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A Reconstructed Vision of Environmental Science Literacy: The case of Qatar

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The purpose of this study was twofold: (a) develop a conceptual framework for environmental science literacy; and consequently (b) examine the potential of science standards/curricula to prepare environmentally literate citizens. The framework comprised four pillars: science content knowledge, scientific inquiry, nature of science (NOS), and socioscientific issues (SSI). A conceptual understanding of these pillars as interconnected was presented and justified. Then the developed framework was used to examine the potential of the Qatari science standards to prepare environmentally literate citizens. Results showed that the secondary Qatari science standards generally take up the pillars of science content and scientific inquiry in an explicit manner. The NOS pillar is rarely addressed, while the SSI pillar is not addressed in the objectives and activities in a way that aligns with the heavy emphasis given in the overall aims. Moreover, the connections among pillars are mostly manifested within the activities and between the science content and scientific inquiry. The objectives and activities targeting the environment were less frequent among the four pillars across the Qatari standards. Again, the connections related to the environment were less frequent in conformity with the limited environmental objectives and activities. Implications from this study relate to the need for the distribution of the four pillars across the standards as well as the presentation of the different pillars as interconnected.

Keywords: *Science Literacy; Environmental Education; Science Content Knowledge; Scientific Inquiry; Nature of Science; Socioscientific Issues*

Introduction

In a world dominated by science and technology, it is crucial to raise students who are scientifically and environmentally literate so that they would actively engage and participate in addressing challenges that affect our society. This goal is crucial for people to participate in contemporary society as qualified and responsible citizens. Along

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these lines, all the recent worldwide reform movements in science education have advocated the preparation of scientifically literate students (American Association for the Advancement of science [AAAS], 1989, 1993; Council of Ministers of Education Canada [CMEC] Pan-Canadian Science Project, 1997; Millar & Osborne, 1998; National Research Council [NRC], 1996; Osborne & Dillon, 2008). According to BouJaoude (2002), four components define scientific literacy: (a) knowledge of science, (b) doing and understanding about scientific inquiry, (c) understanding about nature of science (NOS), and (d) understanding of interactions of science, technology, and society (STS). The importance of students' understandings of these components or pillars has been emphasized in the reform documents in science education.

Derived from the scientific literacy framework (BouJaoude, 2002) addressing the four pillars, the primary aim of this paper was to describe and argue for a reconstructed vision of environmental science literacy and then test it on the standards. The conceptual interpretation for the reconstructed vision involves targeting each of the four pillars in an explicit manner both as an educational end and also as a means or an organizational context for the other pillars.

Environmental Scientific Literacy

Scientific literacy has been conceptualized by Heiskanen (2006) as having three main arguments: humanistic (people need to survive in a world infused with science), democratic (people need to take part in public life and decision-making), and socio-economic (people need to be educated and skillful to advance the economic development of the nation). At the same time, Resnick and Hall (2001) advocated for a commitment toward the connectedness of content knowledge, high-level thinking, and active use of knowledge. They argued that real learning takes place in an integrated way, and that also addresses the issue of limited time for teachers at the school level.

Environmental science literacy is an aspect of scientific literacy (Heiskanen, 2006) that extrapolates onto the knowledge of environmental science. The simple notion of environmental literacy as only an education about the environmental science content is insufficient. To achieve a meaningful environmental literacy calls for creating a dialogue between science and society (Heiskanen, 2006), and carrying that dialogue as a means to promote environmental science literacy. Therefore, all the four components framed by BouJaoude (2002) are required for environmental science literacy, and not just the component related to the content. As such, the development of the framework for environmental science literacy in the present study derives from the scientific literacy framework used by Chiapetta, Sethna, and Filman (1993) and adapted by BouJaoude (2002). In addition, we further argue about the interconnectedness among the four literacy pillars, which resembles real-life environmental situations that students encounter in their everyday lives. To promote learning in such a way, we need to continually integrate within the curriculum rigorous content knowledge about environment with high thinking demand and active use of knowledge (Resnick & Hall, 2001) along with the ability to formulate arguments and make informed decisions about controversial science-based issues. Conceptually, the environmental science literacy framework primarily aims at targeting each of the four pillars as an end as well as a context for the other pillars. This integrated view is justified with a core argument that draws upon two lines of research, namely studies that have focused on student achievement and have addressed these four pillars in an isolated fashion, as well as studies that have shown relationships between the pillars at different levels.

Pillars of Environmental Science Literacy

This section discusses the four pillars of scientific literacy and the evidence that shows some difficulties and challenges in the learning and development of these four pillars (content, inquiry, NOS, and STS) among students. The four pillars of scientific literacy were initially used by Chiapetta et al. (1993) and adapted by BouJaoude (2002) and they included the knowledge of science, the investigative NOS, science as a way of knowing, and the interaction of STS. We propose that the difficulties encountered in the learning of these pillars might be due to the unrelated manner in which these pillars were presented and/or taught.

Science content. The aspect about the knowledge of science includes facts, concepts, principles, laws, hypotheses, theories, and models of science (AAAS, 1993; BouJaoude, 2002; Chiapetta et al., 1993; NRC, 1996; National Science Teachers Association [NSTA], 1982, 1992). The role played by this aspect has been strongly emphasized in science education. As noted by Holbrook and Rannikmae (2009), Millar (1997) puts forward data to suggest that the strongest predictor of scientific literacy in adults is the amount of basic school science. Schwab (1964) considered that there are four topics in education: the learners, the teacher, the milieu, and the subject matter. He stressed that 'only subject matter, among the four, has been relegated to the position of a good wife: taken as familiar, fixed, and at hand when wanted' (p. 4). Gabel (2003) noted that the objectives of science instruction should be conceptual understanding as well as scientific inquiry. Marinin and Case (1989) stressed the importance of content knowledge on one's ability to apply the specific knowledge to particular tasks. Along the same lines, Stewart, Finley, and Yarroch (1982) highlighted the role played by the conceptual knowledge in science instruction. They supported their position on the basis of philosophers of science and information processing psychologists. First, they noted that philosophers of science had considered the importance of conceptual knowledge held by the scientific community as a key factor in understanding the nature and functions of science. They further noted that the logical empiricists and the recent philosophers of science emphasize the role of conceptual knowledge in guiding scientific inquiry. Similarly, Hempel (1966) perceived that scientific conceptual knowledge guides scientists' observations and methods. Other epistemologists as Brown (1977) and Hanson (1958) stated that this knowledge shapes the perceptions and observations of scientists, which translates into the idea of 'theory-laden observations'. According to Stewart et al. (1982), the second source supporting the important role of conceptual knowledge comes from information processing psychologists who focus on the schema concept. Schema theorists emphasized the role of conceptual knowledge in the acquisition of new knowledge and the ability to solve problems. At the same time, increasing the science content may force students to memorize, which might be detrimental to conceptual understanding (Gabel, 2003).

Scientific inquiry. The second pillar addresses the investigative NOS or scientific inquiry. Gabel (2003) noted that many meanings have been given to 'scientific inquiry' but that it refers to more than conducting laboratory experiments or hands-on activities. This aspect consists of answering questions about the world (Gabel, 2003) and it involves the student in using methods and processes of science such as observing, measuring, classifying, inferring, experimenting, recording, making calculations, analyzing data, and communicating science (AAAS, 1993; BouJaoude, 2002; Chiapetta et al., 1993; Lederman & Niess, 1998; NRC, 1996; NSTA, 1982, 1992). According to the National Science Education Standards (1996), the term *scientific inquiry* encompasses the doing of inquiry and the understandings about inquiry that enable students to derive conceptual understandings of scientific concepts as well as the limitations of scientific explanations. In general, curricula have focused on the performance of scientific inquiry skills to the exclusion of understandings about inquiry to accomplish the goal of scientific literacy. In other words, students would be involved in an inquiry activity but would not reflect on the process they were engaged in. That would lead to having students become highly skilled in making observations, but they would have little understanding about what they are observing or the basis of the conclusions they made or the 'knowledge' they produced.

Again, many studies that examined students' inquiry abilities have reported difficulties. For example, many have shown that the students cannot distinguish evidence from explanations (Germann & Aram, 1996; Kuhn, Amsel, & O'Loughlin, 1988; Kuhn & Phelps, 1982), and students' failures were attributed to the lack of students' thinking skills and inquiry experiences. In their study, Kuhn and Phelps (1982) found that children had unsystematic experimentation and drew invalid conclusions. They also did not distinguish theory from evidence, or understanding a phenomenon from producing that phenomenon.

Nature of Science (NOS). The third pillar, science as a way of knowing, represents thinking, reasoning, and reflection in the construction of scientific knowledge and the work of scientists (Hurd, 1994, 1998; Lederman & Niess, 1998), as well as the understanding of the NOS and scientific knowledge (Lederman & Niess, 1998; NRC, 1996).

Abd-El-Khalick, Bell, and Lederman (1998) claim that the disagreements regarding a universal definition for NOS are irrelevant to K-12 students. There are some general characteristics of the scientific knowledge (Lederman, 2007) that can be reasonably taught to K-12 students and are relevant to their everyday lives. These involve understanding that scientific knowledge is tentative, subjective, empirical, inferential, creative and imaginative, and socially embedded. An additional aspect is the relationship between theories and laws.

Enhancing learners' views of NOS and the different ways to address that objective have been a focus of science education research (Lederman, 1992). Extensive research has indicated students do not come to understand the NOS solely as a consequence of having experienced scientific inquiry or hands-on activities. That is, students do not come to understand that the development of scientific knowledge involves creativity and human subjectivity, and is partially a function of both observations and inferences. NOS should be taught explicitly within the science content, whereby learners focus deliberately on various aspects of NOS during classroom instruction, discussion, and questioning (Abd-El-Khalick et al., 1998; Khishfe & Abd-El-Khalick, 2002; McDonald, 2010). Researchers (Akerson, Abd-El-Khalick, & Lederman, 2000; Bell, Lederman, & Abd-El-Khalick, 2000) have consistently provided evidence for success of attempts with an explicit approach in improving both students' and teachers' understandings of NOS. However, even with an explicit approach to teach NOS, numerous research studies have shown limited success in enhancing more informed understandings of NOS among students. Some of the studies used a nonintegrated approach, where NOS was addressed as separate from the regular science content through NOS activities, and/or lectures, which have the specific goal of addressing students' understandings of NOS (Durkee, 1974; Liu & Lederman, 2002). In comparison, the integration of the NOS pillar with other pillars as scientific inquiry (Carey, Evans, Honda, Jay, & Unger, 1989; Khishfe & Abd-El-Khalick, 2002) and/or socioscientific issues (Khishfe & Lederman, 2006; Walker & Zeidler, 2007) could help to enhance the success of attempts to improve student learning about NOS.

