PRACTICES INVOLVING THE USE OF DOCUMENTARY IN TEACHING THE NATURE OF SCIENCE

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1. Introduction

Science, which is an effort to understand the natural world, is a human activity and therefore open to interacting with personal, social, and cultural beliefs. Understanding scientific knowledge's nature and structure is essential for science students (McComas, 2020; Lederman & Lederman, 2019). Questions like "what is science" and "how do scientists work" are part of the science programs worldwide. The nature of science appears as a guide in understanding the exact meaning of science (McComas, Clough, & Almozroa, 1998).

2. Nature of Science

The nature of science (NOS) is a critical component of scientific literacy, which improves students' understanding of science concepts and enables them to make informed decisions about personal and societal issues involving science (NSTA, 2022). Lederman (1992) described NOS as "the values and assumptions inherent in science."

Understanding NOS and Scientific Inquiry (SI) provides a guiding framework and context for scientific knowledge. Without understanding NOS and SI, students will only learn science through results and as a body of facts-knowledge without context (Robinson, 1968).

NOS is seen as the blend of the philosophy of science, history of science, sociology of science, and psychology of science (McComas, Clough, & Almazroa, 1998). Therefore, to comprehend and teach the features of NOS, science educators should have competence in subject matter knowledge, philosophy of science, cognitive science, sociology, pedagogy, and history of science (Galili, 2019).

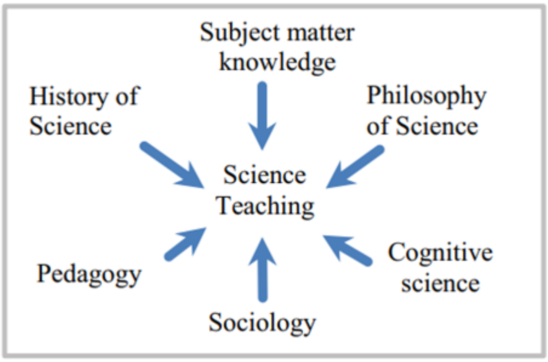

Figure 1. *Competency areas associated with NOS (Galili, 2019)*

3. Tenets of NOS

NOS covers various topics related to the history, philosophy, and sociology of science; thus, it is a complex concept. Therefore, there is no consensus among experts. Nevertheless, NOS has seven fundamental tenets (a) empirical nature of scientific knowledge, (b) scientific theories and laws, (c) the creative and imaginative nature of scientific knowledge, (d) the theory-laden nature of scientific knowledge, (e) social and cultural embeddedness of scientific knowledge, (f) the myth of scientific method and (g) the tentative nature of scientific knowledge (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002).

Experts have a consensus about the tenets of NOS that can be taught to students (Bell et al., 2000; Lederman, 1999; Lederman & Abd-El-Khalick, 1998; Smith et al., 1997). These are; scientific knowledge is variable, based on observations of the natural world, subjective, a product of imagination and creativity, affected by the social and cultural environment, and includes observation and inference (Figure 2). As these tenets do not require specialization in science, they are considered appropriate for teaching from primary to secondary education.

