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An Explicit and Integrated NOS Flow Map in Instruction of Nature of Science based on the History of Science

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Abstract

The aims of this research are, (ⅰ) to consider Kuhn's concept of how scientific revolution takes place based on individual elements or tenets of Nature of Science (NOS), and (ⅱ) to explore the inter-relationships within the individual elements or tenets of nature of science (NOS), based on the dimensions of scientific knowledge in science learning, this study suggests that instruction according to our Explicit Integrated NOS Map should include the tenets of NOS. The aspects of NOS that have been emphasized in recent science education reform documents disagree with the received views of common science. Additionally, it is valuable to introduce students at the primary level to some of the ideas developed by Kuhn. Key aspects of NOS are, in fact, good applications to the history of science through Kuhn's philosophy. And it shows that these perspectives of the history of science are well applied to Einstein's special theory of relativity. Therefore, an Explicit Integrated NOS Flow Map could be a promising means of understanding the NOS tenets and an explicit and reflective tool for science teachers to enhance scientific teaching and learning.

Keywords: Nature of science; Explicit and integrated NOS flow map; Attitudes; Skills; Knowledge; Scientific literacy; Kuhn's philosophy; Einstein's special theory of relativity.

1. Introduction

In the past few years, the role of nature of science (NOS) in supporting scientific literacy has become widely institutionalized in curriculum standards internationally (Allchin, 2014). Understanding NOS is a central component of scientific literacy (AAAS, 1990; Lederman *et al.*, 2002) and a central tenet in science education reform (NRC, 1996). Because scientific literacy involves an understanding of NOS, it is assumed that one will achieve scientific literacy if one obtains a fuller understanding of NOS (Meichtry, 1992; NRC, 1996). Rather than being memorized, however, NOS is experienced; and when we experience NOS, we achieve enhanced scientific literacy. Thus, the scientific enterprise is composed of at least two parts—processes and products—which involve attitudes as well as facts, theories, laws, and applications as a result of doing science (Martin, 2012). NOS requires assumptions involving knowledge products (McComas *et al.*, 1998); thus, NOS involves understanding the limits of the scientific method, the nature of scientific knowledge, and the historical situations of their developments (Lederman, 1992;1999).

Despite continuing disagreements about a specific definition for NOS, at a certain level of generality and within a certain period of time (Allchin, 2011;2012), those aspects of NOS that are of interest for this study are generally agreed on (Akerson *et al.*, 2007; Akerson *et al.*, 2010; Lederman *et al.*, 2002; Lederman, 2006; Martin, 2012). As summarized by Lederman and his colleagues (Lederman *et al.*, 2002), these aspects are as follows:

> Scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), and subjective (involves the personal background, biases, and/or is theory-laden); necessarily involves human inference, imagination, and creativity (involves the invention of explanations); and is socially and cultural embedded. Two additional important aspects are the distinction between observation and inferences, and the functions of and relationships between theories and laws (p. 499)

Abd-El-Khalick *et al.* (2008), subdivided NOS into 10 different features, in which social dimensions are separated from social and cultural embeddedness. Within this framework, social dimensions and cultural embeddedness are combined into one feature for this research. Practically, we constructed an NOS Flow Map and applied it to the evolution of the structure of the atom. Because we limited our discussion to Kuhn, we look at what cognitive science has to say about how individuals learn science (Carey, 2009; Clement, 2008; Nersessian, 2008) and show the parallels in how novel scientific knowledge develops, especially demonstrating how individuals (novices and experts alike) succumb to the same pressures. We offer examples from science history that provide explicit ways to reflect about this connection. This approach may help students be more aware of their own learning and empower them to take some ownership in it.

While teachers must accurately understand the history, philosophy, and sociology of science in order to accurately teach the NOS, such understanding as well as science content understanding does not ensure effective instruction. Research makes clear that students' attention must be overtly drawn to NOS ideas in a manner that requires them to mentally engage and wrestle with those issues (Clough, 2018). Thus, we claim that other factors, Integrated strategies about tenets of NOS, are also important.

1.1. Purpose

This research aims to explore, the procedure scientific revolution as defined by Kuhn, in order to explore the development of scientific knowledge in the history of science, the inter-relationship among the individual elements or tenets of the NOS in the context of the dimensions of scientific knowledge in science learning, and how it applies to the Einstein's special theory of relativity of, one of the modern sciences. It is included in the physics curriculum of high school in South Korea, but it is very difficult to learn it because it is not related to the historical process.

Firstly, we will investigate how Kuhn's philosophy and history of science are connected with NOS. Here, we must look at Kuhn's emphasis on scientific work as essentially communal and social because natural science also has a social character: namely, the scientific community.

Second, we will explore the comprehensive viewpoints by exploring the dimensions of learning in science: Knowledge, Skills, and Attitudes in nature of science.

