

# A STUDY ON DEMONSTRATION OF THE NATURE OF SCIENCE IN SCIENCE TEXTBOOKS: HISTORY AND PHILOSOPHY OF SCIENCE PERSPECTIVES

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## A STUDY ON DEMONSTRATION OF THE NATURE OF SCIENCE IN SCIENCE TEXTBOOKS: HISTORY AND PHILOSOPHY OF SCIENCE PERSPECTIVES

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### ABSTRACT

Many scholars in the teaching of science put forward that the perennial target of science education is to teach the nature of science (NOS), and science textbooks play a crucial role in the teaching of the nature of science (NOS). Understanding the nature of science is said to be effective when both understanding science concepts and doing science. Numerous studies focus on the teaching of NOS. This study investigates the effect of a science content that is prepared in history and philosophy of science (HPS) perspective on the NOS understandings of pre-service science teachers. 34 sophomore pre-service science teachers participated in the study. The quasi-experimental method was used by employing a pre-test, an intervention, and a post-test which is the same as the pre-test. The intervention involved the presentation of science content from the HPS perspective in six weeks long of discussions. Data were collected through a survey that revealed categorical views regarding the characteristics of NOS. The results showed that the demonstration of atom theories in the HPS perspective gave a positive effect on the pre-service science teachers in understanding the NOS.

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Keywords: science textbooks; nature of science; history and philosophy of science; science education

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### INTRODUCTION

The main goal of science education has been controversial for decades. However, scientific literacy is now accepted as the main goal of science education (Allchin, 2013). McDonald & Abd-El-Khalick (2017) proposed that being scientifically literate requires the ability to (1) “apply and reason scientifically” (2) “master the discourse of science”, and (3) “understand the historical and epistemological significance of the learned concepts”. Especially the third component deals with the understanding the nature of science (hereafter NOS) which is seen as an integral element of scientific literacy, and the main focus

of the majority of national science education curricula such as ACARA (2015); NRC (2012); NGSS (2013). Allchin (2017) claims that students should understand how science is done, how science progresses, how knowledge is built on, and how to reach new knowledge. Besides, the recommendations on teaching the NOS and its social practices for school science have been increased (Duschl & Grandy, 2013). Osborne et al. (2003) pointed out the importance of including NOS into science curricula and suggested the need for consensus on determining the components of NOS to integrate into science curricula. Thus, NOS is becoming a core component of both science education research and curriculum policy around the globe (Yang et al., 2020).

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McDonald & Abd-El-Khalick (2017) posit that there is not a common agreement on/ definition of NOS and probably there will never be since science is a “complex and multifaceted human endeavor”. Yet, there are two general views on NOS, namely the domain-general view which poses that there are a set of non-controversial aspects of science that may be taught in school and the domain-specific view of NOS that claim “different science disciplines have their own distinct natures of science” (Kampourakis, 2016). Allchin (2017) argued that before addressing the question of “what is NOS”, the question of “why NOS” should come first. He puts forth answer of “why” as functional scientific literacy especially in criticizing the consensus view of NOS. According to Pearl & Mackenzie (2018), the answer of “why” is “to understand science as a way of learning”. Allchin (2013) extends this idea to the teaching of NOS for a functional scientific literacy that must be contextualized in a whole science approach according to which students understand the process of “how scientific practice is done”, “how scientific knowledge is produced” and “how it reflected to society”. Furthermore, textbooks play a crucial and central role in science education at schools (Kahveci, 2010; Roseman et al., 2010; Kloser, 2013; Yustina et al., 2020) because both classroom teaching and homework activities are majorly textbook oriented. Moreover, Fogleman et al. (2011) stated that school textbooks can influence the teaching and learning strategies followed by teachers, therefore have a high potential of impacting learning experiences and conceptual understandings of students. Similarly, in many countries, science textbooks are the core of teaching and learning resources for teachers and students. Science textbooks are seen as influential teaching resources which have a substantial role in the science classroom and so it should help students develop informed conceptions of NOS because “it is most likely that the values and assumptions embedded or explicated in the language of the textbook, and its associated images, will influence students’ views about the nature of the science” (McDonald & Abd-El-Khalick, 2017). Furthermore, Yang et al. (2020) and McDonald (2017) stated that “how science textbooks should portray NOS aspects have been a keen interest to science educators.”

The previous research investigating how NOS is represented and demonstrated in school’s science textbooks is generally showing that NOS does not receive much attention, not represented in an informed manner, insufficiently and expressed inappropriately (Vesterinen et al., 2013;

Abd-El-Khalick et al., 2017). Given that science textbooks significantly influence students’ understanding of NOS (McDonald & Abd-El-Khalick, 2017), this study focuses on how NOS can be integrated into content presentations in college-level general science textbooks. In this line, we claim that science textbooks are an indispensable component of science education and those elements have an important role in the teaching of the NOS as well. Relevant literature (Niaz, 1998; Rodriguez & Niaz, 2004; Niaz & Coştu, 2009) reported that teaching and learning activities both in and out of the classroom are more emphasized rather than giving attention to the preparation of science textbooks.