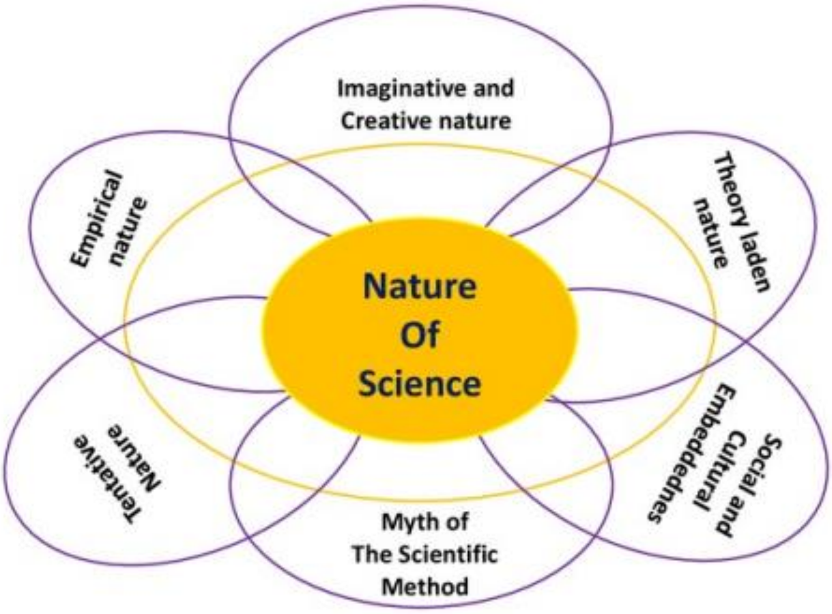

Figure 2. *Tenets of NOS (Hsien, 2016)*

Scientific knowledge is tentative: Scientific knowledge can be abandoned or changed in line with new evidence and technological advances (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The history of science reveals both evolutionary and revolutionary changes. Old ideas are replaced or completed by new evidence and interpretations (NSTA, 2022). In science, new or old theories are constantly tested and refined and occasionally thrown aside (American Association for the Advancement of Science [AAAS], 2022). Therefore, scientific knowledge is tentative and open to change.

Scientific knowledge includes logical, mathematical, and experimental inferences: Science is based on observing nature and interpreting observations. Scientists use experiments when they cannot make direct observations and test the acquired knowledge at the end of the process. However, scientists also encounter situations that cannot be directly experimented with or observed. In these cases, indirect observations or inferences are used. For example, atomic models were suggested using the knowledge resulting from a series of deductions. In history, many scientists, including Mendel, Darwin, Archimedes, Newton, Galileo, and Einstein, used observations, experiments, logic, and mathematics to reach scientific knowledge.

Scientific knowledge is subjective: Scientists have different knowledge, beliefs, cultural background, education, expectations, prejudice, and experience. Since science is a human endeavor, acquiring scientific knowledge is affected by people's thoughts, knowledge, experiences, and prejudices. No matter how much an objective point of view is desired in interpreting the data, the subjective point of view is inevitable (Chalmers 1999). Different scientists can explain the same physical phenomenon differently, and these different explanations can also lead to different results. For example, scientists have different views on the dinosaurs' extinction, the Earth's formation, and evolution. Regarding the extinction of the dinosaurs, some scientists argue that it was caused by a meteor hitting the earth, while others suggest that volcanic eruptions caused it. There are many theories about the formation of the Earth. One of them is the Big Bang Theory. Regarding evolution, some scientists pretend that the origin of life resulted from RNA molecules in a meteor coming from outer space. In contrast, some scientists claim that RNA molecules were formed by chance, originating from the primordial organic soup formed in the seas, with the effect of the UV wavelength in the sun's rays, and they were again put in a sheath by chance. Scientists suggest ideas based on experiments and observations performed to reach scientific knowledge.

Imagination and creativity play an essential role in acquiring scientific knowledge: Creativity is a personality trait present in the generation of scientific knowledge. Scientists need imagination and creativity when interpreting and deducing what they see. Creativity and imagination of scientists are essential at all stages of the research process. Many scientists use their imagination and creativity throughout the whole research process. For example, Friedrich August Kekule von Stradonitz (1829-1896), one of the founders of modern organic chemistry, found the "benzene ring" after a dream.

Observation and inference are different things: In general, all scientific knowledge is a combination of observations and inferences (Chalmers 1999). However, observation is something going behind noticing. It is the process of cognizing something through the senses. Scientists use their senses and different tools (i.e., microscopes, scanners, or transmitters) when making an observation; then, they use them to collect and record data. The interpretation of the obtained data is inference. Many scientists such as Mendel and Darwin made long-term observations to reach scientific knowledge. Students of all ages pay attention to the weather forecast. Weather forecasters make observations, and their predictions are inferences.