Third, it applies the viewpoint of scientific history to Einstein's special theory of relativity based on tenets of Nature of Science.

2. Kuhn's Scientific Revolution for the Tenets of NOS

This section explains the social and cultural embeddedness and social dimension of scientific knowledge and the crisis of normal science as Kuhn explained it. Using a flowchart, which is a tool for simplification, also has some restrictions in that a Kuhnian revolution may be only one way to consider the process of science. However, as Eflin *et al.* (1999) observe,

> It is valuable to introduce students at an elementary level to some of the ideas developed by Kuhn. In particular, students benefit by considering the idea that different paradigms compete with each other, and that they can easily understand some of the ways in which theoretical commitments and social issues can influence the development of science. On the other hand, students should be made aware that some interpretations of Kuhn's views are extreme and not persuasive (radical incommensurability) (p.114).

We turn now to examining the steps or stages in Kuhn's concept of a scientific revolution. **A crisis in normal science** occurs as a result of a number of serious anomalies. In the case of Copernicus, scientists have formulated several elaborate and differing story lines about the heliocentric hypothesis at the time of Copernicus. The dominant problems centered on "calendar reform" and "complexity" in explaining the heavens (Chalmers, 1999). Kuhn described episodes of theory change as tumultuous periods during which scientists with established venues for communication and criticism judged competing theories using a variety of criteria, including social influences (Sadler, 2004). Also, preparing students to achieve the lofty goal of functional scientific literacy entails addressing the normative and non-normative facets of socio-scientific issue (SSI), such as scientific processes, nature of science (NOS) and diverse sociocultural perspectives (Herman, 2018). Thus we claim that SSI, along with diverse sociocultural perspectives, is the most important elements of NOS tenets.

The seriousness of the crisis in normal science then deepens as a result of the appearance of an alternative. **Subjectivity** enters at this stage, for although the crisis in the paradigm is recognized in terms of a socio-cultural need and the problem is partially solved by the submission of new alternatives, new problems are posed with the new paradigm. However, for the disciplinary successors of the new paradigm, new alternatives emerge as the severity of the crisis intensifies for the paradigm. In other words, study is begun to solve the new problems. The subjective and theory-dependent empirical data indicate the study direction of the new paradigm. One of Kuhn's ideas about the nature of science is the **theory-ladenness of observations**. In ancient Greece, Aristarchus suggested that the earth may rotate on its axis and revolve in an orbit around the sun. Almost 2000 years later, Copernicus also came to a conclusion about the system of the universe based on the combination of the earth's two motions about the Sun. In particular, he could explain the retrograde motions of planets without the complex epicycles suggested by Ptolemy (Cohen, 1985).

The Copernican system has more problems in the observational sense than the Ptolemaic system, because Aristotle's idea of the celestial bodies accepted the notion of the uniform circular motion in what is called a natural motion. However, it strongly attracted such disciplinary successors as Galileo, Kepler, and Newton because of its beauty. In other words, Neo-Platonism, which was popular at that time, emphasized simplicity and beauty (qualitatively simple and harmonious), whereas the Ptolemaic system tried to explain in a more and more complicated way. Theory-ladenness relates to social and cultural changes**,** as well as subjectivity. In terms of accuracy, Ptolemy's model is better than Copernicus's model. As well, Neo-Platonism is based on a certain degree of comprehension, not just simplicity. "Putting the Earth in motion around the Sun was that it immediately suggested that Copernicus had not just a workable astronomy but a seemingly coherent cosmology" (Henry, 2012).

A scientific revolution is then completed by disciplinary successors who follow a new paradigm. Science's necessary reliance on empirical evidence is what distinguishes it from other disciplines (e.g., religion, philosophy). Although this evidence may be explained by the new theory, new evidence will still be predicted and estimated. **Empirical Evidence** supporting Copernicus's heliocentric hypothesis**.** Given the empirical evidence for Copernicus's heliocentric theory, mathematical abstraction and idealization in thought experiences became very important in Galileo's research, especially in the study of dynamics. Galileo demonstrated that **inference** is very important, beyond accurate observation on natural phenomena. **Empirical data** that have a favorable influence upon Newton's theory **<Observations and Inferences>**

Based on the observations of Tycho Brahe, Kepler was able to discard the annoying epicycles with a planet's elliptical orbit rather than a circular orbit. Kepler's inference is more significant than Brahe's because he could not estimate an elliptical orbit directly from Tycho Brahe's data. Rather, he explained Brahe's observations because he thought of an elliptical orbit through an intermediate form from an initial circular orbit.

An accurate elliptical orbit is difficult to derive from observation because an accurate elliptical orbit revolves only when there is only one planet with a sun of infinite mass. Thus, the abstraction work of inference is required. Therefore, rather than estimating scientific empirical data from simple observations, inference is absolutely necessary, and this requires a scientist's creativity. Moreover, not only is inference required to interpret observation data but also it becomes the foundation of predicting further observation data.

