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Analysis of High School Chemistry Textbooks Used in Iran for Representations of Nature of Science

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Abstract

This report includes the analysis of three chemistry textbooks in high schools in Iran for representation of nature of science (NOS). The analysis was framed by an analytical tool developed and validated by Abd-El-Khalick and a team of researchers in a large-scale study on the high school textbooks in the USA. The results indicated that NOS aspects of empirical, inferential and social dimensions of science were the most cited in all the three textbooks. The results revealed particularly, the aspects such as tentative, myth of scientific method and scientific theories were less mentioned and have not been addressed in all three textbooks. Generally, the textbooks fared poorly in their representations of NOS. The findings of this work are incommensurate with the strong emphasis in a reformed school science curriculum that underlies the need for learners to understand the scientific enterprise, and how scientific knowledge develops. The results of this study reinforce the need for a review on the mandate given to textbook publishers and writers so that a stronger focus be placed on the development of materials that better represent the tenets of NOS in educational content related to the chemistry textbooks.

Keywords Nature of science · Chemistry textbooks · Textbook analysis · High school · Iran

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Introduction

In the early 21st century, advances in technology have led to changes in science and technology education, most of which focus on students' lifelong learning of scientific literacy. (Lederman et al., 2013; Liu, 2009). A student who is scientifically literate understands scientific and technological issues well, critiques and questions society issues, and has a responsible and satisfying character (Hazen & Trefil, 1991). In order to achieve the desired level of scientific literacy among individuals, special attention should be paid to NOS in science education (Lederman & Lederman, 2014a, b; Driver et al., 1996). NOS has become an essential part of science education research as well as an essential curriculum component for achieving scientific literacy (Jenkins, 1996; Rudolph, 2000; McComas, 2014; Holbrook & Rannikmae, 2009; Lederman et al., 2013; Abd-El-Khalick, 2013; Jenkins, 2013; Ağlarcı et al., 2016; Hodson & Wong, 2017).

NOS as an important part of scientific literacy, is certainly the main target for science education (McNay, 1988; Clough, 1997; Miller, 1998; Matthews, 2004; Lin et al., 2013; Temel et al., 2018). The structure of NOS, as an important purpose for learners who were studying science, has been advocated for more than 100 years (Lederman & Lederman, 2014a, b). Understanding of NOS aspects helps students and also teachers to obtain scientific knowledge and encourages them to have a positive attitude toward science (McComas & Olson, 1998; Peters & Kitsantas, 2010; Yager, 2010; Liu & Lederman, 2010; Ireland et al., 2014; Celik & Bayrakçeken, 2016; Erduran et al., 2020; Caymaz1 & Aydin, 2020). Also, an understanding of NOS is invaluable to both the teacher and learner as it promotes the development of scientifically literate citizens. Lederman (2007) proposes that scientific literacy empowers one to make decisions on a personal and societal level. Scientific literacy allows citizens in a democracy to make informed decisions on economic and environmental issues relating to science, such as issues pertaining to climate change or energy and power and many more. However, despite this importance and the strong imperative for teachers to reflect NOS in their practice, this construct is naively understood by in-service and pre-service teachers throughout the world (Akerson et al., 2012; Liang et al., 2009), and this compromises their efforts for them to address it with their learners.

Science textbooks play an important role in science education, and numerous studies have evaluated textbooks from various perspectives. These perspective include question level (Pizzini et al., 1992), the quantity of scientific vocabulary (Groves, 1995), content accuracy (Hubisz, 2003), gender equality (Elgar, 2004), the concept of error in textbooks (King, 2010), and whether textbooks discuss NOS (Chiappetta & Fillman, 2007; Abd-El-Khalick et al., 2008; Phillips et al., 2015).

What is the explanation for nature of science? The answer to this question is one of the main issues of science education, which unfortunately there is no agreement between experts in its definition. The phrase "nature of science" is usually used by science educators to refer to topics such as what is science?, how does it work?, how scientists function as a social group, and how society influences and responds to scientific efforts (Clough & Olson, 2008) .The phrase "nature of science" often refers to the sociology of science and epistemology of science, science as a meth-

odology of knowing, or beliefs and values for the development of scientific knowledge (Lederman, 1992). Sociologists, philosophers and historians of science agree on these general characterizations but they disagree on specific issues regarding NOS. In literatures, there are different interpretations about the NOS that have been presented by sociologists, philosophers, scientists and science educators.