### Science Textbooks and Teaching of the NOS

Numerous studies (Niaz, 1998; Rodriguez & Niaz, 2004; Niaz & Coştu, 2009; McDonald & Abd-El-Khalick, 2017; Yang et al., 2020) revealed the importance of content presentation. Their common conclusion was that there seems no effort to prepare science textbooks in science teacher education programs to improve prospective teachers’ understanding of the NOS. Patterson et al. (2017) claim that “for many decades, the practice of science education has been dominated by a focus on ‘hands-on’ inquiry”. They emphasize the paucity of interest in preparing textbooks and expressed the importance of reading material and meaning is represented. Moreover, in the study, the learning of scientific knowledge may occur within a social interaction through which the learner can interact with the source of scientific knowledge (Patterson et al., 2017). Accordingly, science textbooks have indispensable potential to reflect the characteristics of science (Kloser, 2013). Furthermore, regarding the philosophical perspective of scientific content presentation in science textbooks, Nobel laureate theoretical physicist Leon Cooper critiques that textbooks are generally written in a positivist epistemological view in which understanding the nature of science is quite difficult (Niaz et al., 2010). As there are numerous efforts trying to enhance teaching and understanding of the NOS in the research area, the situation that Cooper mentions poses a problematic and contradictory situation in terms of both conceptual and theoretical considerations regarding the nature of science.

A recent study conducted by Yang et al. (2020) focused on how NOS is represented and demonstrated by the science textbooks used in Korean schools. Their analysis framework is Erduran & Dagher’s (2014) RFN view which is a re-conceptualized form of Irzik & Nola’s (2011)

FRA view. It explains NOS in terms of similarities and differences among science disciplines in which science is viewed as “a cognitive–epistemic and social institutional system”. The results indicated that science textbooks tend to focus on the cognitive and epistemic characteristics of science, with a limited representation of social and institutional NOS aspects. Another study conducted by DiGiuseppe (2014) examined the role of the author, publisher, editor, and reviewers of a high school chemistry textbook regarding on how representations of NOS were developed and incorporated in two chapters of the textbook. DiGiuseppe (2014) found examined science textbooks as weak in representing aspects of NOS. Among the studies, those focused on the role of science textbook are Park et al. (2019) who studied the representation of NOS within the content presentation of general relativity in physics textbooks. Moreover, Park et al. (2019) studied how textbook-based learning activities can help students improve their understanding of NOS.

Roles of science textbooks in representing the aspects of NOS getting more attention recently. McDonald & Abd-El-Khalick (2017) highlighted that studies in this context can be categorized into “three lines of research”. These include studies that examine science textbooks for the (1) “emphasis given to NOS as a single theme” (2) “historical and philosophical accuracy of representations of science content and its development”, and (3) “accuracy and/or extent of representation of specific aspects or domains of NOS drawn from reform documents”. The current study is in the second category which explores the effects of content presentation on NOS understanding within the lenses of history and philosophy of science (hereafter HPS). Accordingly, this study aims to explore the effects of college-level general chemistry content prepared in the HPS perspective on NOS understanding of pre-service science teachers. The hypothesis is that a science content prepared in the perspective of HPS may implicitly lead to more appropriate NOS understanding for students. The novelty of this study is to see how the content preparation in the HPS perspective may affect NOS understandings of students. We attempt to create textbook content that can implicitly demonstrate aspects of NOS. Yang et al. (2020) stated implicitly that representation of NOS can be “an important means of contextualizing NOS by linking the individual’s scientific knowledge” with the dynamics of human society surrounding the science.

## Earlier Studies on HPS to Develop Student Understanding of NOS through Textbook Representations

Allchin (2013) remarked that the history of science (HOS) can be used within teaching science content, methodological skills, and this way appropriate NOS understanding may be achieved. It is suggested nine ways in which the science teacher may benefit from history. The benefits of HOS are expressed as follows, (1) contextualizing and motivating, (2) clarifying concepts, (3) revealing misconception, (4) celebrating achievements, (5) promoting scientific careers, (6) developing inquiry skills, (7) profiling the nature of science, (8) highlighting science as social, (9) “re-portraying the cultural contexts of science”. Lin & Chen (2002) reported that the inclusion of HPS as a method for enhancing understanding of the NOS into chemistry courses must be considered by science teacher training programs. This study embraces the view that HPS can facilitate pedagogical support for teaching science and NOS. Likewise, Lin (1998) conducted a study in which HOS is used as a pedagogic strategy for enhancing understanding of the NOS. As the result of the study, there was an enhancement because the integration of HOS on understanding the nature of creativity, the theory-based nature of scientific observations, and the function of the theories reported. The author proposes that science teaching, the use of history science does not only contribute to the understanding of the NOS, but it also facilitates enjoyment of teaching during learning. Another study conducted by Şendur et al. (2017) to see the effects of a long term course comprised of instructions, through which HPS instructed and discussed, on pre-service science teachers’ conceptions of chemistry and chemists. Although their study does not aim to build a relationship between the NOS and HPS, it can be said that the conceptions and understanding of chemistry as disciplinary science and chemists as scientists could reflect a meta-understanding about the NOS and scientists.

However, most of those studies can be criticized because presented the stories of most popular and famous scientists and that situation seems leading to view science that may seem developing and progressing on a chronological and procedural line. Yang et al. (2020) stated that textbooks tended to focus on addressing one central NOS idea in each historical episode, which means that diverse NOS aspects are not represented in a holistic and appropriate manner. Therefore,



for students' richer understanding of NOS, textbooks should embrace NOS aspects that are as diverse as possible and reveal their "dynamic interrelations" within each historical episode. We interpret this idea as the progress of science that is a continuous and complex process and even if the historical details are demonstrated, it needs philosophical guidance to interpret and link the historical happenings. Lakatos (1980) stated that the reconstruction of history needs philosophical guidelines. According to Lakatos, to understand the progress of science appropriately, for example, the rivalry between different scientific theories, models, and scientists must be included in the demonstration of HOS. Otherwise, the progress of science can be conceived as "a fresh line" in which in certain times certain people built scientific knowledge. The role of observations, experiments, presuppositions of scientists, and experimental data in inventions of theories can be understood if the rivalry between opponent theories is discussed and why the acknowledged theory is supported.