Law and theory are both in the so-called "hierarchy of credibility," found in most science textbooks, which presents categories of scientific knowledge/ideas (i.e., observations, hypotheses, theories, laws/principles) in an ascending list of credibility or certainty. Individuals often hold the common sense, hierarchical view of the relationship between theories and laws presented in such lists. In this view, theories become laws as they accumulate supporting evidence over numerous years. It follows from this notion that scientific laws have a higher status than scientific theories.

The common notions relating to theories and laws are inappropriate because, among other things, theories and laws are different kinds of knowledge and the one cannot develop or be transformed into the other. Laws are *statements or descriptions of the relationships* among observable phenomena. Theories, by contrast, *are inferred explanations* for observable phenomena.

<No Universal Step by Step Scientific Method>, <Individual Creativity> The development of scientific knowledge is based partly on human **imagination and creativity.** Scientific knowledge is not simply the product of logic and rationality. Scientists follow many and various methods in order to produce scientific knowledge (AAAS, 1993; NRC, 1996; Shapin, 1996). Throughout scientific history, diverse disciplinary successors have not constructed certain laws or theories by a simple collection of data and logical induction; rather, their work has been pursued creatively through insight to solve the problems inherent in a new paradigm.

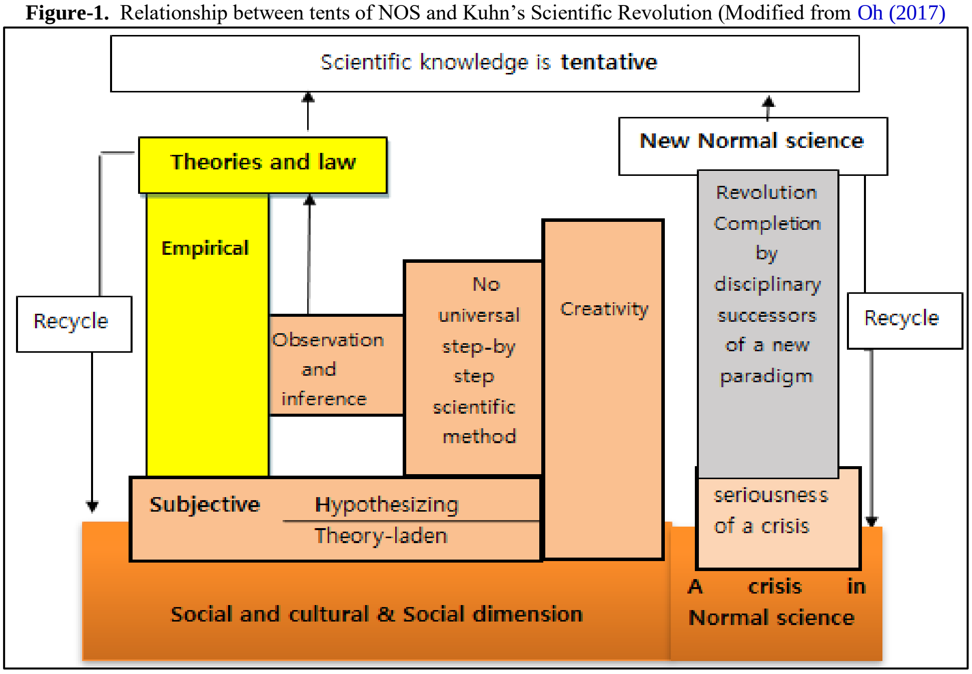
<Law and Theory> Newton's most significant contribution was the law of the universal gravitation, and by this theory, Newton could explain Kepler's law of planetary motion and Galileo's law of falling.

2.1. The Stage of the New Normal Science and its Recycling (Expansion)

<Tentative Character of Scientific Theory> In Newton's theory system, the celestial and terrestrial worlds are unified as one, and each object moves with the force of Newton's law of motion. As soon as Newton's physics was constructed, it was applied in detail to astronomy. However, the discrepancy of Newton's mechanics with electromagnetism and the explanation of Mercury's perihelion shifting provided an opportunity for Einstein to construct his new theory of relativity.

In sum, scientific knowledge is a product of recycling the revolution process toward discovery of a new philosophy and theory system as well as an accumulation procedure through revision and development. Therefore, conflicting ideas may arise from various interpretations of the same data based on individual theory**.**

Figure-1. Relationship between tents of NOS and Kuhn's Scientific Revolution (Modified from Oh (2017)



As shown in Table 1, 'the Social and Cultural effects, & Social dimension' shown in the bottom part of Figure 1 correspond to 'Kuhn's A crisis in normal science'. The yellow area of the process of inquiry corresponds to 'the seriousness of a crisis of Kuhn' and 'the revolution completion by disciplinary successors of a new paradigm'. However,' theory-ladenness, of subjective in tenets of NOS', is commonly associated with Kuhn's 'A crisis in normal science and seriousness of a crisis'. The yellow area is the products of the inquiry process and is the result of 'Kuhn's Revolution Completion by disciplinary successors of a new paradigm'.