The American Association for Advancement of Science in the 2061 project for the nature of science in the book of Benchmarks for science literacy states three components, which are: the scientific worldview, scientific inquiry, and the scientific enterprise. Lederman and co-workers (2002) considered NOS being empirical in nature, constructed on hypotheses, theories, laws and being theory laden, inherently imaginative and creative, with sociocultural embedded knowledge. These ideas are a summary of the basic aspects of NOS that are considered less controversial and related to science education and learning, which should be explicitly stated in science curricula and textbooks (Osborne et al., 2003).

In the paper reported by Lederman (1998) found seven common aspects that underlie NOS. These are: Science is tentative (subject to change), empirically-based (based on and/or derived from observations of the natural world), subjective (theory laden), necessarily involves human inference, imagination, and creativity (involves the invention of explanations), and is socially and culturally embedded. None of these aspects can be considered apart from the others (Schwartz et al., 2004). For instance, tentative aspect of scientific knowledge originates from the creation aspect of that knowledge through empirical observation and inference and each of these actions is influenced by the culture and society in which the science is experienced and also by the theoretical framework and personal subjectivity of the scientist. As new data are considered and exiting data reconsidered, inferences made within a particular context may lead to changes in exiting scientific knowledge (Ramnarain & Chanetsa, 2016).

In recent years, a particular characteristics of NOS, often described as "the consensus view," has obtained acceptance in many countries as a template for curriculum building and research into teachers' and students' NOS understandings. Borgerding and co-worker (Borgerding & Deniz, 2019) have investigated NOS views and epistemological views of college biology students. Yacoubian has also reported (2015) a framework for guiding future citizens to think critically about nature of science and socioscientific issues.

There are reports on the analysis of science textbooks for the representation of NOS aspects (Lumpe & Beck, 1996; McComas, 2003; Chiappetta & Fillman, 2007; Abd-El-Khalick et al., 2008; Wei et al., 2013; Li et al., 2018). For sample, Chiappetta and Fillman, (2007) have reported the analysis of five high school biology textbooks, in the USA, to determine the emphasis given to four themes or facets of the nature of science: (a) science as a body of knowledge, (b) science as a way of investigating, (c) science as a way of thinking, and (d) science and its interactions with technology and society. McComas (2003) has reviewed and analyzed USA secondary school biology texts for representations of "law" and "theory" aspects of NOS. Abd-El-Khalick et al. (2008) have researched the representations of NOS in high school chemistry textbooks and the extent to which these representations have changed during the past four decades. Their analysis focused on the ten aspects of NOS including empirical, tentative, inferential, creative, theory-driven, myth of the scientific method, scientific

theories, scientific laws, social dimensions of science, and social and cultural embeddedness of science. In the study 14 textbooks, including five "series" spanning one to four decades, were analyzed.

The purpose of our study is to use a structured NOS analysis framework to analyze and evaluate three chemistry textbooks approved by the Ministry of Education of Iran for tenth, eleventh and twelfth grades students to determine whether they adequately characterized NOS.

As scientific inquiry has already become a trend in science education throughout the world such as USA, England, Japan, and Australia (McDonald & Abd-El-Khalick, 2017), in Iran also science books have been compiled based on the scientific inquiry process. In the trend, students understand scientific knowledge, acquire scientific skills, comprehend scientific methods and processes, and begin to understand NOS. Scientific attitudes and values are formed in them, and students' creative minds and experimental abilities are developed. High school chemistry textbooks in Iran have also been compiled based on the inquiry process.

The school system in Iran consists of three stages (Since the academic year 2011–2012), the primary school education consists of 6 years (1, 2, 3, 4, 5 and 6 grades) and the middle school education includes 3 years (7, 8, and 9 grades), in which the science book includes chemistry, physics, biology and geology. The high school education consists of 3 years (10, 11, 12 grades) and chemistry is taught as a separate subject in each grade.