In parallel, in the context of this study, the textbook is investigated not only in the perspective of historical details but also tend to embrace a philosophical guideline argued by Lakatos to not embed the historical details into the content presentation but embed the content into the historical development of the scientific knowledge. HOS may eligibly demonstrate "methodological and conceptual" progress of other disciplines while philosophers of science, who think the connections between HPS has been fulfilled, consider historians of science as limiting the connection of the sides. Therefore, we should look back on historical details from a philosophical perspective or view. Moreover, Monk & Osborne (1997) argued that "teaching of science content through HPS has a positive contribution in constructing conception and understanding of the NOS and it must be planned as a pivoting factor in the curriculum". They claim that HPS is an effective factor to enhance the understanding and conception of the NOS because (1) "historical thinking often parallels with their own", (2) "the now accepted scientific idea was often strongly opposed for similar reasons to those proposed by students", (3) "because it highlights the contrast between thinking then, and now, bringing into a sharper focus of nature and achievement of our current conceptions".

Pioneering and earlier studies that utilized the HPS perspective to examine textbook content, are mainly led by Mansoor Niaz and his colleagues. Those studies examined mostly college-le-

vel textbooks and foregrounded discipline-specific topics drawn from the chemical and physical sciences, including atomic structure (Niaz, 1998; Niaz & Coştu, 2009) and the photoelectric effect (Niaz et al., 2010). In this matter, for example, Niaz & Maza (2011) analyzed and evaluated 75 college-level general chemistry textbooks which are published in the United States for their representations of NOS. Results showed that the majority of textbooks do not adequately address aspects of NOS. McDonald & Abd-El-Khalick (2017) reported that "overall, these studies generally found that science textbooks either ignored or lacked coherent history and philosophy frameworks to address the development of theories and constructs, or help students appreciate the role of competing frameworks in scientific progress". Among other scholars who have utilized the HPS perspective to examine science textbook content are, Gerick & Hagberg (2010). It has been found that the examined textbooks are weak to represent the adequate aspects of NOS and none of the examined chapters are provided in their historical context. Gericke & Hagberg (2010) explored the use of multiple historical models for gene function in upper secondary biology and chemistry textbooks. Finding demonstrated that the role of various models is absent in the textbooks which cause textbooks to show an inductivist image of science and progress of science.

### Theoretical Framework of the Study

HPS is more than a collection of stories or histories of experiments. HPS is a notion that is built on a philosophical base, and this might create an image of science and epistemology of scientific knowledge. Kant expresses that "philosophy of science is empty without HOS and HOS is blind without philosophy of science". This famous quote figured out that a reconstruction of HOS needed philosophical guidelines (Lakatos, 1980). According to Lakatos (1980), the "philosophy of science provides normative methodologies in terms of which the historian reconstructs 'internal history' and thereby provides a rational explanation of the growth of objective knowledge" and each of those methodologies interprets HOS differently, up to their normative values and priorities. Lakatos also called those methodologies "logic of discovery". Owing to this assumption we can infer that for the implication for education and teaching NOS through HPS, which philosophical guide we use through HPS will yield a different image of science and epistemological products. In this study, we embrace Lakatos' "Methodology of Scientific Research Pro-

grams” as a philosophical guide to look back on the history of Thomson, Rutherford, and Bohr atom theories (22).

The main goal of this study is to test the effect of a content presentation prepared by 111 on the Lakatosian perspective of HPS on the pre-service science teachers’ understanding of the NOS and the progress of science. In the Lakatosian perspective, NOS characterization of Niaz (2009) and Niaz & Arelys (2011) were employed. Those characteristics of the NOS are (1) “Scientific knowledge relies heavily, but not entirely, on observation, experimental (25) science, rational arguments, and skepticism.” (2) “Observations are theory-laden.” (3) “Science is tentative/fallible.” (4) “There is no one way to do science and hence no universal step-by-step scientific method can be followed.” (5) “Scientific progress is characterized by competition among opposite theories.” (6) “Different scientists can interpret the same experimental data in more than one way.” (7) “Development of scientific theories at times is based on inconsistent foundations.” (8) “Scientists require accurate record-keeping, peer review, and replicability.” (9) “Scientists are creative and often resort to imagination and speculation.” (10) “Scientific ideas are affected by their social and historical milieu.” (Niaz, 2009). In this regard, we assume that the content presentation of the textbook chapter is expected to portray those characteristics of the NOS implicitly.