3. The Dimensions of Learning in Science: Knowledge, Skills, and Attitudes for the Tenets of NOS

Zeitler and Barufaldi (1988), encourage educators to use the experience of scientific enquiries, scientific attitude, and basic scientific knowledge in teaching, which are all integrated as scientific literacy. Therefore, in this study it is necessary to present NOS as a combination of these three elements as well.

Attitudes about science can have a significant effect on scientific literacy. In education theory, understanding of content lies in the cognitive domain, while attitudes lie in the affective domain. According to Flick (1993), there are three major dimensions of learning in science: knowledge, skills, and attitudes.

The **knowledge dimension** of learning in science includes understanding of NOS and technology, science content, and unifying themes or concepts. Through skill activities, students can learn about NOS and technology as parallel human endeavors to create explanations for natural phenomena (science) and solve problems of human adaptation to the environment (technology) (Bybee *et al.*, 1989).

The **skills dimension** of learning includes bodily kinesthetic skills (gross, find motor, and eye-hand coordination) as well as training of the senses. Students can also learn skills in science processes such as inference, data analysis, and hypothesizing (AAAS, 1967) and general organizing skills such as information gathering, problem-solving, and decision making (Bybee *et al.*, 1989). Cooperative group arrangements and the need to interact with a variety of new materials provide opportunities for students to develop social (interpersonal) skills as well as intrapersonal and meta-cognitive awareness skills.

In the science education community, the rational or epistemological characteristics of science are typically tied to empiricism, the process of inquiry, differences between inference and observation, and the tentative nature of scientific conclusions (Abd-El-Khalick, 2012; Irzik and Nola, 2014; Lederman, 2006).

The **attitudes dimension** of learning includes attitudes of science. Attitudes of science are those habits of mind cultivated by scientific investigators for maintaining the integrity of the inquiry and the validity of the information. These include attitudes such as being skeptical, relying on data, and accepting ambiguity (Bybee *et al.*, 1989). As well as exploration of effects of SSI engagement on students' interest and motivation, some researchers have focused on the effects of Science-Technology-Society (STS) issues on students' attitudes towards science (Sadler, 2004). Yager *et al.* (2006), used an STS issue for one class and compared this class with a class following the standard middle school science curriculum. The attitude of students in the intervention class was found to be higher than in the comparison class. Lee and Erdogan (2007), conducted another STS engagement study for middle and high school students and found similar results with Yager *et al.* (2006) findings that students developed positive attitudes towards science. However, SSI (socio-scientific issues) are different from the science issues in that they do not only focus on science content but also on social dimensions of this science content. An SSI approach is characterized by a reconceptualization of the STS approach, and it focuses on not only social dimensions of science and technology but also on students.

Although STS education emphasizes the impact of science and technology, there is also a view that ethical issues and students' moral development are not precisely focused (Zeidler *et al.*, 2002). The importance of science-related social and ethical issues (Socioscientific issues, SSI) education, which includes the educational implications of STS and considers the ethical aspects of science and the morality and development of students, has also increased (Zeidler *et al.*, 2002).

A "consensus view" (Erduran and Dagher, 2014) of NOS emerged recently in science education research that describes social dimensions as including the theory-laden nature of scientific knowledge, creativity, and social and cultural embeddedness (Abd-El-Khalick, 2012; Lederman *et al.*, 2002). Within this framework, social dimensions and cultural embeddedness are collapsed into one feature and separated from other attributes.

In this research, The theory-based nature of scientific knowledge is involved in the exchange of skill and attitude. But creativity is involved in skill detention rather than altitude dimension, we describe that the two "constantly interact with each other"

Martin (2012), defined science as a process by which knowledge is produced. Thus, the scientific enterprise comprises at least two factors—processes and products. The products of science include the facts, concepts, theories, laws, and applications and attitudes that occur as a result of doing science. Zeitler and Barufaldi (1988), defined scientific literacy as the melding of scientific investigative experience, attitudes, and basic knowledge. Therefore, acquiring scientific literacy should be well coordinated between a basic knowledge of science and experiential exploration and attitudes toward science. One development in this regard is the establishment of Project 2061, a publication consisting of a set of recommendations "spelling out the knowledge, skills, and attitudes all students should acquire as a consequence of their total science experience "(AAAS, 1989) in order to be regarded as scientifically literate (Laugksch, 2000).

Martin (2012), has described 'attitudes' as another scientific product, different from facts, concepts, generalization, theories, laws, and applications. These attitudes are formed by individual experiences and explorations; in turn, they affect our learning with explorations, which are once again affected by these attitudes.