As far as we know, Iranian high school textbooks have not been studied on the basis of representation of NOS aspects. Since NOS has gradually made its way into the Iran chemistry curriculum, it is equally important that textbooks are revised for substantial reflection of NOS aspects. This will require authors/publishers to give attention to these approaches (with examples) in presenting chemistry concepts in textbooks. Also, it is expected that researchers make corresponding effort to inform authors and publishers on the need to adequately reflect NOS aspects (with emphases on explicit-reflective approach) in chemistry textbooks for teachers and students to gain a better understanding of the NOS. In the context of the Iran educational setting, the influence of science textbooks in science teaching and learning is enormous and cannot be over-emphasized. Therefore, it becomes necessary to analyze these textbooks for teachers and curriculum developers to be aware of the extent to which NOS aspects are integrated in chemistry textbooks.

Methods

Analytical Framework

Historians, philosophers and social science scientists, as well as science educators and scientists maintain different views on the content of NOS (Abd-El-Khalick et al., 1998; Osborne et al., 2003). This study is according to an analytical framework developed by Abd-El-Khalick et al. (2008). Abd-El-Khalick and his colleagues in the paper were reported the representations of NOS in high school chemistry textbooks over the past four decades. The framework was developed by Abd-El-Khalick et al.

contain 10 key aspects in the NOS. The aspects are as follows: Empirical; Inferential; Creative; Theory-driven; Tentative; Myth of the scientific method; Scientific theories; Scientific laws; Social dimensions of science; and Social and cultural embeddedness of science (Table 1). The analytical framework of this study is according to Table 1.

Explicit Versus Implicit Approaches to Addressing NOS

Abd-El-Khalick et al. (2008) are of the opinion that any analysis of NOS in science textbooks.

should be divided into explicit and implicit characteristics. In the explicit method assumes that students learn about NOS when participating in an experimental design that includes data collection, data analysis, and interpretation. Implicit approaches usually lack any structured opportunities or prompts to help learners reflect on their science-based activities from within a framework that would enable them to build and internalize desired NOS understandings (Abd-El-Khalick & Lederman, 2000). Research has shown that an explicit and reflective approach to teaching NOS aspects will lead to a better understanding of NOS than implicit approaches (Abd-El-Khalick, 2002; Aydin & Tortumlu, 2015; Lederman, 2007).

A Scoring Rubric

The scoring rubric used in this work significantly builds on a distinction between explicit and implicit attention to NOS aspects in the analyzed textbooks. This focus derives from research on the relative impact of implicit versus explicit approaches to addressing NOS instructionally. The representation of NOS characteristics, if any, was assessed based on the scoring rubric developed by Abd-El-Khalick et al. (2008) (Table 2). Permission and include the acknowledgement required by the copyright holder if a table is being reproduced from another source. The score ranging, from +3 to −3, was assigned to a unit of analysis, depending on whether it was explicit or implicit representations of an aspect of the NOS. Abd-El-Khalick and coworkers (2008) in their research were divided analysis of NOS in science textbooks into explicit and implicit characteristics. In the implicit approach, it is assumed that students can learn about NOS as they participate and follow scientific methods in inquiry activities.

According to Table 2, if a unit presented a certain NOS aspect from an entirely explicit perspective, it earned three points. If the unit presented a NOS aspect from an entirely implicit perspective, it earned one point.

Textbook Analysis

In the study, three chemistry textbooks (grades 10, 11 and 12) were analyzed based on aspects of NOS developed by Abd-El-Khalick et al. (2008). The aspects of NOS stated in the Table 1, provided a framework to analysis the textbooks with respect to the extent to which aspects of NOS are represented in the textbooks. The units of analysis included all texts and information on each page of the textbook: complete paragraphs, activities, examples, questions, figures with captions, tables with cap-

Table 1 Explication of the NOS aspects developed by Abd-El-Khalick et al. (2008)