In specific, we focus on how the atom theories of Thomson, Rutherford, and Bohr are demonstrated regarding content and historical progress. Niaz (1998) developed eight criteria (See table 1) that specify what should be included in chemistry textbooks to delineate philosophy and HOS congruent to the Lakatosian perspective. We assume that if those criteria are integrated into science content, it helps to demonstrate the characteristics of NOS which is mentioned by Niaz & Coştu (2009) and Niaz & Arelys (2011). The criteria do not compromise the testing factors; instead, they are part of actual historical progress and development of the content (2) and so that they reflect the dialectic Lakatosian philosophy of science and portray the image of science in the framework of the philosophy. According to Niaz & Arelys (2011), the degree or inclusion amount of the chapter content has a deciding power of showing the characteristics of the NOS and scientific practice as stated originally by Niaz (2016). Moreover, Rodriguez & Niaz (2004), Niaz & Coştu (2009), and Niaz & Arelys (2011) analyzed college-level general chemistry and general physics textbooks. Results showed that the

majority of the textbooks represented science and scientific progress as positivist-inductivist, Schwab’s (1962) “rhetoric of conclusions”. In such a content presentation, there may be lots of epistemological problems, handicaps, and a lack of portrayal of the NOS.

The role of science textbooks in the teaching of the NOS seems neglected in a comparison with teaching and learning activities. In the literature, although there are many studies on textbook analyses and how they must be, there seems no such a textbook or a chapter prepared to measure the effect of it on the understanding of the nature of science. Monk & Osborne (1997) support this claim as they report that even textbooks including HOS, yet, they “only passing reference to the HOS” and “such textbooks are written to provide students with the popular, contemporary, cleaned-up, and pre-justified accounts of the behavior of the natural world”. We aim to cover up the gap in the literature as mentioned above and conducted our study in this direction. The main limitation of the study is restricting the content into one topic which is the atomic structure. In the light of the assumptions so far, the research question is “Does the content representation of Thomson, Rutherford, and Bohr atom theories in college-level general chemistry textbooks in Lakatosian HPS perspective have an affirmative effect in NOS understandings of sophomore pre-service science teachers?”

## METHODS

This research is aimed to see whether a textbook content prepared in the perspective of HPS enhances the NOS views of participants or not. Therefore, the intervention is expected to create effects on participants’ views about the NOS. Cook & Campbell (5) (1976) defined a quasi-experimental study as “the application of an experimental model of analysis and interpretation to bodies of data not meeting the full requirements of experimental control because experimental units are not assigned at random to at least two “treatment” conditions”. Accordingly, the design is proper for social experimentation which consists of the planned intervention. Since the study explores the effect(s) of the learning experience of a group of people who are separated into two groups as experimental and control groups, pure randomization (41) cannot be achieved, thus the study contained pre-test and post-test processes. Hence, a quasi-experimental design was employed. Two researchers firstly prepared atomic structure content in the HPS perspective. One of



the authors of this paper is an experienced expert in the field of teaching chemistry and chemistry education research. Then volunteer participants were determined. All participants firstly responded to the NOS survey. Afterward, participants were randomly divided into two groups as control and experimental group which was provided with the intervention. The intervention lasted in six weeks. Two weeks after the intervention both control and experimental groups were taken with the same NOS survey.

### Participants and Sampling

34 sophomore pre-service science teachers voluntarily participated in the study. Participants have had a general chemistry course in the first year and in that course, a general chemistry textbook of Bağ (2006) used and that textbook was analyzed by a previous study of Niaz & Coştu (2009) according to eight criteria of Niaz (1998) and found as weak to portray characteristics of the NOS and progress of science. A meeting with 41 sophomore pre-service science teachers before the pre-test was held and participants were asked about their participation and 34 of them volun-

tarily accepted to participate in all phases of the study. 13 of the participants were randomly chosen as the experimental group and others as a control group.

After post-test quantitative data analysis, five participants from the experimental group were chosen for a semi-structured interview. Those five participants were selected intentionally according to the highest number of changes from pre-test to post-test. In other words, participants in the experiment group were analyzed individually, and the first five of them had the greatest number of changes in categorical answers (for example from a Positivist to a Transition answer or vice versa). Both groups had taken pre-test and post-test. The experimental group took part in the intervention phase whereas the control group did not. The experimental group participants were served with copies of content prepared from the perspective of HPS or the criteria prepared by Niaz (1998). The content is generated with the modification of the criteria expressed below. Emphasized HPS perspectives in the text and corresponding NOS characterizations implicitly posed by the text are given below in Table 1.

**Table 1.** Integrated HPS Perspectives in the Content and Corresponding NOS Characterization

Focused Content in HPS Perspective in the Text Niaz's (1998) Eight Criteria Emphasized in the Content	Aimed NOS Characterizations in the Text
<p>1 T1— "Cathode rays as charged particles or waves in the ether." This criterion was developed for emphasizing the aim of Thomson's experiment. The criterion points out that Thomson's aim was not to develop an atom model, it was to respond the controversy on the nature of cathode rays whether they are charged particles in the cathode tubes or waves in the ether.</p>	<p>Observations are theory laden. There is no one way to do science and hence no universal step-by-step scientific method can be followed. Different scientists can interpret the same experimental data in more than one way.</p>
<p>2 T2— "Determination of mass-to-charge ratio to decide whether cathode rays were ions or a universal charged particle." This criterion was developed for emphasizing the actual aim of Thomson in determination mass-to-charge ratio. The criterion points out that the aim of the determination of the ratio was not to find its value, but to decide whether they are universal particles. This determination was crucial to conclude that the particles are contained in all kind of matter.</p>	<p>Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism. Scientists are creative and often resort to imagination and speculation.</p>
<p>3 R1— "Nuclear atom." The experiments on alpha particles by Rutherford and his colleagues and the atom model by them had a rival atom theory namely Thomson's plum-pudding model. The criterion focuses on that rivalry and suggests demonstrating how the rivalry was and how the Rutherford model won the rivalry. Especially, the criterion emphasizes progress of science and the roles of theories and experiments in scientific progress.</p>	<p>Science is tentative/fallible. Different scientists can interpret the same experimental data in more than one way. Observations are theory laden. Scientific progress is characterized by competition among rival theories.</p>