In this research, the following terms are used for the processes of science learning that consist of attitude, skill, and knowledge: **Scientific attitudes** refer to the social dimension, social and cultural changes**,** and subjectivity (theory-ladenness). **Scientific skills** do not refer to specific scientific methods but rather to imagination and creativity, observation and inference**,** and subjectivity (hypothesizing). **Scientific knowledge** refers to law and theories, and the elements of nature of science the NOS necessary to achieve wider scientific literacy. In particular, subjectivity consists of hypothesizing (AAAS, 1967), and theory-ladenness (Martin, 2012).

In this study, the dimensions of science learning in science should be understood as supporting the tenet that scientific knowledge is tentative and revisionary.

A "consensus view" (Erduran and Dagher, 2014) of NOS has emerged recently in science education research that describes the social dimension as including the theory-laden nature of scientific knowledge, creativity, and social and cultural embeddedness (Abd-El-Khalick, 2012; Lederman *et al.*, 2002). Within this framework, social dimensions and cultural embeddedness are collapsed into one feature and separated from other attributes in this research, whereas the schema used by Abd-El-Khalick *et al.* (2008) subdivides NOS into 10 different features, in which social dimensions are separated from social and cultural embeddedness. Longino (2002), described social dimensions as including "constitutive values associated with established venues for communication and criticism within the scientific enterprise which serve to enhance the objectivity of collectively scrutinized scientific knowledge" (Abd-El-Khalick *et al.*, 2008), within intrinsic effects. The social and cultural aspects of NOS are described as processes by which scientific knowledge claims are "affected by their social and historical milieu" (Niaz and Maza, 2011) or "embedded and practiced in the context of a larger cultural milieu" (Abd-El-Khalick *et al.*, 2008), within extrinsic effects.

One important aspect of science is the **observation** of events. However, observation requires **imagination and creativity**, for scientists can never include everything in a description of what they observe. Hence, scientists must make judgments about what is relevant in their observations. Empirical theory would argue that there is no imagination and creativity in observation because it happens automatically, though it is filtered by the senses and brain. It is the *interpretation* of those records in our brain, the empiricist would say, that relies on creativity and imagination.

The role of **creativity and imagination** in the development of scientific knowledge also has implications for the supposed objectivity of science; even so-called "objective facts" in science are not really free from **subjectivity**. Scientists' backgrounds, theoretical and disciplinary commitments, and expectations all strongly influence their work. These factors produce a mindset that affects what scientists investigate, how they conduct their investigations, and how they interpret their observations. As two prominent examples, Aristotle (384-322 B.C.) and Galileo (1564-1642) both interpreted motion along a horizontal surface. Aristotle noted that objects, after an initial push, always slow down and stop. Consequently, he believed that the natural state of an object is to be at rest, supporting the geocentric hypothesis that, in his social and cultural context, distinguished between the celestial world and the terrestrial world. Galileo imagined that if friction could be eliminated, an object given an initial push along a horizontal surface would continue to move indefinitely without stopping. He concluded it was just as natural for an object to be in motion as to be at rest. He did so with a leap of the imagination. Galileo made this leap conceptually without actually eliminating friction, supporting the heliocentric hypothesis that unified the celestial and terrestrial worlds' laws, based on the simplicity of Neo-Platonism.

These two examples demonstrate the **distinction between observations and inference,** which is significant in science because these two types of scientific knowledge give rise to different kinds of scientific claims. The **laws** express a relationship that can describe what happens under specific conditions, but **scientific theories** offer explanations for why something happens. Additionally, because both laws and theories are based on tentative knowledge (observation and inferences), neither is absolute. When considering its empirical nature, it is important to remember that scientific knowledge is a product of **both observation and inference**. Observations constitute the empirical basis of scientific knowledge: they are descriptions of natural phenomena that may be directly perceived by the senses (or instrumental extensions of the senses). Inferences are conjectures beyond observable data. The distinction between observations and inferences in science is significant because these two types of scientific knowledge give rise to different kinds of scientific claims. Science involves more than the accumulation of countless observations—rather, it is derived from a combination of observation and explanations derived from observations, and it often involves entities that are not directly observable.