NOS aspect	Dimensions emphasized in textbook analysis
Empirical	Scientific claims are derived from, and/or consistent with, observations of natural phenomena.
Inferential	There is a crucial distinction between observations and inferences. Observations are descriptive statements about natural phenomena that are accessible to the senses (or extensions of the senses) and about which observers can reach consensus with relative ease (e.g. objects released above ground level tend to fall to the ground). Inferences, on the other hand, are statements about phenomena that are not directly accessible to the senses (e.g. objects tend to fall to the ground because of 'gravity').
Creative	Science is not an entirely rational or systematic activity. Generating scientific knowledge involves human creativity in the sense of scientists inventing explanations and theoretical entities. The creative NOS, coupled with its inferential nature, entails that scientific entities (atoms, force fields, species, etc.) are functional theoretical models rather than faithful copies of 'reality'.
Theory-driven	Scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training and expectations influence their work. These background factors affect scientists' choice of problems to investigate and methods of investigations, observations (both in terms of what is and is not observed) and interpretation of these observations.
Tentative	Scientific knowledge is reliable and durable, but never absolute or certain. All categories of knowledge ('facts,' theories, laws, etc.) are subject to change.
Myth of the scientific method	Scientific claims change as new evidence, made possible through conceptual and technological advances, is brought to bear; as extant evidence is reinterpreted in light of new or revised theoretical ideas; or due to changes in the cultural and social spheres or shifts in the directions of established research programs.
Scientific theories	Scientific theories are well-established, highly substantiated, internally consistent systems of descriptions, which (a) account for large sets of seemingly unrelated observations in several fields of research, (b) generate research problems and questions and (c) guide future researches. Theories are often based on suppositions or axioms and posit the existence of non-observable entities. Thus, direct examination is untenable. Only indirect evidence supports the theories: scientists extract specific testable predictions from theories and study them against observations.
Scientific laws	Laws are the description of relationships among observable phenomena. Theories, by contrast, provide explanations for observable phenomena or regularities in those phenomena. Theories and laws are not hierarchically related (the naïve view that theories become laws when sufficient supporting evidence is obtained, or that laws have a higher status than theories). Laws and Theories are different types of knowledge and one does not become the other.
Social dimension of science	Scientific knowledge is socially negotiated. This should not be confused with relativistic concepts of science. This dimension specifically refers to the constitutive values related with established venues for connection and criticism within the scientific enterprise, which serve to increase the objectivity of collectively scrutinized scientific knowledge through decreasing the impact of individual scientists' idiosyncrasies and subjectivities.
Social and cultural embeddedness of science	Science is a human enterprise that is embedded and practiced in the context of a larger cultural environment. So, science affects and is affected by different cultural elements and domains, including social context, philosophy, religion, worldview, power structures, political and economic factors.

Adapted from Abd-El-Khalick et al. (2008)

Table 2 Scoring rubric

Points Allocated	Description of Representation
+3 = Explicit, informed and consistent representation of the target NOS aspect	Explicit statements that convey an informed representation, Consistency across the selected chapters or sections in addressing the target NOS aspect, and Consistency in addressing other directly related NOS aspects.
+2 = Explicit, partially informed representation of the target NOS aspect	Explicit statements that convey an informed, but incomplete representation and consistency across the selected chapters or sections in representing the target NOS aspect. An incomplete representation derives from the textbook materials remaining silent in terms of addressing other related NOS aspects that ensure a complete informed representation.
+1 = Implicit, informed, and consistent representation of the target NOS aspect	An informed representation of the target NOS aspect could be inferred from the textbook materials (e.g., relevant explanations, activities, examples, or historical episodes lacking structured, reflective prompts or explicit statements), and absence of other explicit or implicit messages that are inconsistent with the inferred implicit representation.
0 = The target NOS aspect is not addressed	No explicit or implicit treatment of the target NOS aspect, or not enough materials (statements, examples, historical vignettes, etc.) to make an informed judgment or to convey to the textbook reader a sense about the target aspect of NOS one way or the other.
-1 = Implicit misrepresentation of the target NOS aspect	A naïve representation could be inferred from the textbook materials.
-2 = The textbook materials convey mixed explicit and/or implicit messages about the target NOS aspect	Implicit, informed representations that could be inferred from some parts of the textbook materials are countered by explicit, naïve statements in other parts, or explicit statements that convey conflicting messages about the same NOS aspect.
-3 = Explicit, incorrect and naïve representation of the target NOS aspect	Explicit and incorrect statement that clearly communicate a naïve representation of the target NOS Aspect.