- 4 R2— “Probability of large deflections is exceedingly small as the atom is the seat of an intense electric field”. The experiments done with alpha particles showed led Rutherford and his team make an interpretation that atom has an intense electric field in the center. This idea was supported by probability calculations, because the number of large deflection of rays was (1 in 20000 particles). The criterion focuses on the idea behind the Rutherford atom model.
- 24— Science is tentative/fallible.  
Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism.
- 5 R3— “Single/compound scattering of alpha particles.” The reason of deflection of alpha particles was grounded on different bases by Thomson and his colleagues and Rutherford and his colleagues. To support his theory, Thomson advocated compound scattering according to which the right deflection was due to a sum of small deflections whereas Rutherford supported single scattering according to which a single scattering leads the deflection of alpha particles. The winner of this rivalry was determined by a mathematical calculations and Rutherford showed mathematically that compound scattering is impossible because the angle of deflections is larger than 900. This criterion focuses on the dispute between single and compound scattering models and the reason why the single scattering model became winner.
- Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism. Scientists are creative and often resort to imagination and speculation.  
Scientific ideas are affected by their social and cultural milieu.  
Scientists require accurate record keeping, peer review and replicability.
- 6 B1— “Paradoxical stability of the Rutherford model of the atom.” This criterion emphasizes the purpose of Bohr in terms of his efforts that resulted in a new atom theory. It is highlighted that the aim of Bohr was not develop a new atom theory, but to explain the paradoxical stability of Rutherford atom model.
- Scientific ideas are affected by their social and cultural milieu.  
Different scientists can interpret the same experimental data in more than one way.
- 7 B2— “Explanation of the hydrogen line spectrum.” This criterion focuses on Bohr's explanation of the hydrogen line spectrum. Many textbooks mention in a historical perspective that Bohr firstly used experimental data as hydrogen line spectrum and Balmer and Paschen formulas and then published his atom theory. This fact causes a positivist understanding about science and its progress, because it depicts that a positivist line in which an experimental data (Balmer's data), and Bohr experiments for verification and finally postulating a theory. However, HOS demonstrates that Bohr did not even hear and had no idea about the Balmer and Paschen series. This situation shows that, science does not progress in a positivist approach.
- Science is tentative/fallible.  
There is no one way to do science and hence no universal step-by-step scientific method can be followed.  
Scientists require accurate record keeping, peer review and replicability.
- 8 B3— “Deep philosophical chasm.” Bohr atom theory's theoretical principle is a mixture of classical electrodynamics and modern physics. Niaz explains this situation as “a deep philosophical chasm”, defines as a theory building on different bases and clarifies the aim of the criteria as showing “how scientists, when faced with difficulties, often resort to such contradictory “grafts”.
- Development of scientific theories at times is based on inconsistent foundations  
Scientists are creative and often resort to imagination and speculation.



Two weeks after the pre-test, the intervention phase was started. The intervention process consisted of six lessons that per two of which were allocated for each atom theory. Totally, there was an eight weeks long gap between the pre- and post-tests that this time-gap is supposed to be enough to diminish the familiarity to items of the survey. In the lessons, the experimental group was given copies of the chapter of the atomic structure which was prepared according to the eight criteria determined previously by Niaz (2009). Participants were suggested to read the content before coming to lessons and discussed it in the classroom. For each of the atom models, there were two lessons executed. The main and crucial role of the instructor in the lessons was to eliminate unclear and unknown points especially about terminology, concepts, and methodological processes, and create a discussion climate during lessons. The control group was not given further

information or intervention. While the experimental group was engaged in intervention, the control group continued their routines of usual courses of their department and participated to post-test.

### Data Collection and Instrument

#### NOS Survey

To reveal the views of pre-service science teachers' understanding of the NOS and scientific progress, a questionnaire as a survey was used. The questionnaire was used to reveal and collect views of participants on domain-general content knowledge about the NOS and the progress of science. In this study, NOS characterizations of Niaz (2009) were modified to the questionnaire and validated by an expert who studies on NOS, HPS, and science education. Items, target aspect of the NOS, and corresponding categorical views are demonstrated in Table 2.

**Table 2.** Item, Content, and Corresponding Categories of the Test Instrument

Item	Content	Corresponding Category*
Science, finds temporary solutions to problems (Item 1).	The ideas about tentativeness of scientific knowledge were explored. Views of participants about tentativeness of science and scientific knowledge imply epistemological understandings of them.	Agree → L No Idea → T Not agree → P
Presuppositions of scientists influence their researches (Item 2).	This item aims to explore views about scientists are subjective as they design an experiment or develop a theory. Their personal stances in terms of personal beliefs, feelings or avid aims have an effect on their studies or researches. This view reflects that science is a human activity not a system of a mechanical entity.	Agree → L No Idea → T Not agree → P
Imagination of scientists and their creativity influence their researches (Item 3)	This item explores that scientific experiments, theories or laws are products of a human and they are not discovered in the nature, they are invented by scientists.	Agree → L No Idea → T Not agree → P
There is a difference between scientific theory and scientific law (Item 4).	This item explores epistemological beliefs of participants whether they have a view about the difference between a scientific theory and a scientific law.	Agree → L No Idea → T Not agree → P
Scientific experiments are generally done just to see their results without any prediction before them (Item 5).	This item asks for if scientists' previous knowledge, studies or their adhesion to a certain theoretical framework accepted by a scientific community or, by the definition of Kuhn, their loyalty of a paradigm, or, by Lakatosian terminology, their positions in a research program affects when they design and conduct an experiment.	Agree → P No Idea → T Not agree → L
Different scientists can have different ideas in front of same experimental data (Item 6).	This item tries to reveal the views about different scientists' stances and reflections in front of same experimental data as they have properties and factors mentioned in the item 5.	Agree → L No Idea → T Not agree → P