Scientific knowledge is affected by the social and cultural environment at the development and implementation stages: Contributions to science can and have been made by people worldwide. Science affects the society and cultures it is in; at the same time, it is also affected by them (AAAS 1993). It is known that many scientists in history were influenced by the environment and culture in which they lived. For example, the church and scientists at the time did not like Darwin's assertion that species are not immutable and Galileo's heliocentric theory of the universe. For this reason, many scientists were forced to give up their thoughts, tried, and even sentenced to death throughout history.

Scientific theories and laws are different types of knowledge: Laws are generalizations or universal relations about how certain aspects of the natural world behave under certain conditions. They describe the relationships between the observations of the natural world. The difference between theory and law is similar to the difference between observation and inference. Theories are inferred explanations of some aspects of the natural world (Abd-El-Khalick et al., 1998). Laws are descriptions of events that occur in nature, whereas theories are inferences based on observable events. For example, Mendel's inheritance laws are explained by the chromosome theory. We can give examples of scientific laws and theories (Mendel's Laws of Inheritance, Newton's Laws of Gravity, Chromosome Theory, and The Theory of Evolution). Laws and theories play different roles in science - so students should remember that theories may not become laws even with additional evidence. The tentative or volatile nature of scientific knowledge also means that laws and theories can change.

4. Misunderstandings about NOS

People develop ideas about science from their experience, previous education, popular media, and peer culture. Unfortunately, many of these ideas are common misconceptions or myths about NOS. Some of the misunderstandings about NOS in science education are: experiments are the only way to achieve scientific knowledge; science and its methods can answer all questions; scientific knowledge will not change; science is a solitary pursuit; science does not involve imagination and creativity; scientists are objective; scientific models are accurate; hypotheses turn into theories and laws (McComas, 1998; 2000).

One of the most common misconceptions is the existence of the scientific method. The scientific method is often taught to be a step-by-step protocol that all scientists follow when doing science. Students define the problem, form a hypothesis, make observations, test the hypothesis, draw conclusions, and report the results. In reality, however, there is no linear way of doing science; scientific research is fluidal, reflexive, context-dependent, and unpredictable. Scientists approach and solve problems in countless ways using their imagination, creativity, prior knowledge, and perseverance (Hsien, 2016).

5. Approaches to Teaching NOS

Sometimes we assume that students will learn about NOS simply by making scientific inquiries. Therefore, it is helpful to emphasize NOS's tenets in teaching science. There are three different approaches to NOS teaching: the indirect approach, the historical approach, and the clear-reflective approach (Abd-El-Khalick & Lederman, 2000a; Khishfe, & Abd-El-Khalick, 2002). The direct reflective approach has been widely used recently (Demirbas, 2016).

Indirect reflective approach: It is based on the idea that individuals' understanding of NOS will improve by participating in scientific activities (Abd-El-Khalick & Lederman, 2000b;

McComas, 1996). This approach aims for individuals to understand science and the tenets of NOS by working like scientists; students are expected to make inferences individually during the activity. However, this approach is ineffective in gaining the qualities of NOS (Khishfe and Abd-El-Khalick, 2002; Lederman, 1992). One of the reasons behind it is the misperception that people will automatically acquire the right concepts about NOS (Abd-El-Khalick & Lederman, 2000a).

Historical approach: It uses history to develop individuals' NOS understanding (Lederman, 1998, 2007). Scientific developments are discussed in the historical process. In this approach, the development of scientific knowledge over time is taught through case studies based on scientists' life and works (Khishfe & Abd-El-Khalick, 2002). Addressing the microscope's invention and the cell theory while teaching the cell subject is an example of this (Demirbas, 2016). Many studies show that this approach is effective for NOS teaching (Abd-El-Khalick, & Lederman, 2000b; Fouad, Masters, & Akerson, 2015; Kim, & Irving, 2010; Rudge, Cassidy, Fulford, & Howe, 2014).

Direct reflective approach: It emphasizes scholarly activity and inquiries to develop individuals' NOS understanding (Akerson, Abd-El-Khalick, & Lederman, 2000; Lederman, 2007; Schwartz, Lederman, & Crawford, 2004). This approach aims for individuals to think, discuss and question the characteristics of NOS. Research has shown that a straightforward approach is more effective than an implicit approach in developing NOS concepts among students (Abd-El-Khalick & Lederman, 2000a; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2007).