Adapted from Abd-El-Khalick et al. (2008)

tions, charts with captions and marginal phrases. The textbook units were read and then assessed to determine whether the units represented the NOS aspects, and which of the 10 aspects of the nature of science are represented in the textbook units?

Results

In using the scoring rubric, the authors analyzed all units of analysis, including paragraphs, activities, examples, questions, figures with captions, tables with captions, charts with captions and marginal phrases in the textbook targeting the same NOS

aspect for their representation of NOS units that targeted NOS aspects, until a consensus was reached. As individual score for each aspect of NOS can range from −3 to +3, so for the 10 aspects of the NOS, the total score can range from −33 to +33.

Three grades chemistry textbooks (10, 11 and 12 grades) were analyzed in the research and were pseudo-named textbook 10, textbook 11 and textbook 12. The textbook 10 has three chapters. The Chap. 1 discusses about atomic models, periodic table, Lewis structure, conversion of atom to ion and molecule. Chapter 2 includes oxidation reaction, metals and non-metals oxides, chemical reactions, the law of conservation of mass, chemical equation, green chemistry and behavior of gases. Chapter 3, includes concentration, solubility of gases and atmosphere. The textbook 11 also includes three chapters, the Chap. 1 addresses behavior of materials and elements (physical and chemical properties), atomic radius, continuation of the periodic table, reactivity of elements and communication with industry, hydrocarbons and organic chemistry and communication with industry and oil. Chapter 2 includes thermochemistry, chemical kinetics, food, material and energy, heat capacity, specific heat, enthalpy, Hess's law and thermo chemical reaction. Chapter 3 discussed polymerization, types of polymers and communication with life and industry, alcohols, acids and theirs application in the polymerization and green polymer. The textbook 12 has four chapters. The Chap. 1 includes soap and non-soap detergents, acids and bases, electrical conductivity of the solutions, equilibrium constant and corrosion. Chapter 2 discussed about electrochemistry and its relation to industry, electrolysis, corrosion and electroplating. Chapter 3 includes about types of interatomic bond, behavior of molecules and the distribution of electrons in them, chemistry of the dyes and inorganic pigments. Chapter 4 addresses the application of spectroscopy in chemistry, activation energy in the reactions, the production of ammonia, equilibrium in chemical reactions and Le Chatelier's principle, functional groups in organic molecules and production of common polymeric materials in industry and recycling.

It should be noted that text under analysis may present a multiplicity of meanings to different researchers which they may interpret differently (Grbich, 2007). Therefore, the textbooks were analyzed independently by two researchers, both of whom have PhDs in chemistry and educated chemistry. Researchers assessed the textbooks individually and allocated scores for the aspects of NOS that were represented. In the next step, the reviewers agreed on the scoring the desired items, after discussion. Table 3 includes results on the scoring of the 10 NOS items for three textbooks. In this table, these items are presented separately for each textbook and also, after assigning each NOS aspect a point value the total score for each textbook was calculated.

Discussion

In order to illustrate the scoring, some of the desired quote from the textbook was presented (Table 4). In the table, examples of units that agree with aspects of NOS and the score that the authors agreed to assign to the representation of the nature of science are presented. This table provides readers with details on how to allocate for NOS aspects and score them. For example, on page 17 of the textbook 10 is mentioned "Amedeo Avogadro (1776–1856) is the famous Italian chemist who, in honor

Table 3 Textbook scores on the aspects of NOS

NOS Aspect	Textbook 10 Score	Textbook 11 Score	Textbook 12 Score
Empirical	+1	+1	0
Inferential	+1	+1	0
Creative	+1	+1	+1
Theory driven	+1	0	+1
Tentative	+1	0	-1
Myth of scientific method	+1	+1	-1
Scientific theories	0	0	0
Scientific laws	+1	+1	+1
Social dimension	+1	+1	+1
Social and cultural embeddedness	+1	+1	0
Cumulative score	9	7	2

of him, named the number of the particles in a mole of matter as Avogadro's number." This unit represents Theory driven aspect of the NOS, which the authors agreed to assign a+1 score to or on page 49 of the textbook 10 is cite "Alembic is a simple tool designed by Jaber Ibn Hayyan (an Iranian scientist) for distilling materials. This container was used to heat the mixtures as well as to collect and direct the resulting vapors" This unit represents Creative aspect of the NOS, which the authors agreed to assign a score of +1. Another example, which according to the authors is the representation of aspect Inferential of the NOS with a score of +1, is the phrase "The fall of an apple from a tree on the ground is the result of gravitational force and is a sign of gravitational potential, while the electrical conductivity of an electrolyte solution is the result of the force of attraction between ions and unequal poles, and is a sign of electric potential. In fact, the potentials are the result of various interactions." on page 61 of textbook 11.

