, for example:
   a. The solar system: https://kids.britannica.com/kids/article/solar-system/353789
   b. Geocentric theory of the universe: https://www.universetoday.com/32607/geocentric-model/
   c. Heliocentric theory of the universe–Copernican revolution: https://www.britannica.com/topic/Copernican-Revolution
   d. Galileo, his telescope, and the revolutionized discoveries: https://kids.britannica.com/kids/article/Galileo/351402

CONCLUSIONS

Integrating historical perspectives in teaching middle school science is beneficial for effective student learning. First, the teaching method creates a friendly and highly engaging learning environment. Listening to stories about past or

present scientists and their discoveries or watching short clips about these scientists and their achievements expands students' knowledge about science and give them opportunities to explore further on why and how the scientists accomplished their feats. In supporting this notion, National Research Council (1996) advises science teachers, "through the use of short stories, films, videos, and other examples, elementary teachers can introduce interesting historical examples of women and men (including minorities and people with disabilities) who have made contributions to science" (p. 141). This helps students understand the contributions, which scientists make in our society. Second, historical perspectives bring real-life experiences into teaching; these help students connect scientific concepts to real-world activities and events. According to Longo (2016), incorporating "activities that are based upon real-life experiences ... promote engagement" (p. 36). It is important that students are able to apply scientific concepts they were taught in science classrooms to their daily life activities. For example, students understand that a thermometer is an instrument for measuring temperature. In a situation where the tool is required for measuring people's body temperature during COVID-19 testing, the students would not need to struggle to understand what thermometer does. Applying scientific knowledge learned in the classroom to students' daily life activities makes science practical and authentic.

Third, integrating historical perspectives in science classes ignites students' interests in science careers. Some students would be inspired by the stories told about scientists and their work, and they may decide to become scientists in the future. National Research Council (1996) points out that "students can learn some things about scientific inquiry and significant people from history, which will provide a foundation for the development of sophisticated ideas related to the history and nature of science [NOS] that will be developed in later years" (p. 141). When students learn through histories how scientists' contributions changed the world and created better life opportunities for people, the students' inspirations of becoming future scientists increase.

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