STS issues. The interaction of STS aspects reflects an understanding of the interrelationships between science, society, and technology (AAAS, 1993; Hurd, 1994; Lederman & Niess, 1998; NSTA, 1982, 2010). It also encompasses the ability to understand careers and science-related social issues (Hurd, 1994; NSTA, 1982). Addressing the interactions of STS can be conceptualized in terms of socioscientific issues (SSI) (Fleming, 1986; Klosterman & Sadler, 2010; Kolsto, 2001; Sadler, Chambers, & Zeidler, 2004; Topcu, Yilmaz-Tuzan, & Sadler, 2010; Zeidler, 2003; Zoller, 1982), which refer to social science-based ill-structured problems that involve multiple perspectives (Sadler & Zeidler, 2005a). Zeidler and Nichols (2009) noted that having students interact with SSI has been recognized as being essential by the international science education community. Students need to develop the knowledge and skills to use and apply science to make informed decisions (Zoller, 1982) relative to socioscientific issues confronted in their daily lives in order to achieve the vision of the scientifically literate citizen and advance more democratic societies (Aikenhead, 1985; Fullinwider, 1987). Therefore, the curriculum needs to include science-related issues of public concern (Tytler, Duggan, & Gott, 2001).

Engaging students in argumentation is critical to help them make decisions about personal and global issues. To start with, developing the students' skills of decision-making is targeted in STS education (Aikenhead, 1994). Students need to base their decisions on scientific evidence and information in relation to SSI. At the same time, decision-making is developed and built up through argumentation (Patronis, Potari, & Spiliotopoulou, 1999, Zeidler & Nichols, 2009) about SSI. Decision-making and argumentation in relation to SSI are considered as two closely connected competence areas in science education in the new National Standards in Germany (as cited in Eggert & Bogeholz, 2010). Therefore, the process relating to argumentation and decision-making needs to be addressed in the context of SSI within the science curriculum (Osborne, Erduran, & Simon, 2004).

Yet previous studies have shown that people regardless of their age struggle in their argumentation skills when examined in the context of informal reasoning. A study (Kuhn, 1991, 1993) showed that only a few of a sample of 160 people across their life span were able to consistently generate arguments, counterarguments, and rebuttals. A link between knowledge and reasoning or argumentation has been supported in studies (Hogan, 2002; Tytler et al., 2001; Zohar & Nemet, 2002) that explored relationships between students' understanding of science concepts and their socio-scientific argumentation practices. However, the foci of these studies were not directly related to informing these relationships, and the evidence was not particularly strong (see Sadler & Zeidler, 2005b). At another level, Means and Voss (1996) found that content knowledge is related to some aspects of argumentative thinking, such as generating more reasons or stating more qualifiers, but not to other aspects. However, Kuhn (1991) found that a large or sophisticated knowledge base in a content domain does not determine the quality of argumentative thinking skills used in that domain. Perkins, Farady, and Bushey (1991) found no significant correlation between prior thinking about an issue and the quality of arguments about it. Sadler and Donnelly (2006) proposed the *Threshold Model of Content Knowledge Transfer* as a theoretical model to account for the interaction of argumentation practice and science content knowledge in relation to SSI. They proposed a nonlinear relation, where they suggested that science content knowledge can affect the manner in which individuals defend and justify their positions.

Connectedness of the Science Literacy Pillars

Following is a discussion of the connectedness of the pillars of science literacy, as evidenced from research efforts. Such evidence about the success of connectedness among the pillars of science literacy (content, inquiry, NOS, and SSI) would also support the argument for connectedness among the pillars of environmental science literacy.

Science content and scientific inquiry. Resnick and Hall (2001) endorsed the need to engage students in thinking in the context of a solid knowledge base. According to them, content knowledge and thinking process are intimately joined and interconnected. NRC (2000) claimed that one of the common myths about inquiry is that it can be taught without attention to subject matter. Therefore, the view that thinking can be taught without content knowledge or the view that content knowledge can be taught without engaging students in thinking must be abandoned. The connections between science knowledge and inquiry or problem-solving skills have been well-documented in literature (Saunders & Jesunathadas, 1988). On one hand, some studies focused on the role of content knowledge in the acquisition of inquiry and problem-solving strategies. Novak (1979) claimed that one's prior knowledge is the best predictor of his or her ability to learn discipline facts and concepts. Stewart (1982) identified the lack of content knowledge, and not the ability to use combinatorial reasoning, as a major factor that contributed to the poor performance of students on genetics problem solving. Furthermore, Saunders and Jesunathadas (1988) found that students were not able to apply the reasoning strategy to unfamiliar task content, which implies that the content had influenced the application of reasoning skills (Linn, Pulos, & Gans, 1981). Similarly, Chi and Koeske (1983) found that a child who is expert in a specific domain knowledge as dinosaurs had a more integrated knowledge structure for familiar dinosaurs and less integrated for less familiar dinosaurs. Children who have more experience in domain-specific knowledge (e.g. in mathematics or science) move more rapidly in acquiring more complex skills (Bowman, Donovan, & Burns, 2001). At the same time, Klahr, Chen, and Toth (2001) argued that general scientific reasoning skills are always 'couched-perhaps even overwhelmed by specific context' (p. 81). Therefore, content-specific knowledge further plays a major role in shaping an individual's problem-solving strategies (Stewart et al., 1982).

On the other hand, there were other studies that highlighted the role of inquiry skills in problem solving and content acquisition. Champagne, Klopfer, and Anderson (1980) found that reasoning and mathematical skills had a greater influence than students' prior content on their achievement in mechanics. The lack of reasoning skills, rather than lack of prior content knowledge, was reflected as the major source of difficulty and limited performance in achievement and solving genetics problems (Mitchell & Lawson, 1988; Smith & Good, 1984; Walker, Mertens, & Hendrix, 1979). At the same time, Heyworth (1999) found differences between expert and novice students in both their content knowledge and inquiry skills when solving a chemistry problem. All of these studies suggest that each of the two pillars (content and inquiry skills) influences the application of the other pillar, and consequently both have an influence on student outcomes. Accordingly, the teaching of scientific inquiry needs to be incorporated within specific subject domains (Mayer & Wittrock, 1996).

Science content and NOS. For the connections between the science content and NOS, some studies hinted at the possibility of a relationship between views of NOS and the science content. In fact, the limited success of the research efforts in promoting better understandings of NOS has been attributed to the context of the science content in which NOS has been explicitly taught (Abd-El-Khalick, 2001; Khishfe & Abd-El-Khalick, 2002), and is thus affected by the learning of science content knowledge. In light of that, many researchers (Brickhouse, Dagher, Letts, & Shipman, 2000; Clough, 2003; Ryder, Leach, & Driver, 1999) claimed that integrating the explicit teaching of NOS within the context of the science content would lead to more improvements in students' views of NOS. Along these lines, Khishfe and Lederman, (2006) found that the improvement in students' understandings of NOS into more informed views was 'slightly' higher when NOS was integrated within the science content about global warming. It would have been also beneficial if the study also explored the improvement of students' science content knowledge to trace whether it was influenced by the integration with NOS. In that study, the author considered that the teaching of NOS and science content as distinct does not entail an accurate and representative conceptualization of what occurs in a real classroom. Along these lines, it has been argued for integrated NOS instruction, whereby the experimental work of scientists and the NOS activities are ultimately linked and integrated within the science content for K-12 students (Clough, 2003; Khishfe & Lederman, 2006).

Science content and SSI/Argumentation. Driver, Leach, Millar, and Scott (1996) argued that students can have different views of science and different forms of reasoning (phenomenon-based, relation-based, and model-based) that are activated in different contexts. To start with, the understanding of content knowledge was found to correlate positively with the quality of informal reasoning regarding SSI (Sadler & Zeidler, 2005b). Further, Sadler and Fowler (2006) advocated that the way individuals defend and justify their positions is affected by their science content knowledge. Recently, Fowler and Zeidler (2010) found variations in the way students utilized their arguments about SSI due to the specific nature of the issue. Furthermore, it was found that one's science content knowledge significantly relates to the number and types of reasons generated by argumentations (Means & Voss, 1996).

The underlying assumption in many of these studies is that learners' content knowledge related to the SSI under study can considerably influence their argumentation practice (Dawson & Schibeci, 2003; Patronis et al., 1999; Yang & Anderson, 2003). That is, learners depend on their scientific understandings when analyzing and justifying their positions in relation to SSI. More support for the presumed relationship between content knowledge and socioscientific argumentation comes from another study by Sadler and Zeidler (2005b) who found that the group of science majors with well-developed understandings of genetics demonstrated significantly higher quality argumentation in the context of genetic engineering issues than the group of non-science majors with naive understandings of genetics.

Scientific inquiry and NOS. As for the connections between scientific inquiry and NOS, it can be viewed from two lenses: (a) understanding NOS is a necessary step in making scientific inquiry a meaningful part of the students' world and (b) scientific inquiry can serve as a context or a framework to teach about NOS, another component of scientific literacy.

Students' NOS views could be enhanced when NOS instruction is explicitly taught as embedded in the context of content-related scientific inquiry (Carey et al., 1989; Khishfe, 2008; Liu & Lederman, 2002). In these studies, students engaged in inquiry-oriented activities that addressed particular science content. The activities allowed students to engage in a problem-solving situation, and students were guided to use data to come up with their conclusions and answer the question under study. Explicit discussions of NOS aspects usually followed the inquiry activities and students were guided to discuss and reflect on the work of scientists and the development of scientific knowledge in relation to the activity under study. Therefore, the context of inquiry has allowed students to reflect on their own inquiry process in relation to that of scientists.