Finally, NOS tenets were collected for each grade (Table 5). The result of Table 3 reveals that some of the NOS aspects were further addressed by all three textbooks, these aspects were empirical, inferential, social dimension, creative, and scientific laws while the aspects tentative, theory driven, myth of scientific method, and social and cultural were addressed poorly (especially the textbook 12), Scientific theories were completely disregarded by all three textbooks.

In the Table 5, the distribution of NOS aspects was revealed. In the textbook 10, there were 87 occurrences of NOS in 126 pages. Also, in the textbook 11, were presented 67 aspects of NOS in 126 pages and in the textbook 12, were presented 51 aspects of NOS in 126 pages. In all three textbooks, more empirical, inferential and social dimension were addressed and scientific theories were not presented at all in any of three textbooks. The "tentative" NOS aspect was displayed three times in the textbook 10 and one time in the textbook 12, and in the textbook 11, it was not addressed at all. Scientific laws in the textbook 10 were more addressed (seven times) than the textbooks 11 and 12 (three and two times respectively). There was scant attention, especially in the book 12, given to the social dimension. The results of Table 5 also show the textbook 10 has the most representation compared to the other

Table 4 Excerpts from the textbooks representation on the scores assigned to the NOS aspect[a]

NOS aspect	Textbook 10	Textbook 11	Textbook 12
Empirical	Scientists use a device called a mass spectrometer to measure the mass of atoms with high accuracy (+1). (page 17)	Chemists, by observing the materials and performing various experiments, study them accurately. (+1) (page 6)	For example, with a copper blade and another blade, such as zinc and with a fruit such as lemon, you can make a kind of battery and use it to light the LED lamp (Fig. 4). (0) (page 39)
Inferential	Chemists, by giving energy to the atom, also shake it to be become aware of within it! The difference is that instead of hearing sound, they receive and observe the radiation emitted from the atom. (+1) (page 27) The yellow color of the flame indicates incomplete combustion, and the blue color of the flame indicates that the gas burner is working properly and that there is enough oxygen in the reaction medium (+1). (page 57)	The fall of an apple from a tree on the ground is the result of gravitational force and is a sign of gravitational potential, while the electrical conductivity of an electrolyte solution is the result of the force of attraction between ions and unequal poles, and is a sign of electric potential. In fact, the potentials are the result of various interactions. (+1) (page 61)	This color change is a measure of whether the solutions are acidic or playful.(0) (page 24) Experimental findings show that water and all aqueous solutions contain hydronium and hydroxide ions. (0) (page 26) Pure silica is used in the manufacture of prisms and lenses due to its special light properties. (0) (page 68)

Table 4 (continued)