6. Using Documentaries in Science Education

Films, one of the mass media tools, appear as an effective and enriched learning tool, and movies are used for motivation in teaching specific subjects. The new generation's familiarity with visual media plays a role in the effectiveness of films. Thanks to movies, students have the opportunity to analyze many controversial issues (Stoddard, 2009).

Short-term films have genres such as fiction, documentary, experimental, animation, commercial-promotional film, and video clips (Aladag & Karaman, 2018). Documentaries is a movie genre. Advances in technology, communication, and internet networks make it easier for teachers to access various films. Akbas (2011) named short films aimed at the gains in the curriculum as "educational films". Therefore, teachers can use educational films in their lessons. However, there are factors teachers should pay attention to while using movies in their lessons. These are: Choosing the movies regarding the learning outcomes of the course, considering students' development level, and realizing the movie activity in a planned way (Oztas, 2009). A planned short film activity consists of preliminary preparation, implementation, and evaluation stages (Aladag & Karaman, 2018). In addition, students should be able to take notes while watching the movie, the classroom should not be darkened completely, and the movies should not be too long (Lumlertgul, Kijpaisalratana, Pityaratstian, & Wangsaturaka, 2009).

Before the documentary film, the teacher asks students to watch the documentary film carefully; takes students' comments on documentary short films after watching the entire film; stops the film from time to time and asks about the things that the students do not understand in long documentary films; and finally, establishes a discussion environment around the issues that should be emphasized (Seckin Kapucu & Cakmakci, 2017). As a result, teachers should prepare pre-movie, movie-time, and post-movie activities (İscan, 2016).

This study has tried to present an example of how some subjects covered in the science curriculum can be taught to students by using documentaries within the framework of the tenets of NOS. First, the documentaries that can be used to teach NOS have been reviewed here. Afterwards, the speeches in the documentary were analyzed and associated with the tenets of NOS, science course units, and achievements. The documentaries mentioned in this study can be used in lessons to teach students the tenets of NOS. The concepts and documentaries suggested for the "DNA & Genetic Code" unit in the science curriculum are shown in Table 1.

Table 1. Examples of Documentaries Involving DNA & Genetic Code Unit in the Science Curriculum

Grade	Subject Area	Units	Concepts	Documentaries	Tenets of NOS
8th Grade	Creatures and Life	DNA and Genetic Code	Heredity	Science & Life-Mendel	Scientific knowledge includes logical, mathematical, and experimental inferences. Imagination and creativity play an essential role in acquiring scientific knowledge.
			DNA and Genetic Code	Science & Life-DNA	Scientific knowledge includes logical, mathematical, and experimental inferences. Scientific knowledge is tentative. Imagination and creativity play an essential role in acquiring scientific knowledge.
			Adaptation and Evolution	Charles Darwin & Tree of Life	Scientific knowledge is tentative. Scientific knowledge is subjective. Imagination and creativity play an essential role in acquiring scientific knowledge. Observation and inference are different things.

Documentary films are associated with the tenets of NOS (Table 1). Accordingly, *Science & Life-Mendel, Science & Life-DNA, and Charles Darwin & Tree of Life* documentaries are recommended for teaching the concepts related to the *"DNA & Genetic Code"* unit in the science course (heredity, DNA and genetic code, adaptation, and evolution). Lesson plans and activity examples related to documentaries in teaching NOS are shared below.

6.1. Lesson plans and activities related to documentaries

Documentary 1: Lesson Plan for Science & Life-Mendel Documentary

Course Name: Science Course

Subject Area: Creatures and Life

Unit: DNA & Genetic Code

Grade: 8th Grade

Documentary: Science & Life-Mendel

Scientists Mentioned in the Documentary: Gregor Mendel, H. De Vries, Correns, E. Von Tschermak

The Purpose of the Documentary: Comprehending the importance of Mendel's works in heredity.