Scientific inquiry and SSI. For effective scientific inquiry in the classroom, it has been suggested that the problems investigated must be authentic whereby the investigation is embedded in a real-world context that addresses students' everyday lives (Crawford, 2000; Eisenhart, Finkel, & Marion, 1996; Moss, Abrams, & Robb, 2001). Authentic inquiry experiences are a way to contextualize content information and promote scientific literacy regarding the process of science (AAAS, 1993; Rutherford, 1964). For example, local environmental SSI can be explored as part of inquiry in the science classroom.

NOS and SSI. At another level, SSI can also offer a natural, inherent, and effortless context for NOS discussions (Khishfe & Lederman, 2006; Matkins & Bell, 2007; Sadler et al., 2004, Walker & Zeidler, 2007). Many researchers have argued that SSI provide an ideal context for enhancing students' understanding of NOS since they present 'science in the making' and bring students into direct contact with the values and assumptions that compromise NOS (Matkins & Bell, 2007). The relative success of using SSI as a context to teach NOS has been documented in recent work (Khishfe & Lederman, 2006; Khishfe, 2012a; Matkins & Bell, 2007; McDonald, 2010) in relation to enhancing learners' understandings of NOS. At the same time, NOS can be thought of as providing a context or a means for argumentation and decision-making in relation to SSI. One of the arguments that has been advanced for the teaching of NOS in school science curricula is democratic in nature (Driver et al., 1996); it identifies the importance of NOS in helping people take part in argumentation and decision-making regarding SSI. In that sense, SSI can help students to apply their understanding of NOS into real-world decision-making (Bell & Lederman, 2003). Recently, a study by Khishfe (2012a) provided empirical evidence to support the claim that teaching high school students about NOS can help to promote their decision-making in relation to controversial SSI such as genetically modified food.

Studies have also shown a relationship between learners' understandings about NOS and their argumentation skills, and explicitly suggested that one of them might influence the other (Bell & Linn, 2000; McDonald, 2010; Zeidler, Walker, Ackett, & Simmons, 2002). Along these lines, Khishfe (2012b) found a relationship between students' understandings of NOS aspects and their argumentation (particularly their counterarguments) without any explicit instruction on NOS or argumentation. To such a degree, emerging research studies (Bell & Linn, 2000; McDonald, 2010; Ogunniyi, 2006; Sandoval & Milwood, 2008) have suggested that engaging students in argumentation may assist in the development of their NOS understandings. At another level, other research has put forward that learners' NOS understandings have some influence on their engagement in argumentation (Nussbaum, Sinatra, & Poliquin, 2008; Sandoval & Milwood, 2008). That translates into the view that students with naïve understandings of the NOS aspects have difficulties in their argumentation about scientific issues (Clark & Sampson, 2006; Kuhn & Reiser, 2006). With the integration of both explicit NOS and explicit argumentation instruction, McDonald (2010) found that the development of pre-service teachers' understandings of NOS was enhanced in a science content course.

Concluding summary and purpose

To sum up, building on these matters that consider effective student development of the four pillars of literacy seems to favor an attempt that advances the interconnectedness among the four pillars to promote environmental science literacy. Each literacy pillar (content, inquiry, NOS, and SSI) needs to be addressed as an end by itself as well as a means, which can contextualize the other pillars. Thus, the purpose of this study was to (a) develop a conceptual framework for environmental science literacy, which emphasizes the distribution and interconnectedness of the four pillars; and consequently (b) examine the potential of science standards/curricula in aligning with the framework to prepare environmentally literate citizens.

A Framework for Environmental Science Literacy

The above definitions and arguments supported from the literature lead to the conclusion that integration among the pillars would better promote environmental science literacy. BouJaoude (2002) emphasized four aspects of science literacy and they included the knowledge of science, the investigative NOS, science as a way of knowing, and the interaction of STS.

Few adaptations and additions to the framework were needed in order to address environmental science literacy and align it with recent findings about the different pillars of science literacy. In the present framework for environmental science literacy, there are two stages. The first stage addresses the presence of the four pillars of environmental science literacy. First, the primary pillar addresses the knowledge of content in relation to environmental science. Second, the second pillar focuses on the use of scientific inquiry methods and processes in relation to the environment. The third pillar emphasizes the reflection on the construction of scientific knowledge and work of scientists in relation to environmental science. The fourth theme related to interaction of STS; it is conceptualized in terms of SSI. The components of this theme discussed in the framework by BouJaoude (2002) included (a) impact of science on society; (b) inter-relationships between science, society, and technology; (c) careers; (d) science-related social issues; (e) personal use of science to make everyday decisions, solve everyday problems, and improve one's life; and (f) science-related moral and ethical issues. In the present framework, all the above components (except for careers) are conceptualized through the emphasis on argumentation and decision-making in the context of SSI. The component about careers does not seem to be vital for environmental science literacy. Table 1 shows the first part of the framework, which was adopted and revised from BouJaoude (2002) to be used in the present study for the purpose of investigating the distribution of these pillars (especially the environmental) in the standards and curricula. Table 2 shows the second part of the framework, which was specifically designed in the present study to examine the connections among the four different pillars.

Then the second part of the framework was specifically designed in this study to examine the connections among the four different pillars. To further validate the

Table 1. Part I: Presence of pillars of environmental science literacy

	Strands in the Qatari science standards							
	Scientific inquiry	Life science	Materials	Earth and space	Physical processes	Biology	Chemistry	Physics
Pillar								
1. The knowledge of science Facts, concepts, principles, laws, hypotheses, theories, and models related to environmental science								
2. The investigative nature of science (scientific inquiry) Using methods and processes of science as observing, measuring, classifying, inferring, experimenting, recording, making calculations, analyzing data, and communicating in relation to environmental science								
3. Science as a way of knowing (NOS) Emphasizes thinking, reasoning, and reflecting on the construction of scientific knowledge (NOS aspects) and work of scientists in relation to environmental science								
4. Interaction of science, technology, and society (SSI) Emphasizes argumentation and decision-making in relation to controversial environmental SSI								

Table 2. Part II: Connectedness among the pillars of environmental science literacy

Connectedness among the four pillars	%
1. Connection between Pillar 1 and Pillar 2 Addresses the content and scientific inquiry in the objective/activity	
2. Connection between Pillar 1 and Pillar 3 Addresses the content and NOS in the objective/activity	
3. Connection between Pillar 1 and Pillar 4 Addresses the content and SSI in the objective/activity	
4. Connection between Pillar 2 and Pillar 3 Addresses scientific inquiry and NOS in the objective/activity	
5. Connection between Pillar 2 and Pillar 4 Addresses scientific inquiry and SSI in the objective/activity	
6. Connection between Pillar 3 and Pillar 4 Addresses scientific NOS and SSI in the objective/activity	
7. Connection between Pillar 1, Pillar 2, and Pillar 3 Addresses the content, scientific inquiry, and NOS and SSI in the objective/activity	
8. Connection between Pillar 1, Pillar 2, and Pillar 4 Addresses the content, scientific inquiry, and SSI in the objective/activity	
9. Connection between Pillar 1, Pillar 3, and Pillar 4 Addresses the content, NOS, and SSI in the objective/activity	
10. Connection between Pillar 2, Pillar 3, and Pillar 4 Addresses scientific inquiry, NOS and SSI in the objective/activity	
11. Connection between Pillar 1, Pillar 2, Pillar 3, and Pillar 4 Addresses the content, scientific inquiry, NOS, and SSI in the objective/activity	

above framework, there was a need to test the framework with its two parts with science standards and curricula. For that purpose, the Qatari science standards were selected and that was based on two criteria. First, we looked for new recent educational reform in science education in the Arab world. It was assumed that a new science reform would strive to prepare students to attend to the modern world through science and its applications. Moreover, a new reform would and should attend to environmental science literacy. In the case of Qatar, the environment is greatly valued. The General Secretariat for Development Planning (2008) created a national development vision for Qatar, which became the Qatar National Vision (QNV) 2030. This vision places environmental development among Qatar's strategic goals in a concerted effort to advance a modern society capable of sustaining its development and providing a high standard of living for all Qataris by 2030. The QNV also highlights the importance of increasing citizens' awareness of their role in protecting the country's environment for the country's future generations. Toward achieving that, there have been many sophisticated environmental institutions aiming to promote public awareness about environmental education through conducting awareness-raising campaigns, employing environmental planning tools, and carrying out environmental research.

Of the many high-impact projects and sprouting initiatives, the Qatar General Electricity & Water Corporation –KAHRAMAA – (2000) is a government initiative that provides Qatar's need of high-quality electricity and water services. KAHRAMAA also promotes the culture of conservation among all society classes. It launched the National Campaign for the Conservation and Efficient Use of Water And Electricity 'Tarsheed' to ensure sustainability and raise awareness with the intention of reducing consumption for the better living of Qatari people over the years.

Another institute, the Qatar Energy and Environment Research Institute – QEERI – (2011) is the member of Qatar Foundation for Education, Science and Community Development. It was launched in 2011 to conduct and coordinate research that addresses critical national priorities relating to energy and the environment. QEERI focuses on supporting two of Qatar's challenges: energy and water security. For example, the water security challenge focuses on water sustainability and the increase of food production in Qatar. QEERI's target research on the development of energy-efficient water desalination technologies and water re-use and water quality will lead to increased energy efficiency, reduced costs, and minimized health risks and environmental impacts. For outreach, QEERI also contributes to local capacity building and scientific literacy, engaging different sectors of the public in an active dialogue for a community targeting better environmental habits, cleaner technologies, and informed decisions in energy and environment matters. Toward that end, QEERI took the leadership in forming an outreach network, which has been promoting and facilitating collaborations for better awareness programs.

Description of the Qatari Science Standards

A new reform initiative, *Education for a New Era*, was launched in 2005 as Qatar's education system. According to the Supreme Education Council (2002), what defines the science curriculum standards is a focus on the content vital for preparing students to be engaged and productive citizens. Critical thinking, inquiry, and reasoning are themes that are emphasized in all grades to prepare students who develop the ability to work creatively, think analytically, and solve problems.