NOS aspect	Textbook 10	Textbook 11	Textbook 12
Creative	About 7,000 years ago, humans were able to heat copper ore along with coal to extract copper metal in molten form. (+1) (page 19) Alembic is a simple tool designed by Jaber Ibn Hayyan (an Iranian scientist) to distill materials. This container was used to heat the mixtures as well as to collect and direct the resulting vapors. (+1) (page 49)	In 1927, the French chemist Charles Janet, by putting the known elements together, in his time, presented a model based on which elements with atomic numbers greater than 118 could be classified. (+1) (page 10) Mohammed Bah Abba, a Nigerian teacher, provided valuable services to the people of his country by designing and building a simple and inexpensive device. (+1) (page 62)	In the past, burning magnesium was used as a light source for photography. In this reaction, Mg (s) burns in O_2 (g) with a dazzling light and becomes MgO (s). (+1) (page 42) Alessandro Volta invented the Volta cell. A cell made up of circular plates of copper and zinc, placed alternately on top of each other, and between them there is a paper smeared in a solution of table salt. (+1) (page 44) Historical evidence shows that the ancient Iranians had made a device for converting chemical energy into electricity by using pottery, pieces of ferrous and copper metals, along with a solution of table salt or vinegar. (+1) (page 44) ….Charles Martin Hall (1863–1914) This American chemist invented this method at the age of 23. (+1) (page 61)
Theory driven	Amedeo Avogadro (1776–1856) is the famous Italian chemist who, in his honor, named the number of the particles in a mole of matter as Avogadro's number. (+1) (page 17) Argon is a colorless, odorless, and nontoxic gas. The word argon means lazy; Because it has very low reactivity. (+1)(page 50) ….an element that called helium (the Greek word helios means sun). (+1) (page 23)	Methane gas was first collected from the surface of the lagoons, hence it is known as lagoon gas. (+1) (page 73) Methanoic acid is the simplest organic acid discovered in 1670, and because it was obtained from the distillation of a red ant, it was named after the formic acid or ant substance. In Latin, the ant is called Formica. (+1) (page 109)	Terrylen is the old brand name of polyethylene terephthalate. The name is derived from the monomers of this polymer, terfetalic acid and ethylene glycol. (0) (page 113)

Table 4 (continued)

NOS aspect	Textbook 10	Textbook 11	Textbook 12
Tentative	Although the Bohr model was able to successfully justify the linear hydrogen emission spectrum, it was unable to justify the linear emission spectrum of other elements. Although the Bohr model was able to successfully justify the linear hydrogen emission spectrum, it was unable to justify the linear emission spectrum of other elements. Following the justification and reason for the linear emission spectrum of other elements, as well as how light emits from atoms, scientists have proposed a layered structure for atoms. (+1) (page 24)		With the advancement of science and technology, new fuel cells have been designed in which methane gas is used instead of hazardous hydrogen gas. (-1) (page 53)
Myth of scientific method	To decipher what God has created, scientists in the experimental sciences discover scientific concepts and formulate relationships between them in order to benefit from them. Sometimes mathematical relationships and formulas predict some new concepts. (+1) (page 29)	Prominent and great scientists are scientists who can understand and explain the patterns, trends and relationships between them by carefully examining the information and findings about various materials and phenomena. (+1) (page 4)	A lot of chemical research is being done to find a way to convert methane gas to methanol. (-1) (page 119)
Scientific theories			
Scientific laws	This trend shows that the filling of the substrates is not only dependent on the quantum's number but also follows a general rule called the Aufbau rule. (+1) (page 30) One of the important properties of chemical reactions is that they all follow the law of conservation of mass. (+1) (page 61)	In other words, the physical and chemical properties of the elements are periodically repeated that known as the Elements Periodic Law. (+1) (page 9) Chemists use other precise methods, such as Hess's law, to determine the ΔH of such reactions. (+1) (page 72)	Equilibrium is shifted in a way that compensates for the effect of that change as much as possible. This description is an expression of the Le Chatelier's Principle. (+1) (page 103)

Table 4 (continued)

NOS aspect	Textbook 10	Textbook 11	Textbook 12
Social dimension	Chemistry helps us to find ways to maintain a healthy life by examining the properties, behavior, and interactions of the gases in this blue coating (earth); May you not leave a heavy footprint on this beautiful planet. (+1) (page 45) Green chemistry is a field of chemistry in which chemists are looking for processes and products that can be used to increase the quality of life by using natural resources and at the same time protect nature. (+1) (page 68)	Roasting a variety of meats is a practical and pleasant example of thermochemistry, especially the enthalpy of burning in life. (+1) (page 70)	Increasing global demand for soap and its applications, on the one hand, and declining supply of this product, on the other, have led chemists to take action. (+1) (page 10) The arrival of phosphate salts from detergents caused (Lake Erie) disaster in the 1960s and destroyed many of the lake's aquatic life. (+1) (page 12) Utilizing chemical knowledge provides the way for the prevention and treatment of diseases. Therefore, it can affect the life expectancy index. (+1) (page 32)
Social and cultural Embeddedness	… The answer to this question was so important that a scientist named Fritz Haber won the Nobel Prize in Chemistry in 1918 for the production of ammonia from H_2 and N_2 gases. (+1) (page 82) it is hoped that with the training of chemistry, educated and responsible citizens will be trained who, relying on knowledge, will use and use God-given resources properly and at the same time prevent the creation of heavy and large footprints on various parts of the globe. (+1) (page 88)	…Chemistry knowledge helps us to identify the exact structure of these gifts, to understand their behavior, and to learn how to use them properly. May we understand that the earth is God's trust and that we believe in friendship with it (+1). (page 1)	The Haber process is an interesting historical example of the complex impact of chemistry on our lives. Although, ammonia production prolonged World War I; but subsequently, the production of chemical fertilizers and increase the efficiency of agricultural products was provided. (0) (page 108)