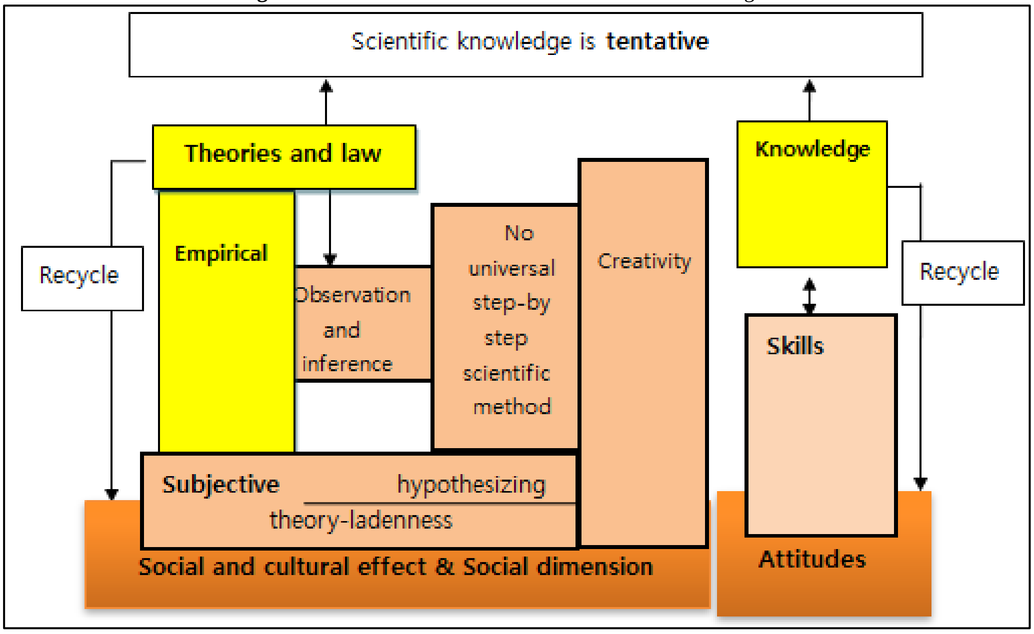
Bauer (1994), said that scientific knowledge is composed of the following: fundamental concepts in science, the nature of scientific activities, and the role of science in society-culture. One who achieves these three types of knowledge is a person well-equipped with scientific literacy. In light of these elements, scientific literacy is actually a part of historical and cultural literacy. Anyone who understands that scientific progress is limited through a filter of scientific agreement can develop their science literacy, even if he or she does not know the content of science very well. Accordingly, our research ranks these scientists, socio-cultural contexts, and attitudes as foundational in terms of affecting the development of scientific knowledge.

Table-1. The views about the elements of NOS

	The elements of NOS		
Scientific Literacy (Zeitler and Barufaldi, 1988)	Skill	Attitude	Knowledge
Inter-relationship NOS	Process of inquiry	Social dimension	Productions
	No scientific methods, observation & inference (theory – dependence, creativity)	Social and Cultural effects, & Social dimension (theory – ladenness, creativity)	Scientific knowledge, Empirical
Kuhn's Philosophy and History of Science	The seriousness of a crisis & Revolution Completion by disciplinary successors of a new paradigm	A crisis in Normal science	Revolution Completion by disciplinary successors of a new paradigm

As shown in Table 1, 'the Social and Cultural effects, & Social dimension', shown in the bottom area of Figure 2, correspond to the 'Attitude of Scientific Literacy'. The yellow area of the process of inquiry corresponds to 'the skill of Scientific Literacy'. However, 'theory-ladenness' in the subjectivity NOS tenet, is commonly associated with the 'skill and attitude of Scientific Literacy'. The yellow area corresponds to the 'knowledge' of Scientific Literacy as products of the inquiry process.

Figure-2. The tenets of NOS and the dimensions of learning in science



Next chapter will present Einstein's special theory of relativity to solve the problems of Newtonian Mechanics under two simple assumptions: 1) the speed of light is constant relative to any observers; 2) laws of nature are equally true for anyone. This study will explore if these assumptions are applied to major tenets of the NOS.

4. The Formulation of Einstein's Special theory of Relativity for the Tenets of NOS

4.1. Social and Cultural, & Social Dimension

According to Maxwell's equations, the speed of light should remain constant while it travels in specific material medium or in a vacuum. In other words, the speed of light should be a constant regardless of the viewpoint of the observer. On the other hand, according to Newton's law of motion, the velocity of objects is supposed to change according to the velocity of the observer. Therefore, if the observer moves as fast as the object he or she is observing, the object will be seen as if it is not moving. Newton applies the principles to all motions, but Maxwell's equation on the movement of light does not say anything about it. This may imply that the speed of the observer does not have any influence on the speed of light (Halpern, 2004). At least it was what the contemporary scientists believed.