*Duration:*10 minutes

Concepts in the Documentary: Heredity, Gene, DNA, Genetic Diseases

Tenets of NOS in the Documentary:

1. Scientific knowledge includes logical, mathematical, and experimental inferences.
2. Imagination and creativity play an essential role in acquiring scientific knowledge.

Summary of the Documentary (1):

Austrian botanist and priest Johann Gregor MENDEL (1822-1884) is considered the father of genetics, today's popular science. From 1856 he began collecting various pea seeds, growing them in the monastery garden, and studying their differences. **Mendel did not use plants in food but in experiments.**

In the 18th and 19th centuries, scientists did not try to explain how the characteristics of living things are passed from generation to generation. Mendel did this without realizing it. Mendel observed that some physical characteristics of some plants resemble their parents or even their ancestors. So he engaged in a series of experiments on peas that lasted for years. Mendel chose peas because it is possible to obtain easily distinguishable non-sterile hybrids, cross-fertilization is easily prevented, and peas are cultivated in the garden and greenhouse. Mendel conducted thousands of different experiments focusing on seven different characteristics, including the height of the plant, the color of the flower, the position of the flower, the color and shape of the seed, and the color and shape of the pod. He has grown around 24,000 plants. At the end of his studies, he reached a conclusion that no scientist had reached. As it is understood from here, the experiment is vital in science. **Scientific knowledge is based on data collected from the observation of nature and experiments. The data obtained from the observations and experiments are interpreted in a way that is partially affected by the scientist's creativity and imagination.** Creativity and imagination affected Mendel's selection of the pea plant in his studies. Scientists may not be successful in many natural phenomena through direct observation. At such times, they use experiments to collect scientific information. The emergence of scientific knowledge sometimes occurs quickly, like Archimedes' accidental discovery of the lifting force in the bath. Sometimes it may require a lengthy process like the work of Gregor Mendel. This process includes evaluating the data collected from numerous observations and experiments, creating new hypotheses, and testing them.

Mendel published the results of his years of research in his article "Experiments on plant hybrids" in the journal of the natural sciences society published in Brünn. Moreover, he sent it to 40 scientists and organizations with his private effort. His efforts show that the generation of scientific knowledge is not sufficient alone and that scientific knowledge should be accepted by society as well. **Moreover, society's cultural values and expectations decide how and in what way science will be accepted.**

Mendel's studies and discoveries did not arouse any interest during his lifetime, and no one noticed their importance. Sixteen years after his death, three biologists, H. De Vries in the Netherlands, Correns in Germany, and E. Von Tschermak in Austria, demonstrated the validity of Mendelian laws in the research they conducted, unaware of each other on various plants. They combined all results under the name of Mendel's laws. **Here, it is seen that people from all cultures participate in doing science because scientific knowledge requires collaborative work.**

Measurement Tools: VNOS-E questionnaire (Question 1-2-7), Interview

Activity Name (1): Evaluation of the tenets of NOS in Science & Life-Mendel Documentary

Directions: The entire documentary should be watched to realize this activity. Before watching the documentary, the teacher should inform students about the tenets of NOS in the documentary. Then the students are told to watch the film by paying attention to these tenets. After the documentary, students are given a worksheet consisting of questions on which they can evaluate the tenets of NOS in the film. Ununderstood parts of the worksheet are explained. Finally, student responses are evaluated by the class.

An Example of Activity Worksheet (1)

1. What questions came to your mind while watching the documentary?
2. Who are the scientists mentioned in the documentary?
3. What is the role of observations in acquiring scientific knowledge?
4. What are your thoughts on the function of imagination and creativity in acquiring scientific knowledge?

5. Does cooperation play a role in the acquisition of scientific knowledge? Please tell us the parts of the documentary you watched that might be related to this subject?

Documentary 2: Lesson Plan for Science & Life-DNA Documentary

Course Name: Science Course

Subject Area: Creatures and Life

Unit: DNA & Genetic Code

Grade: 8^{th} Grade

Documentary: Science & Life-DNA

Scientists Mentioned in the Documentary: Rudolph Virchow, Louis Pasteur, Oswald Avery, Friedrich Miescher, James Watson-Francis Crick, Maurie Wilkins

The Purpose of the Documentary: Comprehending the impact of DNA discovery on human history.