[a]Representative quote translated from Persian to English

two textbooks and textbook 12 has the least representation, which may be due to the great variety of topics discussed in this textbook. These differences in the extent to which NOS aspects are represented can be attributed to the authors' view and interest in incorporating aspects of the NOS in the textbooks.

In the study revealed the characterizations of NOS are almost entirely implicit, rather than explicit that implicit presentations are not effective in facilitating students' understanding of NOS. The variety of concepts in the textbooks, especially the textbook 12, is relatively high and not every subject is covered in detail, which is probably why representation of NOS is so poor.

The limited emphasis on aspects of the NOS can probably be attributed to the fact that authors of the textbooks do not infer the importance of the NOS from the curriculum documents. In view of this, the findings of this study suggest that chemistry

Table 5 Distribution of NOS aspects in the textbooks

NOS Aspect	Textbook 10	Textbook 11	Textbook 12
Empirical	20	18	14
Inferential	22	18	11
Theory driven	7	5	2
Tentative	3	0	1
Myth of scientific method	4	2	1
Scientific theories	0	0	0
Scientific laws	7	3	2
Social dimension	16	15	17
Social and cultural embeddedness	8	6	3
Total	87	67	51

textbook authors should have a stronger focus on developing materials that better demonstrate the aspects of NOS.

Conclusion

The purpose of this research was to analysis Iran's chemistry textbooks to representations of NOS aspects. Our analysis showed that some aspects of NOS, although minor, were more mentioned in textbooks than others, and some aspects of NOS were not addressed at all. The results of this study revealed that the three chemistry textbooks that were evaluated do not touch upon scientific theories of NOS aspects and tentative was poorly addressed (especially in the textbook 12). In these three textbooks, more attention has been paid to empirical, inferential and social dimension aspects of the NOS. In comparing the three textbooks in this study, the textbook 10 scored the highest marks overall for their presentations of NOS (87, 67, and 51 points, respectively). The analysis of these books shows that, like the analysis conducted in textbooks in other countries, not all aspects of NOS have been given sufficiently attention (Lumpe & Beck, 1996; McComas, 2003; Chiappetta & Fillman, 2007; Abd-El-Khalick et al., 2008; Ramnarain & Chanetsa, 2016; Li et al., 2018). Because textbooks can play an important role in understanding NOS for teachers and students, researchers can establish a line of communication with textbook authors in writing or revising the textbook to gain ideas for ways to allocate NOS in these textbooks. The results of this research have some implications for future study, in this field, and especially the authors and reviewers of chemistry textbooks. For the author of the chemistry textbooks, they must realize the importance of the NOS aspects and the deficiency of NOS in chemistry textbooks (chemistry textbooks of Iran). The results of presented study, showed this situation does not meet the international requirements of chemistry inquiry teaching. We suggest to improve chemistry education in Iranian schools, the chemistry textbook authors should take a variety of methods and measures to integrate the latest insights and NOS aspects into the chemistry textbook. For the textbook reviewers, the present study provides them with specific findings and a way to evaluate chemistry textbooks.

In order to discover the problems and deficiencies in the representation of NOS in the Iranian chemistry textbooks, it is necessary to compare the high-quality chemistry textbooks of other countries with the Iranian chemistry textbooks. Although our research has some results and can be a reference for future research in this field, there are some limitations in this study. In order to understand fully the development trend of representations of NOS in the Iranian chemistry textbooks, future researches can analyze and compare different periods of chemistry textbooks in Iran.

Declarations

Conflict of interest There are no conflicts of interest/competing interests that would affect the decision to publish the manuscript.

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