The school system abides by free education to all citizens and a compulsory education policy until the end of the elementary stage. The public school system consists of 12 years with the following three stages: (1) Elementary stage: six years, (2) Preparatory (intermediate) stage: three years, and (3) Secondary stage: three years. The branches in the science standards for Grades K-9 are: scientific inquiry; life science; materials; Earth and space (beginning in Grade 4); and physical processes. As for science standards for Grades 10–12, these include biology; chemistry; physics; and a scientific inquiry branch.

The education system in 'Qatar' is governed mostly by 'the Supreme Education Council and by the Ministry of Education'. The Council aims to improve the quality of secondary schools by creating independent schools. There are also a large number of private and international schools. The Outstanding Schools Program has also been developed as part of Qatar's ongoing educational reform to meet the needs of Qatar's growing population. The educational reform, Education for a New Era, is based on principles that include offering a variety and choice of educational options to families in Qatar as well as a deep respect for local values and traditions. The Outstanding Schools Program addresses these core principles and merges them with the best from the world of international education. Two private international schools opened in 2008, a third opened in 2009, and new Outstanding Schools are expected to open in Qatar over the coming years. These three Outstanding Schools are selected from top schools throughout the world which teach accredited international or national curricula. These schools run the International Baccalaureate program. In addition to implementing the curriculum model from their home campus, all Outstanding Schools in Qatar teach Arabic, Islamic Studies, and Qatari Social Studies.

Procedures

As noted earlier, a second purpose of this research study was to examine the potential of a science curriculum to prepare environmentally literate citizens. For the purposes of this study, the focus was on the Qatari curriculum or standards. As such, the purpose of the study was addressed by investigating the presence and description, as well as the connectedness of the pillars of environmental science literacy in the Qatari science standards. That was carried out by analyzing all the overall aims of the science standards, the objectives, and curriculum activities for each of the targeted grade levels using the above framework with its two parts.

The analysis involved several stages and was conducted by the author and another science educator to establish inter-rater reliability. In the first stage, the author met with the other researcher to discuss the framework with its two parts and reach a common understanding about their components. Then the two researchers jointly categorized two of the overall aims, four of the objectives, and four of the activities in the standards as addressing one or a combination of the four pillars (science content, scientific inquiry, NOS, and SSI) to secure consistency. In the third stage, the author and the other science educator categorized another set of the standard objectives and activities. Discrepancies were discussed and consensus was reached between the two researchers. Finally, the rest of the aims, objectives, and activities were similarly and independently categorized by the two researchers, who met to discuss and settle the discrepancies in categorization. Then the percentages of the objectives and activities belonging to each pillar were computed across the different levels. For the first part of the framework, the distribution of the four pillars (with a focus on the environmental) was examined. Some of the overall aims, objectives, and/or activities addressed more than one pillar, and that also indicated the presence of connections among the different pillars and that was more clearly defined and described in the second part of the framework.

Results

The results are organized as four categories: the overall aims or goals, the K-4 grades, the 5–9 grades, and the 10–12 grades.

Overall Aims or Goals

The percentage distribution of the pillars of environmental science literacy in the overall aims or goals of the Qatari science standards shows that three of the four pillars are represented in varying degrees (Table 3), with the exception of the third pillar that addresses science as a way of knowing (NOS). It is interesting to note that the first, second, and fourth pillars (science content, inquiry, and SSI) that relate to environmental science are equally represented. At another level, there are connections between some of the pillars within the same aim (Table 4). For example, the following overall aim of the Qatari science standards (Supreme Education Council, 2002) connects between the content, scientific inquiry, and SSI. Further, it sends a clear and explicit message about the attention to environmental issues, where students should:

> have a sound and systematic knowledge of important scientific facts, concepts and principles, and possess the skills needed to apply these in new and changing situations in a range of personal, domestic, industrial and environmental contexts

Grades K-4

The percentage distribution of the pillars of the environmental science literacy in the objectives of the Qatari science standards for Grades K-4 shows that the first pillar (science content) is well represented, while the second pillar about scientific inquiry is represented to a lesser extent (Table 5). And, the third and fourth pillars that address NOS and SSI are poorly represented in these grades. Above all, Table 5 demonstrates that the four pillars related to the environment are not frequently and consistently addressed in all grades. For example, they are well addressed in Level K only in the branch of scientific inquiry where they are related to the pillars of science content and scientific inquiry. However, they are well addressed in Levels 1–4 in the branch of life science and are specifically related to the pillar of science content. Also, the pillars related to environment are to some extent addressed in Grade 2 in the Physical Processes branch and is specifically related to the pillars of science content and SSI.

Table 3. Percentage distribution of the pillars of science literacy and environmental science literacy in the overall aims of science standards

Pillars of science literacy	%
1. Science content	22
Environmental	22
2. Scientific inquiry	55
Environmental	22
3. NOS	0
Environmental	0
4. SSI	22
Environmental	22

Table 4. Percentage distribution of the connections among the pillars of environmental science literacy in the overall aims of the science standards

Connections among the four pillars	%
1. The objective connects between content and scientific inquiry	22
Environmental	22
2. The objective connects between the content and NOS	0
Environmental	0
3. The objective connects between the content and SSI	22
Environmental	22
4. The objective connects between scientific inquiry and NOS	0
Environmental	0
5. The objective connects between scientific inquiry and SSI	22
Environmental	22
6. The objective connects between NOS and SSI	0
Environmental	0
7. The objective connects between the content, scientific inquiry, and NOS	0
Environmental	0
8. The objective connects between the content, scientific inquiry, and SSI	11
Environmental	11
9. The objective connects between the content, NOS, and SSI	0
Environmental	0
10. The objective connects between scientific inquiry, NOS, and SSI	0
Environmental	0
11. The objective connects between the content, scientific inquiry, NOS, and SSI	0
Environmental	0

At another level, there are connections between some of the pillars within the same objective, even though the percentage distribution of these connections is low (Table 6). For example, the following overall aim of the Qatari science standards (Supreme Education Council, 2002) connects between content and scientific inquiry where the highest percentage distribution of this connection is in Grade 3 (14%). Also, other connections are found between science content and SSI. Furthermore, the connections related to the environment are less frequent in accordance with the limited objectives that are environmental. As an example, the following objectives address both content and SSI, where they relate to social issues that are science-based. The first two address general issues, but the third one addresses the environment:

> Know the general effects of alcohol, tobacco and harmful drugs on humans. (Life science, grade 4)
>
> Know that metals, particularly steel, are useful for making machines that have moving parts, such as cars and aeroplanes, and that steel is used in making buildings. (Materials, grade 4)
>
> Illustrate how local industry takes steps to care for the environment. (Life science, grade 2)

With respect to the activities, the percentage distribution of the pillars for Grades K-4 is shown in Table 7. Similarly, most of the emphasis rests on the science

Table 5. Percentage distribution of the pillars of environmental science literacy in the objectives of Grades K-4 of the Qatari standards

	Pillars of environmental science literacy																			
	Science content (%)					Scientific inquiry (%)					NOS (%)					SSI (%)				
	Grades																			
Strands	K	1	2	3	4	K	1	2	3	4	K	1	2	3	4	K	1	2	3	4
Scientific inquiry	21	6	2	2	2	21	28	37	29	21	0	0	0	0	0	0	0	0	0	0
Environmental	14	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Life science	21	14	22	26	27	0	0	0	2	0	0	0	0	0	0	0	0	5	0	0
Environmental	0	14	15	10	13	0	0	0	2	0	0	0	0	0	0	0	0	5	0	0
Materials	36	14	20	14	23	7	0	2	2	1	0	0	0	0	0	0	0	0	0	6
Environmental	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Earth and space	–	–	–	–	10	–	–	–	–	0	–	–	–	–	0	–	–	–	–	0
Environmental	–	–	–	–	0	–	–	–	–	0	–	–	–	–	0	–	–	–	–	0
Physical processes	14	38	22	31	19	0	0	2	10	0	0	0	0	0	0	0	0	5	2	0
Environmental	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	
Total	92	66	66	73	71	28	28	41	43	22	0	0	0	0	0	0	0	10	2	6
Total (environmental)	14	14	20	10	17	14	0	0	2	0	0	0	0	0	0	0	0	10	0	4

Table 6. Percentage distribution of the connections among the pillars of environmental science literacy in the objectives of Grades K-12 of the Qatari standards

	Grades												
Connections among the four pillars	K	1	2	3	4	5	6	7	8	9	10	11	12
1. The objective connects between content and scientific inquiry	7	0	7	14	4	7	5	7	9	3	9	6	8
Environmental	7	0	0	2	0	2	2	1	3	0	0	0	1
2. The objective connects between content and NOS	0	0	0	0	0	0	0	0	1	0	0	0	0
Environmental	0	0	0	0	0	0	0	0	0	0	0	0	0
3. The objective connects between content and SSI	0	0	7	2	8	7	3	2	9	20	2	5	13
Environmental	0	0	7	0	4	7	3	0	1	17	1	2	11
4. The objective connects between scientific inquiry and NOS	0	0	0	0	0	0	0	0	3	1	0	0	0
Environmental	0	0	0	0	0	0	0	0	0	0	0	0	0
5. The objective connects between scientific inquiry and SSI	0	0	0	0	0	0	2	0	2	1	0	0	0
Environmental	0	0	0	0	0	0	2	0	0	1	0	0	0
6. The objective connects between NOS and SSI	0	0	0	0	0	0	0	0	0	0	0	1	1
Environmental	0	0	0	0	0	0	0	0	0	0	0	0	0
7. The objective connects between content, scientific inquiry, and NOS	0	0	0	0	0	0	0	0	1	0	0	0	0
Environmental	0	0	0	0	0	0	0	0	0	0	0	0	0
8. The objective connects between content, scientific inquiry, and SSI	0	0	0	0	0	0	2	0	2	1	0	0	0
Environmental	0	0	0	0	0	0	2	0	0	0	0	0	0
9. The objective connects between content, NOS, and SSI	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental	0	0	0	0	0	0	0	0	0	0	0	0	0
10. The objective connects between scientific inquiry, NOS and SSI	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental	0	0	0	0	0	0	0	0	0	0	0	0	0
11. The objective connects between content, scientific inquiry, NOS, and SSI	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental	0	0	0	0	0	0	0	0	0	0	0	0	0

content and scientific inquiry. The pillar about SSI is rarely addressed. As for the pillar about NOS, it is absent from the activities of Grades K-4 (Table 7). Table 7 shows that the activities targeting the environment are more frequent and it is addressed in all Grades K-4 in the branch of life science where it relates to the pillars of science content and scientific inquiry.