Duration: 10 minutes

Concepts in the Documentary: DNA, Nucleotide, Gene, Chromosome, Genetic Engineering

Tenets of NOS in the Documentary:

1. Scientific knowledge includes logical, mathematical, and experimental inferences.
2. Scientific knowledge is tentative.
3. Imagination and creativity play an essential role in acquiring scientific knowledge.

Summary of the Documentary (2):

After years of work, Mendel reached a conclusion that no scientist did before; he discovered the transfer mechanism of physical characteristics from one lineage to another. The physical characteristics of species were transferred from parents to offspring through certain particles. About 35 years after Mendel put his theory forward, his approach that inheritance is transferred through particles was accepted worldwide. However, there were new and vital questions to be answered. For example, what are these particles? Where are they located in the body? The answer to the second question came from the German biologist Walther Flemming in 1879. Flemming observed that during cell division, the cell nucleus is divided first. **Scientific knowledge is generated by investigating and observing the causes of events occurring in nature and the interpretation of these observations by the scientist. It is based on data collected from the observation of nature and experiments.** However, it is not always possible to conduct experiments. For example, the structure of the atom has not been directly observed until now. Nevertheless, by interpreting the data obtained in the laboratory environment and observed activities, reliable information about the structure of the atom has been reached, and atomic models have been developed in light of this information. **As it is understood from here, experimenting is essential in science. Science contains experimental implications, but it is not always possible to perform experiments. On the other hand, predictions and assumptions are also crucial in science. Scientists often deal**

with events that cannot be directly traced; therefore, they try to support their claims with evidence obtained indirectly. For this reason, estimation and theoretical assumptions are crucial in science. The best examples are gravity, the structure of the atom, and the theory of evolution.

The first thing dividing in the cell nucleus was a set of threadlike particles. Flemming named these filamentous fragments "chromatin," which means "color" in Greek. Over time, they were called chromosomes. **Imagination and creativity are essential in the generation of scientific knowledge. Besides the observation of nature, the creativity and imagination of the scientist are also a part of the generation and development of scientific knowledge. Since science is a human activity, the explanations, inventions, and theoretical subjects included in science are generated as a result of scientists' creativity and imagination.**

Oswald Avery et al. found that DNA carries the knowledge of life rather than the protein, as it seems. James Watson, Francis Crick, and Maurice Wilkins started working on DNA with this method at Kings College, London. In 1953, this trio realized the second breakthrough in biology. Watson, Crick, and Wilkins found that DNA has a double helix structure, resembling a spiral staircase. They won the Nobel Prize in 1962 for this important discovery. DNA analysis is one of the most important scientific events of the 20th century with all its biological consequences. **Scientist is curious; they think and evaluate the work of other scientists. For this reason, people from all cultures participate in science because scientific knowledge requires collaborative work.**

Measurement Tools: VNOS-E questionnaire (Question 1-2-3-7), Interview

Activity Name (2): Evaluation Activity of the Tenets of NOS in Science & Life-DNA Documentary

Directions: The entire documentary should be watched to realize this activity. Before watching the documentary, the teacher should inform students about the tenets of NOS in the documentary. Then the students are told to watch the film by paying attention to these tenets. After the documentary, students are given a worksheet consisting of questions on which they can evaluate the tenets of NOS in the film. Ununderstood parts of the worksheet are explained. Finally, student responses are evaluated by the class.