4.2. Subjective

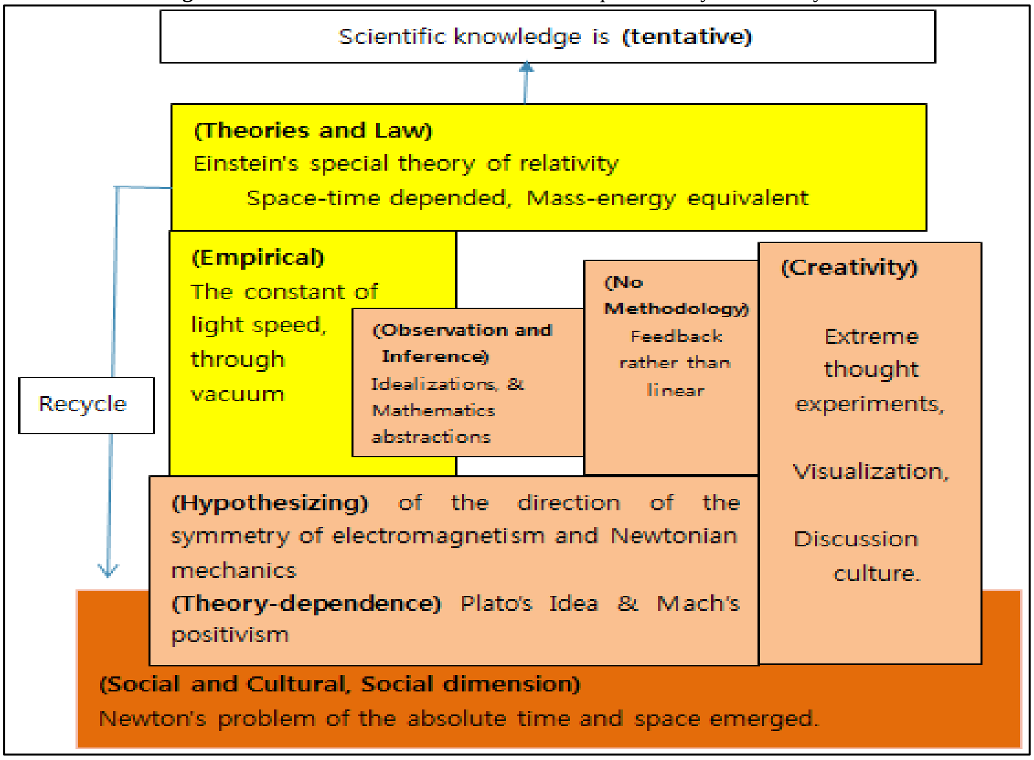
(Theory-dependence) Plato's Idea & Mach's positivism. As "matter of facts" cannot lead to certain truths (Hume), Kant concluded one cannot think without general concepts such as cause and effect, time, or space and certain truths are a priori, which is universal, inevitable, and free from experience. He tried to throw off metaphysical premises on time and space suggested by Newton. In addition to play a part of Kant's solving human dilemma, Einstein, unlike Kant, accepted the fact that perceptions through the senses cannot provide any ideas on the nature of objects in outside world. He used Kant's proposition to refute the argument of empiricists who believe knowledge is derived from one's sense-based experience without depending on mental activities. Einstein was a firm believer of Plato's idea that the world around us exists objectively and independently from our mind (Gribanov, 1987). Einstein's thoughts, concepts and principles of science, and theories should be understood from the perspective of history, though. They should be reviewed and adjusted to reality with time. It was no accident that Einstein highly appreciates Mach when he took a historical approach to classical mechanics although he argued principles and categories have an objective nature contrary to the position taken by Mach and Kant (Gribanov, 1987).

(Hypothesizing) Newtonian mechanics started from a metaphysical belief that absolute time and space respectively are independent aspects of objective reality but Einstein reached a conclusion that time and space are intrinsically connected in an inertial space based on the assumption that the speed of light is constant. In his theory of special relativity, Einstein also predicted a phenomenon, time dilation and length contraction, which could not be understood at the time. Such new phenomena, changes in length, time, and mass, might look separate entities to laymen. Then what is a simpler explanation penetrating all these seemingly unrelated phenomena? It is symmetry that penetrates the thoughts of Einstein. If it is symmetry, a constant can relate them (**Hypothesizing**), say, constant speed of light. To sum up, Einstein identified the problems of Newtonian Mechanics through thought experiments, destroyed its concept of absolute time and space, and suggested a new theory of special relativity in a kind of mathematical abstraction.

4.3. Empirical

In 1887, Albert A. Michelson and Edward W. Morley, conducted an experiment which compared the speed of light in perpendicular directions, in an attempt to detect the influence of the speed of the earth moving through the aether. Surprisingly, they found no significant influence on the speed of light in the opposite direction of movement of the earth. The result is against the then-prevalent Newton's laws of motion unlike other natural phenomena known at the time.