At another level, there are connections between some of the pillars within the same objective. The connections between content and scientific inquiry are relatively high (32–73% in Grades 1–4), and that is somewhat displayed within the activities

Table 7. Percentage distribution of the pillars of environmental science literacy in the activities of Grades K-4 of the Qatari standards

	Pillars of environmental science literacy																			
	Science content (%)					Scientific inquiry (%)					NOS (%)					SSI (%)				
	Grades																			
Strands	K	1	2	3	4	K	1	2	3	4	K	1	2	3	4	K	1	2	3	4
Scientific inquiry	29	18	0	1	0	6	16	6	1	0	0	0	0	0	0	0	0	0	0	0
Environmental	0	8	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Life science	32	29	39	39	46	6	12	20	23	13	0	0	0	0	0	0	2	2	1	3
Environmental	16	25	23	9	27	3	12	14	7	4	0	0	0	0	0	0	2	2	0	1
Materials	23	12	25	23	24	13	4	18	17	15	0	0	0	0	0	0	0	2	1	2
Environmental	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Earth and space	–	–	–	–	9	–	–	–	–	6	–	–	–	–	0	–	–	–	–	0
Environmental	–	–	–	–	0	–	–	–	–	0	–	–	–	–	0	–	–	–	–	0
Physical processes	16	42	29	36	20	10	25	15	33	17	0	0	0	0	0	0	0	4	4	0
Environmental	0	0	5	0	0	0	0	3	0	0	0	0	0	0	0	0	0	5	0	0
Total	100	100	93	99	99	35	57	59	74	51	0	0	0	0	0	0	2	9	6	5
Total (environmental)	16	33	28	9	28	3	20	17	7	4	0	0	0	0	0	0	2	7	0	2

Table 8. Percentage distribution of the connections among the pillars of environmental science literacy in the activities of Grades K-12 of the Qatari standards

	Grades												
Connections among the four pillars	K	1	2	3	4	5	6	7	8	9	10	11	12
1. The objective connects between content and scientific inquiry	32	57	55	73	52	74	74	71	56	64	55	50	57
Environmental	3	20	16	6	4	16	18	18	13	19	5	4	14
2. The objective connects between content and NOS	0	0	0	0	0	0	1	3	7	4	2	3	3
Environmental	0	0	0	0	0	0	1	2	0	0	0	0	1
3. The objective connects between content and SSI	0	2	7	6	6	15	3	5	10	28	13	15	17
Environmental	0	2	7	0	3	11	3	3	2	19	10	9	12
4. The objective connects between scientific inquiry and NOS	0	0	0	0	0	0	1	2	1	1	1	0	0
Environmental	0	0	0	0	0	0	1	1	0	0	0	0	0
5. The objective connects between scientific inquiry and SSI	0	0	5	0	0	3	1	1	5	15	3	5	4
Environmental	0	0	2	0	0	2	1	1	1	10	3	2	2
6. The objective connects between NOS and SSI	0	0	0	0	0	0	0	1	0	1	0	0	1
Environmental	0	0	0	0	0	0	0	1	0	0	0	0	0
7. The objective connects between content, scientific inquiry, and NOS	0	0	0	3	0	0	1	1	1	1	0	0	0
Environmental	0	0	0	0	0	0	0	1	0	0	0	0	0
8. The objective connects between content, scientific inquiry, and SSI	0	0	2	0	0	3	1	1	4	12	0	5	4
Environmental	0	0	0	0	0	2	1	1	1	8	0	3	2
9. The objective connects between content, NOS, and SSI	0	0	0	0	0	0	0	1	0	1	0	0	1
Environmental	0	0	0	0	0	0	0	1	0	0	0	0	0
10. The objective connects between scientific inquiry, NOS and SSI	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental	0	0	0	0	0	0	0	0	0	0	0	0	0
11. The objective connects between content, scientific inquiry, NOS, and SSI	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental	0	0	0	0	0	0	0	0	0	0	0	0	0

(Table 8). Also, other connections are found between science content and SSI for Grades 1–4. Furthermore, the connections related to the environment are less frequent in accordance with the activities that were environmental. As an example, the following activities address both content and SSI. The first addresses general issues, but the second one addresses the environment:

> Use the internet to gain information on the negative effects of drugs on the body. (Life science, grade 4)

> Find out about how methane is obtained out of the ground and stored in Qatar. (Materials, grade 4)

As another example, the following activities address both content and scientific inquiry. The first addresses general issues, but the second one addresses the environment:

> Make a simple forcemeter from elastic bands for propelling toy cars or containers along a flat surface. (Physical processes, grade 3)

> Observe and record over time the growth of similar green plants of the same species kept in different conditions. (Life science, grade 3)

Grades 5–9

The percentage distribution of the pillars of environmental science literacy in the objectives of Grades 5–9 is presented in Table 9, which clearly shows how the pillar of science content is widely addressed at Grades 5–9. As for the pillar of scientific inquiry, it is represented in Grades 5–9 and its objectives contribute to 15–23% of total objectives. The SSI pillar is poorly represented in Grades 5–9. As for the third pillar about NOS, it is almost absent in the objectives of Grades 5–9. Above all, Table 9 demonstrates that the four pillars related to the environment are not frequently and consistently addressed in all grades. The pillars related to the environment are well represented in the objectives of Grades 5–9, which are related to the pillar of science content and specifically to the branch of Life Science. The objectives related to the environment are almost absent from the pillars of scientific inquiry, NOS, and SSI for Grades 5–9.

At another level, there are connections between some of the pillars within the same objective, even though the percentage distribution of these connections is low (Table 6). For example, there are connections between the science content and scientific inquiry as well as between science content and SSI. It is worth noting that the connections between science content and SSI for Grade 9 are present as 20% in relation to the total objectives. Also, there are poor connections between content and NOS, scientific inquiry and NOS as well as between scientific inquiry and SSI. It needs to be noted that these connections are not frequently and consistently addressed among all grade levels. Finally, there are very modest connections among the three pillars: content, scientific inquiry, and NOS for Grade 8 only as well as between content, scientific inquiry, and SSI for Grades 6, 8, and 9. Furthermore, the connections related to the environment are less frequent in accordance with the objectives that are environmental. As an example, the following objectives address both content and SSI. The first addresses general issues, but the second and third ones address the environment:

> Know that the structures such as bridges are systems of moments in equilibrium that take best advantage of the specific properties of the materials from which they are made.

Table 9. Percentage distribution of the pillars of environmental science literacy in the objectives of Grades 5–9 of the Qatari standards

	Pillars of environmental science literacy																			
	Science content (%)					Scientific inquiry (%)					NOS (%)					SSI (%)				
	Grades																			
Strands	5	6	7	8	9	5	6	7	8	9	5	6	7	8	9	5	6	7	8	9
Scientific inquiry	2	2	1	0	3	16	17	15	13	15	0	0	3	3	4	0	0	0	0	2
Environmental	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1
Life science	25	37	13	22	20	0	0	1	2	0	0	0	0	0	0	0	3	0	0	3
Environmental	7	12	11	9	8	0	0	1	2	0	0	0	0	0	0	0	3	0	0	2
Materials	23	14	29	22	26	0	3	5	1	0	0	0	0	1	0	9	2	0	0	9
Environmental	12	2	1	0	10	0	2	0	0	0	0	0	0	0	0	9	2	0	0	9
Earth and space	7	12	11	8	7	2	0	0	0	0	0	0	1	1	0	0	0	1	1	0
Environmental	7	0	9	0	0	2	0	0	0	0	0	0	1	0	0	0	0	1	0	0
Physical processes	26	23	33	30	27	5	0	0	4	0	0	0	0	0	0	0	0	2	9	7
Environmental	0	0	2	3	4	0	0	0	1	0	0	0	0	0	0	0	0	0	1	4
Total	83	88	86	82	83	23	20	21	20	15	0	0	4	5	4	9	5	3	10	20
Total (environmental)	26	14	23	12	22	2	2	1	3	1	0	0	1	0	1	9	5	2	1	16

(Physical processes, grade 9)

> Know that air pollution is an inevitable consequence of the petrochemical and petroleum industries and explain steps taken by companies to minimize it. (Materials, grade 9)

> Know that water is essential for life; recognize the importance of water conservation and of not polluting seas, rivers, and other water supplies. (Materials, grade 5)

The percentage distribution of the pillars of environmental science literacy in the activities ofGrades 5–9 is presented in Table 10, which clearly shows how the pillar of science content and scientific inquiry are widely addressed in the activities of Grades 5–9 (Table 10). The SSI pillar is rarely addressed except in Grade 9, where the percentage of SSI activities is 35% of total activities (Table 10). As for the pillar about NOS, it is poorly represented in the activities of Grades 5–9. Above all, Table 10 demonstrates that the environmental issues are very well represented especially in the branch of Life Science in relation to the pillars of science content and scientific inquiry. Also, environmental issues are well represented in the branch of Materials for Grades 5 and 9 where they are related to the pillar of science content. Again it is well addressed in the branch Earth and Space for Grades 5 and 7.