An Example of Activity Worksheet (2)

1. What questions came to your mind while watching the documentary?
2. Who are the scientists mentioned in the documentary?
3. Are experiments and observations always done to acquire scientific knowledge? What do you think about this topic?
4. How do you think scientists explain an event they can observe but are unaware of the details? How would you explain it if it were you?
5. What are your thoughts on the function of imagination and creativity in acquiring scientific knowledge? Give examples by thinking about the documentary you watched

6. Regarding acquiring scientific knowledge, what parts set an example for cooperation?

Documentary 3: Lesson Plan for Charles Darwin & Tree of Life Documentary

Course Name: Science Course

Subject Area: Creatures and Life

Unit: DNA & Genetic Code

Grade: 8th Grade

Documentary: Charles Darwin & Tree of Life

*Scientists Mentioned in the Documentary***:** Charles Darwin, Richard Owen, Marie Curie

The Purpose of the Documentary: Learning about the diversity of plants and animals living on earth through Darwin's research and recognizing that there are different views on evolution.

Duration: 14 minutes

Concepts in the Documentary: Adaptation, Biodiversity, Evolution

Tenets of NOS in the Documentary:

1. Scientific knowledge is tentative.
2. Scientific knowledge is subjective.
3. Imagination and creativity play an essential role in acquiring scientific knowledge.
4. Observation and inference are different things.

Summary of the Documentary (3):

Our Earth is the only planet known to host life. Furthermore, it is very rich in life. A man, who explained this astonishing diversity of life, was born 200 years ago. Thus, it has completely changed our view of the earth and our place on it. This man was Charles Darwin. Darwin was a fanatical insect collector in his childhood. He once discovered 69 different insect species in a small area in just one day. **Science is based on observations in the natural world and their interpretation. Mendel observed the plants he grew in the monastery's garden for eight years; Darwin had the opportunity to observe many species, from birds to seashells, during a five-year journey. Based on this information, we can say that scientists make observations for many years to reach scientific knowledge and base their data on solid foundations.**

Darwin, who studied botany and geology at Cambridge University, collected plant and animal samples. He made it a habit to write what he found in his diary. He sent most of the mammalian bones and fossils to Richard Owen, one of the most outstanding zoologists of the time. Owen was the first person to identify dinosaurs and the one who gave them that name. He later founded the Natural History Museum in London. Many of the samples collected by Darwin are still preserved and exhibited in this museum, established by Owen, along with 17 million other samples. **Scientific knowledge is affected by the social and cultural environment at the development stage. Science is inevitably open to the influence of that culture and society's**

value judgments, as well as political, economic, and similar formations. At the same time, scientific knowledge is subjective. In other words, scientists' origins, previous experiences, knowledge, and prejudices affect their observations and conclusions.

Darwin also pondered what he had seen on the Galapagos island and other parts of the world. Perhaps the species were not fixed. Every day he walked to this little grove in the corner of his garden. It was where he came to ponder nature's history, including the question of how species mutated into another, which was the biggest mystery. He realized that most animals produced far more offspring than needed to replace those who died. For example, this female blue tit can produce a dozen eggs yearly and 50 in her lifetime. The survival and reproduction of two offspring are enough to sustain the blue tit population. These surviving babies are, of course, the healthiest ones, best adapted to their environment. These characteristics are passed on to the next generation. Thus, the species may change after many generations if environmental changes occur. Only the strongest survive. That was the trick. Darwin called this process "natural selection." It also explained the differences between the finches he had brought from the Galapagos. They were very similar to each other except for their beaks. Some of these birds had a thin and delicate beak that allowed them to catch insects, while others had a strong beak suitable for cracking nuts. So these changes may lead to radical changes over perfectly lengthy geologic time if species conquer new environments.

Darwin sketched out his idea in one of his notebooks. He showed how a single ancestor could give rise to many species. He wrote "I suppose" on it. Now, he had to prove his theory. Furthermore, he spent years collecting convincing and sufficient evidence. He was an outstanding letter writer. He wrote a dozen or so letters every day and sent them to naturalists and scientists worldwide. **New knowledge should be reported clearly and precisely because the generation of scientific knowledge alone is not enough. Its socialization is just as crucial as its generation. For new knowledge to be accepted by society, it should be reported and shared with others.** Owen did not deny that all these different species had arisen. But, he believed that each was separate and created by God. Darwin's theory needed connections. Not only among similar species but also in large groups of animals. If fish, reptiles, birds, and mammals have evolved from one another, there must have been intermediate life forms between these large groups. However, they were lost.