An experimental data can refute a scientific theory (Item 7).	This item explores philosophical and methodological stances about refutations and acceptations of theories.	Agree → P No Idea → T Not agree → L
Science progresses through scientific experiments (Item 8).	This item is to reveal the thoughts about scientific progress. According to Lakatos science progresses through progressive problem shifts in scientific theories, whereas the positivist view considers it progresses with new experimental data and methodologic developments.	Agree → P No Idea → T Not agree → L
Scientific theories can be found on inconsistent bases (Item 9).	According to positivist view, scientific theories are constructed on consistent and parallel bases, whereas Lakatosian view admits that scientific theories can base on inconsistent bases and Lakatos defends this view as giving the Bohr atom theory example. Bohr atom theory is constructed on classical Maxwellian theory and modern quantum theory.	Agree → L No Idea → T Not agree → P
Science progresses through rivalry between different scientific theories. (Item 10).	This item poses an alternative situation to item 8. According to Lakatosian theory in the progress of science theories are the main factors. Lakatos emphasizes that an experimental data can contradict a what a theory assumes but this data cannot refute the theory and that theory is still accepted. If a new theory or another existing theory explains the new experimental data, it becomes accepted and refutes existing unsuccessful theory. This means that rivalry between theories determines the progress in science.	Agree → L No Idea → T Not agree → P

\*L refers to "Lakatosian", P refers to "Positivist", and T refers to "Transitional".

The effects of the intervention were expected to result in changes in those categorical responses, also in philosophical and epistemological views about the NOS. Participant responses/views were classified according to the procedure developed by Blanco & Niaz (1997). The categorization procedure of the first item in the survey is given below as an illustration of the whole categorization process.

*Positivist Views:* The responses in this classification portrays "experimental observation, demonstration and description of an absolute reality that has little to do with the hypotheses and theoretical framework of the scientist" (Niaz & Coştu, 2009). The classification was made according to the study of Lakatos (1980).

*Transitional Views:* Blanco & Niaz (1997) characterizes this type of response having "a partial understanding concerning the existence of alternative / competing models for explaining the experimental observations and that no knowledge is ever absolutely established".

*Lakatosian Views:* This class of responses shows and includes "conflicting frameworks, based on processes that require the elaboration of opposite hypotheses and their evaluation in the light of new evidence" and the classification was made according to the study of Lakatos (1980).

### Participant Interviews

Since the test has close-ended responses, an individual interview with five participants from the experimental group was conducted to deeply understand the background factors. After the post-test, five participants in the experimental group were chosen for an interview. The selection of five participants was done according to the procedure of purposive sampling. In this aim, participants who had the greatest change in categorical answers (the change was considered from Positivist to Lakatosian) were asked to participate to interview voluntarily. In the interview, each participant was asked for each question in which the interviewee changed previously given responses or views.

### Data Analysis

The survey revealing categorical views about the NOS provided two types of information. Firstly, changes in individual responses from pre-test to post-test for both control and experimental group. Secondly, difference in frequencies of given categorical responses. In the study, the independent variable was the reading material prepared from the perspective of HPS and the dependent variable was the view about the NOS. Therefore, frequencies of categorical answers

were given before intervention and after intervention for each item. The quantitative analysis procedure was done in two ways. Firstly, frequency analysis and comparison were done to see the situations before the intervention and after for both groups (Table 2 and Table 3). Because we were dealing with changes in frequencies of categorical responses in two different cases (before and after intervention), the non-parametric chi-square test was used to check whether there occurred a significant difference from pre-test to post-test. Chi-square testing was done in SPSS.22 for each item from the survey and the test was done for both the control and experimental group. The Chi-square test results were considered as strong inferences to see for which item of the survey significant change takes place due to the effect of the

intervention. Data gathered through interviews was used to interpret results gathered through the survey.

## RESULTS AND DISCUSSION

### Survey Findings

Data obtained from the survey was analyzed separately regarding control and experimental groups. In the pre-test for the Control Group (see Table 3), 98 (57,7 %) out of 170 total answers were Lakatosian (L), 45 (26,4 %) Positivist (P), and 27 (15,9 %) Transitional (T) responses were obtained. The post-test results showed that there were 99 (58,2%) Lakatosian, 48 (28,2%) positivist responses, and 23 (13,6%) transitional responses given.