Figure-3. The tenets of NOS based on Einstein's Special theory of Relativity



Creative,
No Methodology: Feedback rather than linear,
Observation and Inference: Idealizations, & Mathematics abstractions)

Thought experiments have multiple functions: First, they can verify an established fact and establish a new theory (Miller, 1998); Second, they destroy a prevailing theory and construct a new one. As Brown argues that Plato's thought experiments are a priori, they are "constructive" and "destructive" at the same time. A historical case in point is Galileo's thought experiments (Brown, 1991; Oh, 2016). **(Feedback rather than linear),** The author suggests Einstein's thought experiments on special relativity not only destroyed previous theories but includes the process of constructing new hypotheses and of justification to verify a new hypothesis. Above all, observation and inference are combined through thought experiments (Oh, 2016). **(Idealizations, & Mathematics abstractions)**

Albert Einstein was born in Ulm, in Germany in 1879 and soon the family moved to Munich. When he went to high school there, Einstein, then 16, was already interested in the problems which would become his life-long research questions. One of the questions of his interest was how to reconcile Newton's law of motion and the fact that the speed of light is constant. He thought about what would happen if he runs fast enough to catch up with the speed of light? Would it look like "vibrating electromagnetic field", which is still in space? Then how could he explain Maxwell's statement that the light of speed should not change as it is an electromagnetic wave? Finally, at the age of 26, he was able to suggest an amazing solution: Einstein's theory accepts the fact that the speed of light is constant and relative simultaneously. Moreover, this theory does not need the existence of hypothetical "aether". **(Idealizations, & Mathematics abstractions). "**In 1905, Poincare and Einstein presented with the same set of data, for which they produce essentially identical mathematical formulations. Whereas Poincare interpreted the mathematics as improving on Lorentz's electron theory, Einstein interpreted it as the special theory of relativity (Miller, 1998)." **(Hypothesizing)** of the direction of the symmetry of electromagnetism and Newtonian mechanics.

What is noteworthy is that Einstein was able to visualize thought experiments in an intellectual atmosphere at the time where lively debate was considered important. Idealization through thought experiments, instead of following existing methodology, was used as a tool to make inferences. Mathematical abstraction gives feedback to idealization and vice versa. **(Creative),**

4.4. Limitations

This investigation firmly established an association exists between NOS views, compassion for others, However, the main limitation of the present investigation is that the learning and teaching outcomes described here and teaching according to the NOS Map have not been presented to pre-service teachers and students. A formal assessment of the effects of the NOS Map on learning outcomes will be needed in future research.

5. Discussion and Conclusion

We insist that none of these aspects should be considered apart from the others. Thus, the key aspects of NOS should be viewed in this study as interdependent, dynamic, explicit, and reflective. Empiricists argue that our perception gives us objective facts about the world, configuring the foundations of science, and that general laws and theories are inductively produced, based on those facts. However, we maintain that judgments and inferences on observable facts in a specific situation will change depending on the person, the culture, and the theoretical school.

That is, under the themes of **social and cultural background,** including communication and criticism (**Social dimension**) within the scientific enterprise, perception is formed and developed in a decisive manner by the **subjectivity of observers**, which involves their cultural and theoretical background, expectations, and perspectives. Such considerations are handled under the heading of **the theory-ladenness of observation** in the philosophy of science. Additionally, **law**, which shows regularity, and **theory**, which requires our creativity, should be separated. We insist that **law** (regularity) and **theory** (creativity) should be considered as a dynamic combination rather than separated because of the theory-ladenness of observation. Likewise, most modern philosophers of science have questioned the hierarchical/dichotomous relationship between laws and theories (Giere, 1999; Niaz and Maza, 2011).

The development of scientific knowledge involves making observations about nature. That is, observations do not equate to **scientific methods**, which are represented as universal step-by-step processes. This additional aspect is what we have alluded to as "no single scientific method" but rather a host of methodologies to produce scientific knowledge (Bell, 2006; Lederman *et al.*, 2002). Finally, because objective law or theory is not produced from objective facts, a scientific theory is, indeed, tentative. This research has proposed a new flow map, using core elements of NOS and the prerequisite conditions of a scientific revolution proposed by Kuhn (1996), to apply to the atomic understanding process. The core elements of the NOS and Kuhn (1996) prerequisite conditions for a scientific revolution are systematically related and shown to correspond well to each other. These results show that Einstein's special theory of relativity is well applied to modern science.

The process of science learning is held to consist of attitudes, skills, and knowledge: **scientific attitudes** include social and cultural changes**,** and subjectivity (theory-ladenness; (Martin, 2012), **scientific skills**, while involving no single scientific method, include imagination and creativity, observation and inference**,** and subjectivity (hypothesizing; (AAAS, 1989); and **scientific knowledge** includes laws, theories, and empirical evidence. The elements or tenets of NOS necessary to achieve scientific literacy are connected with scientific content.

However, our explicit NOS approach instructions include the history and philosophy of science in a dynamic exchange with the history of science as focused on implicit NOS approach instruction. In this way, we can use historical case studies and encourage students to analyze for the multi-faceted effects of the direction of scientific knowledge creation (Allchin, 2013; Irzik and Nola, 2011; Osborne *et al.*, 2003).

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