At another level, the connections among the pillars are more frequent in the activities for Grades 5–9, as compared with the objectives especially for the science content and scientific inquiry (Tables 6 and 8). There are also connections between science content and NOS for Grades 6–9 as well as between science content and SSI for Grades 5–9. Finally, there are modest connections among the three pillars: content, scientific inquiry, and SSI for all 5–9 grades (17% for Grade 9) as well as between content, scientific inquiry, and NOS for Grades 6–9. Also, there is a connection between science content, NOS, and SSI for Grades 5–9. As for the connections related to the environment, they are generally as frequent as the activities that are environmental and those are mostly addressed between the content and scientific inquiry. As an example, the following activities address both content and SSI. The first addresses general issues, but the second one addresses the environment:

> Explain everyday observations in terms of particle theory (e.g. clothes drying, water leaking from an air conditioner, ice in a refrigerator, smelling a perfume, the pressure in a balloon. (Materials, grade 7)

> Make a study of the origins of the Qatar gas field. (Earth and space, grade 7)

As another example, the following activities address both content and scientific inquiry. The first addresses general issues, but the second one addresses the environment:

> Prepare slides of cheek cells and onion epidermis and examine them under the microscope. (Life science, grade 6)

> Use numerical data on animal populations in various habitats to draw a pyramid of numbers for each habitat. (Life science, grade 8)

Table 10. Percentage distribution of the pillars of environmental science literacy in the activities of Grades 5–9 of the Qatari standards

	Pillars of environmental science literacy																			
	Science content (%)					Scientific inquiry (%)					NOS (%)					SSI (%)				
	Grades																			
Strands	5	6	7	8	9	5	6	7	8	9	5	6	7	8	9	5	6	7	8	9
Scientific inquiry		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Life science	24	38	18	35	39	16	27	13	37	26	0	0	0	2	3	2	5	1	0	8
Environmental	5	20	13	13	15	3	16	11	10	10	0	0	0	0	0	0	5	1	0	3
Materials	24	18	40	26	23	13	16	32	16	11	0	0	1	2	1	8	1	3	1	24
Environmental	15	1	3	1	22	3	1	2	1	5	0	0	0	0	0	8	1	2	0	22
Earth and space	13	20	11	10	5	11	11	5	6	1	0	1	1	2	0	0	0	2	3	0
Environmental	13	0	10	0	0	11	0	5	0	0	0	0	1	0	0	0	0	2	0	0
Physical processes	37	24	29	29	25	37	19	21	19	22	0	0	1	0	1	0	0	1	6	3
Environmental	0	0	1	5	1	0	0	0	2	1	0	0	1	0	0	0	0	1	2	1
Total	98	100	98	100	92	77	73	71	78	60	0	1	3	6	5	9	6	7	10	35
Total (environmental)	23	21	27	19	38	17	17	18	13	16	0	0	2	0	0	8	6	6	2	26

Table 11. Percentage distribution of the pillars of environmental science literacy in the objectives of Grades 10–12 of the Qatari standards

	Pillars of environmental science literacy											
	Science content (%)			Scientific inquiry (%)			NOS (%)			SSI (%)		
	Grades											
Strands	10	11	12	10	11	12	10	11	12	10	11	12
Scientific inquiry	6	1	1	12	9	12	1	3	1	1	1	1
Environmental	0	1	1	1	0	1	0	0	0	1	0	1
Biology	22	26	23	0	1	1	0	0	0	0	0	3
Environmental	2	3	12	0	0	1	0	0	0	0	0	3
Chemistry	40	34	40	2	1	1	0	0	0	1	4	6
Environmental	9	3	5	0	0	0	0	0	0	1	2	5
Physics	27	37	23	12	11	5	0	0	0	9	1	4
Environmental	10	1	1	4	0	0	0	0	0	8	0	3
Total	95	98	87	26	22	19	1	3	1	11	5	14
Total (environmental)	21	8	19	5	0	2	0	0	0	10	2	12

Grades 10–12

The percentage distribution of the pillars of environmental science literacy in the objectives of the secondary grades (10, 11, and 12) is presented in Table 11 and that clearly shows how the pillar of science content is widely addressed in the secondary grades. The pillar of scientific inquiry is also well represented but less than science content (Table 11). As for the pillar about NOS, it is almost absent in the objectives of the secondary grades. Similarly, the pillar about SSI is addressed in a marginal way where the highest percentage distribution of this pillar is found in Grade 12 (14%) within the objectives of scientific inquiry, biology, chemistry, and physics. Above all, Table 11 demonstrates that the four pillars related to the environment are not frequently and consistently addressed in all grades. The pillars related to the environment are addressed in Grades 10–12 mostly in relation to the pillar of science content. It is also important to note that the pillars related to the environment are rarely represented except in relation to the pillar of SSI in Grade 12.

Equally important are the connections between some of the pillars within the same objective. Table 6 provides a summary of these connections, which is shown to be minimal within the same objective. As such, the more frequent connections, when presented, are found between the content and scientific inquiry on one hand, and between the content and SSI on the other hand. Also, there are modest connections between NOS and SSI for Grades 11 and 12. Furthermore, the connections related to the environment are less frequent in accordance with the objectives that were environmental. As an example, the following objectives address both content and SSI. The first addresses general issues, but the second one addresses the environment:

Show an understanding of the properties of hydrogen peroxide as an acid and an oxidizing agent and understand the use of peroxides as oxidants in rockets and explosives. (Chemistry, grade 12)

Explain how micro-organisms are used in the treatment of wastewater. (Biology, grade 12)

The percentage distribution of the pillars of environmental science literacy in the activities of the secondary grades (10, 11, and 12) is presented in Table 12, which clearly shows how the pillar of science content is widely addressed at the secondary grades (similar to that of the objectives). The pillar of scientific inquiry is also well represented but less than science content (Table 12). As for the pillar about NOS, it is rarely represented except in Grade 12 (15%). The pillar about SSI is more frequent than that addressed in the objectives of Grades 10–12.

At another level, the connections among the pillars are more frequent in the activities for Grades 10–12, as compared with the objectives, especially for the science content and scientific inquiry (Tables 6 and 8). There are also more frequent connections than the objectives between science content and NOS as well as between science content and SSI for Grades 10–12. Some connections are also present between scientific inquiry and SSI for Grade 10–12 and between the content, scientific inquiry, and SSI for Grades 10 and 11. Connections are also noted between the content, scientific inquiry, and SSI for Grades 11 and 12. Furthermore, the connections related to the environment are generally as frequent as the activities that are environmental. As an example, the following activities address both content and scientific inquiry. The first addresses general issues, but the second one addresses the environment:

Table 12. Percentage distribution of the pillars of environmental science literacy in the activities of Grades 10–12 of the Qatari standards

	Pillars of environmental science literacy											
	Science content (%)			Scientific inquiry (%)			NOS (%)			SSI (%)		
	Grades											
Strands	10	11	12	10	11	12	10	11	12	10	11	12
Scientific inquiry	14	27	1	12	12	13	2	3	1	2	7	6
Environmental	2	6	1	0	2	5	0	0	0	2	5	5
Biology	23	25	23	13	11	13	0	0	1	1	2	5
Environmental	2	2	12	2	1	8	0	0	1	0	1	3
Chemistry	21	27	40	8	12	10	1	1	0	5	5	5
Environmental	3	4	5	1	1	0	0	0	0	3	3	1
Physics	27	19	23	20	12	10	0	0	1	1	2	3
Environmental	0	1	1	0	0	0	0	0	0	0	1	2
Total	85	98	87	53	47	46	3	4	3	9	16	19
Total (environmental)	7	13	19	3	4	13	0	0	1	5	10	11

> Investigate the rate of osmosis between solutions of different concentrations. (Scientific inquiry, grade 12)

> Investigate the rate of photosynthesis of an algal culture at different light intensities. (Scientific inquiry, grade 12)

As another example, the following activities address both content and SSI. The first addresses general issues, but the second addresses the environment:

> Study the social benefits brought by the simple drug aspirin (acetylsalycilic acid) since its discovery over a century ago. (Chemistry, grade 12)

> Study issues raised by the release into the environment of potentially harmful chemicals such as DDT, polychlorinated biphenyls and certain chlorofluorocarbon refrigerants. (Chemistry, grade 12)

Discussion

The purpose of the present research study was to (a) conceptualize an understanding of environmental science literacy as an integration among four pillars (science content, scientific inquiry, NOS, and SSI) and (b) investigate the potential of a science curriculum to prepare citizens to be literate about the environment.

For the science curriculum, results show that three of the four pillars of environmental literacy in the overall aims or goals of the Qatari science standards are represented in varying degrees, with the exception of the third pillar that addresses NOS. The Qatari standards do not clearly and convincingly address science as a way of knowing (NOS, Pillar 3) in the aims, objectives, and activities. The knowledge of science content (Pillar 1) is emphasized in its entirety in the aims, objectives, and all activities. In the overall aims of the Qatari science standards, the environment and its issues have a considerable emphasis and it is addressed within the content, scientific inquiry, and SSI. It is interesting to note that the two pillars (science content and SSI) relating to environment are very well represented among the overall goals. Connections among the pillars in the overall aims and objectives are noted and equally addressed between the content and scientific inquiry, the content and SSI, as well as between scientific inquiry and SSI.

For the distribution of the pillars in the objectives, results showed that the pillars of science content and scientific inquiry are both addressed, with scientific inquiry to a lesser extent. As for the NOS pillar, it is almost absent in the objectives of the different grades. With respect to the pillar about SSI, it is addressed in a marginal way within the objectives of the different grades. Above all, the four pillars related to the environment are not frequently and consistently addressed in all grades. Equally important are the connections between some of the pillars within the same objective. Results show that these connections are minimal within the same objective. As such, the more frequent connections, when present, are found between content and scientific inquiry on one hand, and between content and SSI on the other hand. Again, the connections related to the environment are less frequent in accordance with the limited objectives that were environmental.

With respect to the activities for the different grades, they shared a similar distribution to the objectives for the four pillars. There is heavy emphasis in the activities on the content and then on scientific inquiry. There is marginal emphasis on SSI in the activities and almost null on NOS. As for the connections among the pillars in the activities, these are mostly addressed between the content and scientific inquiry and rarely between the content and SSI. And most importantly, the activities targeting the environment are less frequent in accordance with the modest objectives related to the environment. Again, the connections related to the environment are less frequent in conformity with the limited environmental activities. Further, the connections among the pillars are more frequent in the activities, as compared with objectives, especially for the science content and scientific inquiry.