Table 3. Control Group Responses of Pre-test and Post-test Items

Test Items	Lakatosian				Positivist				Transitional			
	Pre-test		Post-test		Pre-test		Post-test		Pre-test		Post-test	
	f	%	f	%	f	%	f	%	f	%	f	%
1	12	71	9	53	4	24	8	47	1	6	0	0
2	11	65	12	71	0	0	1	6	6	35	4	24
3	14	82	15	88	3	18	2	12	0	0	0	0
4	16	94	15	88	0	0	0	0	1	6	2	12
5	13	77	12	71	1	6	2	12	3	18	3	18
6	17	100	16	94	0	0	1	6	0	0	0	0
7	0	0,0	2	12	17	100	14	82	0	0	1	6
8	0	0,0	0	0	13	77	15	88	4	24	2	12
9	9	53	9	53	3	18	3	18	5	29	5	29
10	6	35	9	53	4	24	2	12	7	41	6	35

In a comparison of the control group's pre-test and post-test results, there was no a significant change in the percentages and number of given response categories. The biggest change was not more than 2%. In a comparison pre-test results of the control group and experimental group, there seem no significant difference between the pre-test results of both groups, however, the control group was better about % 4 in Lakatosian answer. This means that the control group was slightly better than the experimental group in the pre-test.

Experimental group results (Table 4) demonstrate that the Lakatosian answer increased from 91 to 126 in pre-test and post-test, respectively. The 53,5% percentage raised to 74,1% percentage in terms of Lakatosian answers and the Positivist answers decreased from the number of 63 (36,5%) to 22 (22,4). There was also a decrease in the number of Transitional answers from 17

to 6. While the rise in the number of Lakatosian answers in the control group was from 57,7% to 58,2% and the rise in the experimental group was from 53,5% to 74,1%. As the control group's pre-test and post-test result showed that there seems no other factor that may influence the views of participants about the NOS and progress of science in the time elapse of intervention, this study assumes that the total rise of about 20% in the number of Lakatosian answers delineates the effect of the intervention.

To see the changes in views regarding each item, each item's results was analyzed individually. Results showed that the highest changes were seen from Positivist to Lakatosian responses and from Transitional to Lakatosian responses. The highest change of percentage was in item-7 from Positivist to Lakatosian view. The Chi-square results showed that there was no significant difference in the results of all items in the control



group. This finding<sup>35</sup> supports the hypothesis that posits the change in the views of the control group happened in the time elapse of intervention can be underestimated. In the tables of the control group, there seems rises and decreases. The percentage of Lakatosian answers slightly raised in items 2, 3, and 4, and in item-10 the percentage raised from 35,3% to 52,9%. In items 4, 5, and 6 there were slight decreases in the percentages of Lakatosian answers, but there was a sharp decrease in item-1 that was from 70, 6% to 52,9 %. In the results of item 7, 8, and 9 there seemed no change in the percentages of Lakatosian answers.

For the experimental group, chi-square test results showed that there were significant differences in the responses of item-2, item-7, and item-7, respectively. In other words, 3 of 10 items had a significant difference between pre-test and post-test. This means that statistical data verifies that there are significant changes in the views of experimental group participants. Moreover,

the Lakatosian responses in item-1 raised from 35,3% to 64,7%, in item-3 raised 94,1 % to 100%, in item-4 raised from 88,2% to 100%, in item- 5 raised from 70,6 to 82,4%, in item-6 raised from 82,4% to 100%, in item-9, raised from 41,2% to 70,6%. However, in item-8 there was no rise and no change in the number and so the percentage of Lakatosian answers, and no one gave any Lakatosian answer to item-8. The overall results showed that there happened roughly 20-30 % changes in the responses toward the Lakatosian category and then we can claim that our hypothesis, which is the content preparation of science textbooks in the HPS perspective may contribute in developing student understanding of NOS, is positively answered.

In Table 4, survey findings<sup>37</sup> experimental group are presented. Changes from pre-test to post-test in the categorical views are demonstrated and the effects of the intervention are visible as quantitative change of categorical views.

**Table 4.** Experimental Group Response Frequencies and Percentages of Pre-test and Post-test Items

Test Items	Lakatosian				Positivist				Transitional			
	Pre-test		Post-test		Pre-test		Post-test		Pre-test		Post-test	
	f	%	f	%	f	%	f	%	f	%	f	%
1	6	35	11	65	11	65	5	29	0	0	1	6
2	12	71	16	94	5	29	0	0	0	0	1	6
3	16	94	17	100	0	0	0	0	1	6	0	0
4	15	88	17	100	1	6	0	0	1	6	0	0
5	12	71	14	82	1	6	2	12	4	24	1	6
6	14	82	17	100	3	18	0	0	0	0	0	0
7	2	12	8	47	15	88	9	53	0	0	0	0
8	0	0	0	0	16	94	17	100	1	6	0	0
9	7	41	12	71	4	24	2	12	6	35	3	18
10	7	41	14	82	6	35	3	18	4	24	0	0

### Interview Episodes

Qualitative data gathered from the semi-structured interview with five participants in the experimental group that demonstrated empirical support for the changes in participants' views. This poses a relation between changes in views and the intervention. Furthermore, some episodes are noted from the interview for firstly the items possessing significant change and other items possessing an increase in the number of Lakatosian responses. The participants were coded as EP (experimental group participants) in the interview episodes. An anecdote of the interview is given below.

*Interviewer:* For the first item, "Science, finds temporary solutions to problems", you

replied in the pre-test as "I do not agree" and in the post-test, you changed your view in which you declared that you accept. What was the reason that made you change your view?

*EP-1:* Because at the beginning there was the Dalton atom model, and then the Thomson atom model was postulated, after that, the Rutherford atom model emerged. It means that they are temporary, and they find temporary solutions.

*Interviewer:* Why did not you accept it at the beginning?

*EP-1:* I thought that science always finds absolute and super solutions.