Then, two years after The Origin of Species was published, Richard Owen bought the most remarkable fossil for his museum. The fossil was found in a lime quarry in Bavaria, where stones are divided into flat and smooth layers. They have been used as roof tiles since Roman times, and most of them are empty. However, from time to time, a crayfish or a fish appear when you break them. It is nearly impossible to stop without breaking off every edge you see. Then you open it almost like a book, check the pages, and see if it contains a new fossil. However, this fossil was unprecedented. It is still one of the most valuable treasures in the Natural History Museum. That was it. Its name is Archeopteryx. It obviously has (bird) feathers on its wings. Therefore, Owen had no hesitation in characterizing it as a bird. However, this was not like any known bird species. Because it had claws on the front of its wings and, as was later discovered, it did not have a beak but a jaw with teeth and a set of bones supporting its tail. In other words, it was half reptile-half bird. It was the link between the two large groups of animals. The link was not lost anymore. **Estimates and assumptions are critical in science. Scientists' creativity and imagination are essential at all stages, from shaping a scientific problem to designing research and interpreting its results. Therefore, imagination and creativity are essential in the generation of scientific knowledge. Scientists not only use their imagination and creativity in scientific studies but also make analogies.** For example, Walther Flemming observed that several filamentous particles were the first thing divided in the cell nucleus. He named these filamentous fragments "chromatin," which means "color" in Greek. Over time, they were called chromosomes. Here, Flemming likened chromosomes to a set of filamentous particles.

Scientists believed that the age of the Earth could be measured in millions. However, no one could say the exact number of million years. Then, less than 50 years after Darwin's theory was announced, a significant breakthrough was made in a field that seemed completely unrelated. This invention would finally provide a solution to this problem. A Polish woman working in Paris, Marie Curie, discovered that some rocks contain an element called uranium. It was an element that decomposed at a constant rate in a process called radiation. Today, a century after this vital discovery, the methods of calculating age by measuring the change in radioactivity have been greatly improved. **Scientists are curious; they think about and evaluate other scientists' works. For this reason, people from all cultures participate in scientific work here because scientific knowledge requires collaborative work.**

Measurement Tools: VNOS-E questionnaire (Question 1-4-5-7), Interview

Activity Name (3): Evaluation Activity of the Tenets of NOS in Charles Darwin & Tree of Life Documentary

Directions: The entire documentary should be watched to realize this activity. Before watching the documentary, the teacher should inform students about the tenets of NOS in the documentary. Then the students are told to watch the film by paying attention to these tenets. After the documentary, students are given a worksheet consisting of questions on which they can evaluate the tenets of NOS in the film. Ununderstood parts of the worksheet are explained. Finally, student responses are evaluated by the class.

An Example of Activity Worksheet (3)

1. What questions came to your mind while watching the documentary?
2. Who are the scientists mentioned in the documentary?
3. What is the role of experimental processes in the acquisition of scientific knowledge? Do you think experimental processes are sufficient alone? Think about the movie you watched and give examples.
4. How do we know dinosaurs existed when we have never seen them?
5. In the documentary, it is seen that Darwin wrote down his observations in his diary. What do you think about it?

6. Is scientific knowledge subjective or objective? What are the reasons for the different explanations of Richard Owen and Charles Darwin on the same phenomenon? What draws your attention on this subject in the Documentary?
7. What role do you think imagination and creativity play in acquiring scientific knowledge? Give examples considering the documentary you watched.
8. What do you think about people from different cultures working together to acquire scientific knowledge?

7. Acknowledgements or Notes

*This study was produced from the doctoral thesis titled "*The Effect of Using Documentary in Science and Technology Lesson on 8th Grade Students' Achievement in Cell and Force Subjects and Their Views on NOS*".

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To Cite This Chapter

Seçkin-Kapucu, M. (2022). Practices involving the use of documentary in teaching the nature of science. In O. Tunaboylu & Ö. Akman, *Current studies in social sciences 2022,* (pp. 102-119). ISRES Publishing.