Therefore, the Qatari science standards have the seeds toward planting literacy for environmental science. However, there needs to be more focus on environmental integration within the different branches of the science standards and curriculum. Further, there needs to be emphasis on the NOS (Pillar 3). Furthermore, it is important to integrate the pillar about SSI within the objectives and activities in a way that aligns with the heavy weight given to it in the overall aims of the Qatari science standards. In the current Qatari science standards, there is heavy emphasis on the science content, moderate emphasis on scientific inquiry, null emphasis on NOS, and marginal emphasis on SSI.

As such, this paper sheds light on how school science curricula can maximize their effectiveness by targeting the science literacy pillars both as an educational end as well as an organizational context for the other pillars. In this paper, we have witnessed that in relation to the Qatari science curriculum, one pillar was a context for another pillar and that was represented in the curriculum as the integration between the pillars. For example, scientific inquiry was displayed at many times as a context for teaching the scientific content. Along these lines, we advocate for integration among pillars, which is envisioned with an example about the SSI of genetically modified food. One of the activities on that topic might be to ask students to obtain statistics on the occurrence of genetically modified food in one's own city and explain how this knowledge might change our views on genetically modified food in the future. Through the following activities, the science content about genetic engineering can be addressed and is used as a context to address scientific inquiry. At that level, students will collect data on the occurrence of genetically modified food so they will experience the doing of scientific inquiry. They will also understand the role of evidence by explaining how the evidence might change the knowledge about genetically modified food and that can explicitly address the empirical and tentative aspects of NOS. Again, the SSI about genetically modified food is used as a context to house the integration of the others pillars of scientific inquiry and NOS. Another activity on that topic might be to ask students to investigate people's views about genetically modified food and explain how their views about the effects of genetically modified food might change in the future. Through the following activities, the science content about genetic engineering, which is a controversial SSI, can be addressed and is the context to introduce the other pillars. Students will also investigate people's views so they will experience the doing of scientific inquiry. Further, students get to discuss how the effects of genetically modified food might change in the future and that can explicitly address the empirical and tentative aspects of NOS. In that sense, the effectiveness can be maximized when one pillar is used as a context for another pillar as shown in the above examples.

This integration among pillars that we have advocated for in this paper can foster a deeper understanding of science in order to achieve scientific literacy for our K-12 students. Tanner and Allen (2005) claim that the science education reform movements in the USA in the last 20 years witnessed an explicit shift in the goals of science teaching, from students simply creating a knowledge base of scientific facts to students developing deeper understanding of major concepts within a scientific discipline. To achieve this deeper understanding, we have argued in this paper that there needs to be an interplay among the scientific content, scientific inquiry, NOS, and SSI. In the process of teaching and learning, these components need to be viewed as inseparable. There is a need to view the components of scientific literacy as inseparable, because scientific literacy as a requirement for adapting to the challenges of a rapidly changing world (Holbrook & Rannikmae, 2009) relates to an ability of a citizen to function within society, both at the knowledge level and at the practical level in making decisions and acting as a responsible citizen.

Implications

Preparing students to be future citizens of the twenty-first century requires that we equip them with the pillars of scientific literacy, an ultimate goal in science education (AAAS, 1989, 1993; NRC, 1996). Consequently, the reform documents support the importance of students' understandings of scientific inquiry and NOS, as well as engaging in argumentation and decision-making in relation to environmental socio-scientific issues. Based on the evidence and support from literature, the paper offered an original outlook on environmental science literacy by presenting and justifying a conceptual understanding for environmental literacy as integration and interconnection among four pillars, which is a key for achieving environmental science literacy. Then the framework was illustrated through an example from the Qatari standards. And it would be very important to investigate the potential of other international curricula to prepare scientifically literate citizens.

Hence, the implications from this study relate to the need for the distribution of the four pillars across the standards as well as the presentation of the different pillars as interconnected. The four pillars of scientific literacy should not be taught as isolated but rather integrated. In other words, this paper argued for a reconstructed vision of environmental science literacy that addresses each of the four pillars explicitly both as an educational end and also as a means (or organizational context) for the other pillars. This integrated vision would require further investigation and research at the classroom level. This outlook of science literacy in general and environmental science literacy in particular, as interconnections among the four pillars, mirrors real-life situations.

References

Abd-El-Khalick, F. (2001). Embedding nature of science instruction in preservice elementary science course: Abandoning scientism, but . . . . *Journal of Science Teacher Education*, *12*, 215–233.

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, *82*, 417–436.

Aikenhead, G. S. (1985). Collective decision making in the social context of science. *Science Education*, *69*, 453–475.

Aikenhead, G. S. (1994). What is STS science teaching? In J. Solomon & G. Aikenhead (Eds.), *STS education: International perspectives on reform* (pp. 47–59). New York: Teachers College Press.

Akerson, V., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching*, *37*(4), 295–317.

American Association for the Advancement of Science. (1989). *Project 2061: Science for all Americans.* New York: Oxford University Press.

American Association for the Advancement of Science. (1993). *Benchmark for science literacy: A project 2061 report*. New York: Oxford University Press.

Bell, P., & Linn, M. C. (2000). Scientific arguments as learning artifacts: Designing for learning from the web with KIE. *International Journal of Science Education*, *22*(8), 797–817.

Bell, R. L. & Lederman, N. G. (2003). Understandings of the nature of science and decision making on science and technology based issues. *Science Education*, *87*, 352–377.

Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (2000). Developing and acting upon one's conception of the nature of science: A follow-up study. *Journal of Research in Science Teaching*, *37*(6), 563–581.

BouJaoude, S. (2002). Balance of scientific literacy themes in science curricula: The case of Lebanon. *International Journal of Science Education*, *24*(2), 139–156.

Bowman, B. T., Donovan, M. S., & Burns, M. S. (Eds.). (2001). *Eager to learn: Educating our preschoolers*. Washington, DC: National Academy Press.

Brickhouse, N. W., Dag her, Z. R., Letts, W. J., & Shipman, H. L. (2000). Diversity of students' views about evidence, theory, and the interface between science and religion in an astronomy course. *Journal of Research in Science Teaching*, *37*, 340–362.

Brown, H. I. (1977). *Perception, theory, and commitment: The new philosophy of science.* Chicago, IL: University of Chicago Press.

Carey, S., Evans, R., Honda, M., Jay, E., & Unger, C. (1989). An experiment is when you try it and see if it works: A study of grade 7 students' understanding of the construction of scientific knowledge. *International Journal of Science Education*, *11*(Special issue), 514–529.

Champagne, A. B., Klopfer, L. E., & Anderson, J. H. (1980). Factors influencing the learning of classical mechanics. *American Journal of Physics*, *48*(12), 1074–1079.

Chi, M. T., & Koeske, R. D. (1983). Network representation of a child's dinosaur knowledge. *Developmental Psychology*, *19*(1), 29–39.

Chiapetta, E. L., Sethna, G. H., & Fillman, D. A. (1993). Do middle school life science textbooks provide a balance of scientific literacy themes? *Journal of Research in Science Teaching*, *30*, 787–797.

Clark, D., & Sampson, V. (2006, April). *Characteristics of students' argumentation practices when supported by online personally seeded discussions.* Paper presented at the annual meeting of the National Association for Research in Science Teaching (NARST), San Francisco, CA.

Clough, M. P. (2003, January). *Explicit but insufficient: Additional considerations for successful NOS Instruction.* Paper presented at the annual meeting of the Association for the Education of Teachers, St. Louis, MO.

Council of Ministers of Education, Canada (CMEC) Pan–Canadian Science Project. (1997). *Common framework of science learning outcomes K to 12* [Online]. Retrieved from http://204.225.6.243/science/framework/

Crawford, B. A. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching*, *37*(9), 916–937.

Dawson, V., & Schibeci, R. (2003). Western Australian school students' understanding of biotechnology. *International Journal of Science Education*, *25*, 57–69.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Philadelphia, PA: Open University Press.

Durkee, P. (1974). An analysis of the appropriateness and utilization of TOUS with special reference to high- ability students studying physics. *Science Education*, *58*, 343–356.

Eggert, S., & Bogeholz, S. (2010). Students' use of decision-making strategies with regard to socio-scientific issues: An application of the Rasch partial credit model. *Science Education*, *94*(2), 203–393.

Eisenhart, M., Finkel, E., Marion, S. (1996). Creating the conditions for scientific literacy: A re-examination. *American Educational Research Journal*, *33*(2), 261–295.

Fleming, R. (1986). Adolescent reasoning in socio-scientific issues, part I: Social cognition. *Journal of Research in Science Teaching*, *23*, 689–698.

Fowler, S. R., & Zeidler, D. L. (2010, March). *College students' use of science content during socioscientific issues negotiation: Evolution as a prevailing concept*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Philadelphia, PA.

Fullinwider, R. K. (1987). Technological literacy and citizenship. *Bulletin of Science, Technology and Society*, *7*, 320–324.

Gabel, D. (2003). Enhancing the conceptual understanding of science. *Educational Horizons*, *81*(2), 70–76.

General Secretariat for Development Planning. (2008). *Qatar's national vision 2030*. Retrieved from http://www.gsdp.gov.qa/portal/page/portal/gsdp_en/qatar_national_vision

Germann, P., & Aram, R. (1996). Student performances on the science process of recording data, analyzing data, drawing conclusions, and providing evidence. *Journal of Research in Science Teaching*, *33*(7), 773–798.

Hanson, N. R. (1958). *Patterns of discovery.* Cambridge: Cambridge University Press.

Heiskanen, E. (2006). Encounters between ordinary people and environmental science – A transdisciplinary perspective on environmental literacy. *The Journal of Transdisciplinary Environmental Studies*, *5*(1–2), 1–13.

Hempel, C. G. (1966). *Philosophy of natural science*. Englewood Cliffs, NJ: Prentice-Hall.

Heyworth, R. M. (1999). Procedural and conceptual knowledge of expert and novice students for the solving of a basic problem in chemistry. *International Journal of Science Education*, *21*(2), 195–211.

Hogan, K. (2002). Small groups' ecological reasoning while making an environmental management decision. *Journal of Research in Science Teaching*, *39*, 341–368.

Holbrook, J. & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental & Science Education*, *4*(3), 275–288.