*Interviewer:* For the sixth item, "Different scientists can have different ideas in front of the same experimental data", you replied in the pre-

test as “I do not agree” and in the post-test, you changed your view in which you declared that you accept. What was the reason that made you change your view?

*EP-11:* Yes. Because the experimental data they got was the same, but they thought differently.

*Interviewer:* Who you think they are? Can give an example, in the context of our lessons?

*EP-11:* The experiments done by Rutherford and the results they got. They studied the same experiment but reached different results. Yes, Thomson and Rutherford had the same experiment but thought differently.

*Interviewer:* You mean that they have some experimental data but different interpretations, right?

*EP-11:* Yes. For example, one of them thought the “plum-pudding model” and the other thought “nuclear model”.

In the data, in presented episodes, participants’ views about given items also seem to be affected by the intervention. Because this study engages in the content presentation to affect the views about the NOS in a limited time, short and limited open-ended responses were taken in the interview. However, although they are short and not deep, their relationship between the content presentations, so with the intervention, seems bare.

### CONCLUSION

Teaching NOS is seen as an important goal of science education (Niaz & Coştu, 2009; Niaz, 2016; McDonald & Abd-El-Khalick, 2017), and demonstration of scientific knowledge in textbooks has a crucial role in this goal (McDonald, 2017; Yang et al., 2020). Textbooks build a learning experience in a one-sided interaction and non-interactive ways but social because of the communication between the reader and the author (Kloser, 2013; Patterson et al., 2017). Furthermore, the treasure of science has been transmitted mostly through written texts. Therefore, a science student can open a science textbook written two-hundred years ago and can learn the scientific content through reading it. In the lights on such considerations, the importance and role of science textbooks in the teaching of science, and teaching of the NOS too, cannot be undervalued.

The hypothesis posited by this study is that if science textbook content is prepared in HPS perspectives they may promote NOS understandings of the pre-service science teacher. To test this hypothesis, we presented an atomic structure

topic in the HPS perspective. Results demonstrate that participants who are given with intervention showed positive changes in NOS views. There observed a statically significant difference between pre-test and post-test results of 3 of 10 items. This change is seen from the positivist NOS view to the Lakatosian NOS view and from a neutral NOS view to the Lakatosian NOS view. This result seems sufficient to answer our research question. Positive effects take place in reading science content on the promotion of pre-service science teachers’ understanding of the NOS and the assumption was in parallel with the previous studies (Niaz, 1998). Content should be prepared from the perspective of HPS. In other words, HPS could be used as a perspective in the preparation of science textbooks. Yet, as Lakatos (1980) puts forth that HOS is a reconstruction of history and it needs a philosophical point of view, depending on which lens of the philosophy a scientist looks back to the history, his interpretations and priorities will be different. Therefore, we claim that presenting historical details is not a mere criterion of the HPS perspective, the content may be viewed in the logic of development and progress of scientific knowledge with the contributors.

Quantitative findings of the study revealed that, in the experimental group, content prepared in the perspective of HPS has a positive effect on the understanding of the NOS and progress of science because the descriptive results yielded more significant changes in the results of the experimental group, while no significant change was observed in the results of the control group. That we found similar results with Seung et al. (2009) who investigated the effect of the “Science Methods” course through which topics of philosophy of science handled and pre-service science teachers’ understandings of the NOS. They reported that textbooks should portray characteristics of science and scientific inquiry implicitly with a complementary role to the teaching learning activities. Furthermore, the study of Abd El-Khalick et al. (2017) a similar interest in this study. They analyzed high school biology and physics textbooks to see how they present the NOS according to the criteria they developed. Their analysis was to see how those textbooks portray the “NOS aspects included the empirical, tentative, inferential, creative, and theory-laden”, the social dimension of the NOS and epistemological nature of scientific laws and theories. Secondly, they investigated how much they present the NOS regarding the author and the publisher. In other words, they wondered which factor is more effective to present the NOS better. They

found that the “author” factor is more effective in depicting the NOS in the science textbooks they analyzed.

Furthermore, findings imply that the intervention leads statistically significant differences in the views about certain NOS aspects and qualitative data makes us infer that, “the intervention seems to help interviewees to give specific examples from the HOS”. Firstly, the view of “science is a human product” seemed to be enhanced. Secondly, the idea, which lies in the core of Lakatosian philosophy of science, “a scientific theory can be refuted by another scientific theory and if there is no another scientific theory that can explain the natural phenomena, the current scientific theory stays valid even nature shows contradictions toward it” seemed to be enhanced. Third, another view of Lakatosian philosophy of science which expresses that “progress of science is not linear and is not always found on consistent bases” seemed to be enhanced. Presenting the content from the perspective of HPS should not be giving historical detail besides the scientific content or equations. It may be considered as a guide to write and arrange the scientific content, or it may be considered as a way to teach the scientific contents. It should be remembered that textbooks convey more than equations or information about a certain discipline of science. Therefore, they should be written in a strategy concerning how will they reflect the characteristics of science and the progress of it.

This study had an interest in the importance of content presentation in science and chemistry textbooks and its relationship with an understanding of the NOS. It supported the idea that how the content in the science textbook is prepared to influence readers' understanding of the NOS. Therefore, in the teaching of the NOS, textbooks have crucial roles in portraying characteristics of the NOS. Based on the results of the study, it is recommended that there should be paid more attention to science textbooks preparation and specific recommendation is content in science textbooks should be prepared from the perspective of HPS.

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