Hurd, P. (1998). New minds for a changing world. *Science Education*, *82*, 407–416.

Hurd, P. D. (1994). Technology and the advancement of knowledge in the sciences. *The Bulletin of Science, Technology, and Society*, *14*, 125–131.

Khishfe, R. (2008). The development of seventh graders' views of nature of science. *Journal of Research in Science Teaching*, *45*(4), 470–496.

Khishfe, R. (2012a). Nature of science and decision making. *International Journal of Science Education*, *34*(1), 67–100.

Khishfe, R. (2012b). Relationship between nature of science understandings and argumentation skills: A role for counterargument and contextual factors. *Journal of Research in Science Teaching*, *49*(4), 489–514.

Khishfe, R., & Abd-El-Khalick, F. (2002). The influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching*, *39*(7), 551–578.

Khishfe, R., & Lederman, N. (2006). Teaching nature of science within a controversial topic: Integrated versus nonintegrated. *Journal of Research in Science Teaching*, *43*(4), 377–394.

Klahr, D., Chen, Z., & Toth, E. E. (2001). Cognitive development and science education: Ships that pass in the night or beacons of mutual illumination? In S. M. Carver & D. Klahr (Eds.), *Cognition and instruction: Twenty-five years of progress* (pp. 75–119). Mahwah, NJ: Lawrence Erlbaum Associates.

Klosterman, M. L., & Sadler, T. D. (2010). Multi-level assessment of scientific content knowledge gains associated with socioscientific issues based instruction. *International Journal of Science Education*, *32*, 1017–1043.

Kolsto, S. D. (2001). Science literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*, *85*, 291–310.

Kuhn, D. (1991). *The skills of argument*. Cambridge: Cambridge University Press.

Kuhn, D. (1993). Science as argument: Implications for teaching and learning scientific thinking. *Science Education*, *77*(3), 319–337.

Kuhn, D., Amsel, E., & O'Loughlin, M. (1988). *The development of scientific thinking skills*. Orlando, FL: Academic.

Kuhn, D., & Phelps, E. (1982). The development of problem-solving strategies. In H. Reece (Ed.), *Advances in child development and behaviour* (pp. 1–42). New York: Academic Press.

Kuhn, L., & Reiser, B. J. (2006, April). *Structuring activities to foster argumentative discourse*. Paper Presented at the annual meeting of the American Educational Research Association (AERA), San Francisco, CA.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, *29*(4), 331–359.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831–880). Mahwah, NJ: Lawrence Erlbaum Associates.

Lederman, N. G., & Niess, M. L. (1998). Survival of the fittest. *School Science and Mathematics*, *98*(4), 169–172.

Linn, M. C., Pulos, S., & Gans, A. (1981). Correlates of formal reasoning: Content and problem effects. *Journal of Research in Science Teaching*, *18*(5), 435–447.

Liu, S., & Lederman, N. G. (2002). Taiwanese gifted students' views of nature of science. *School Science and Mathematics*, *102*(3), 114–123.

Marinin, Z., & Case, R. (1989). Parallels in the development of preschoolers' knowledge about their physical and social worlds. *Merril-Palmer Quarterly*, *35*, 63–87.

Matkins, J., & Bell, R. (2007). Awakening the scientist inside: Global climate change and the nature of science in an elementary science methods course. *Journal of Science Teacher Education*, *18*(2), 137–163.

Mayer, R. E., & Wittrock, M. C. (1996). Problem-solving transfer. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 47–62). New York: Simon & Schuster Macmillan.

McDonald, C. V. (2010). The influence of explicit nature of science and argumentation instruction on preservice primary teachers' views of nature of science. *Journal of Research in Science Teaching*, *47*(9), 1137–1164.

Means, M. L., & Voss, J. F. (1996). Who reason well? Two studies of informal reasoning among children of different grade, ability, and knowledge levels. *Cognition and Instruction*, *14*(2), 139–178.

Millar, J. (1997). Civic scientific literacy in the United States: A developmental analysis from middle school through adulthood. In W. Graeber & C. Bolte (Eds.), *Scientific literacy: An international* *symposium* (pp. 121–142). Kiel, Germany: Institut für die Pädagogik der Naturwissenschaften (IPN).

Millar, R., & Osborne, J. (Eds.). (1998). *Beyond 2000: Science education for the future*. London: King's College.

Mitchell, A., & Lawson, A. E. (1988). Predicting genetics achievement in nonmajors college biology. *Journal of Research in Science Teaching*, *25*(1), 23–37.

Moss, D. M., Abrams, E. D., & Robb, J. (2001). Describing student conceptions of the nature of science over an entire school year. *International Journal of Science Education*, *23*(8), 771–790.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academic Press.

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press.

National Science Teachers Association. (1982). *Science technology-society: Science education for the 80s*. NSTA Position Paper. National Science Teachers Association, Washington, DC.

National Science Teachers Association. (1992). *Scope sequence and coordination of secondary school science. Vol 1. The content core: A guide for curriculum*. Washington, DC: National Science Teachers Association.

National Science Teachers Association. (2010). Teaching science and technology in the context of societal and personal issues. In *2011–12 NSTA handbook* (pp. 233–235). Arlington, VA: NSTA Press.

Novak, J. D. (1979). The reception learning paradigm. *Journal of Research in Science Teaching*, *16*(6), 481–488.

Nussbaum, E. M., Sinatra, G. M., & Poliquin, A. (2008). Role of epistemic beliefs and scientific argumentation in science learning. *International Journal of Science Education*, *30*(15), 1977–1999.

Ogunniyi, M. B. (2006). *Using an argumentation-instrumental reasoning discourse to facilitate teachers' understanding of the nature of science*. Paper presented at the annual meeting of the National Association for Research in Science Teaching (NARST), San Francisco, CA.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. London: Nuffield Foundation.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, *41*, 994–1020.

Patronis, T., Potari, D. & Spiliotopoulou, V. (1999). Students' argumentation in decision making on a socio-scientific issue: Implications for teaching. *International Journal of Science Education*, *21*, 745–754.

Perkins, D. N., Farady, M., & Bushey, B. (1991). Everyday reasoning and the roots of intelligence. In J. F. Voss, D. N. Perkins, & J. W. Segal (Eds.), *Informal reasoning and education* (pp. 83–105). Hillsdale: Erlbaum.

Qatar Energy and Environment Research Institute. (2011). Retrieved December 28, 2013, from http://www.qeeri.org.qa/

Qatar General Electricity & Water Corporation. (2000). Retrieved December 28, 2013, from http://www.km.com.qa/

Resnick, L., & Hall, M. W. (2001). *Principles of learning: Study tools for educators. [CD-ROM, version 2.0]*. Pittsburg, PA: University of Pittsburg, Learning Research and Development Center, Institute for Learning. Retrieved from http://ifl.lrdc.pitt.edu/ifl/index.php/resources/principles_of_learning/

Rutherford, F. J. (1964). The role of inquiry in science teaching. *Journal of Research in Science Teaching*, *2*(2), 80–84.

Ryder, J., Leach, J., & Driver, R. (1999). Undergraduate science students' images of science. *Journal of Research in Science Teaching*, *36*, 201–220.

Sadler, T. D., Chambers, W., & Zeidler, D. L. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. *International Journal of Science Education*, *26*(4), 387–409.

Sadler, T. D., & Donnelly, L. A. (2006). Socioscientific argumentation: The effects of content knowledge and morality. *International Journal of Science Education*, *28*, 1463–1488.
Sadler, T. D., & Fowler, S. R. (2006). A Threshold Model of content knowledge transfer for socioscientific argumentation. *Science Education*, *90*(6), 986–1004.
Sadler, T. D., & Zeidler, D. L. (2005a). Patterns of informal reasoning in the context of socioscientific decision making. *Journal of Research in Science Teaching*, *42*(1), 112–138.
Sadler, T. D., & Zeidler, D. L. (2005b). The significance of content knowledge for informal reasoning regarding socioscientific issues: Applying genetics knowledge to genetic engineering issues. *Science Education*, *89*(1), 71–93.
Sandoval, W. A., & Milwood, K. A. (2008). What can argumentation tell us about epistemology? In S. Erduran & M. P. Jimenez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research,* (pp. 71–88). Dordrecht: Springer.
Saunders, W. L., & Jesunathadas, J. (1988). The effect of task content upon proportional reasoning. *Journal of Research in Science Teaching*, *25*(1), 59–67.
Schwab, J. J. (1964). Problems, topics, and issues. In S. Elam (Ed.), *Education and the structure of knowledge* (pp. 4–47). Chicago: Rand McNally.
Smith, M. U., & Good, R. (1984). Problem solving and classical genetics: Successful versus unsuccessful performance. *Journal of Research in Science Teaching*, *21*(9), 895–912.
Stewart, J., Finley, F. N., & Yarroch, W. L. (1982). Science content as an important consideration in science education research. *Journal of Research in Science Teaching*, *19*(5), 425–432.
Stewart, J. H. (1982). Difficulties experienced by high school students when learning basic Mendelian genetics. *The American Biology Teacher*, *44*(2), 80–89.
Supreme Education Council. (2002). *Science standards*. Retrieved February 16, 2012, from http://www.english.education.gov.qa/section/sec/education_institute/cso/science_standards
Tanner, K. & Allen, D. (2005). Approaches to biology teaching and learning: Understanding the wrong answers – Teaching toward conceptual change. *Cell Biology Education*, *4*, 112–117.
Topcu, M. S., Yilmaz-Tuzan, O., & Sadler, T. D. (2010). Preservice science teachers' informal reasoning regarding socioscientific issues and the factors influencing their informal reasoning. *Journal of Science Teacher Education*. doi:10.1007/s10972-010-9221-0
Tytler, R., Duggan, S., & Gott, R. (2001). Dimensions of evidence, the public understanding of science and science education. *International Journal of Science Education*, *23*, 815–832.
Walker, K. A. & Zeidler, D. L. (2007). Promoting discourse about socioscientific issues through scaffolded inquiry. *International Journal of Science Education*, *29*(11), 1387–1410.
Walker, R. A., Mertens, T. R., & Hendrix, J. R. (1979). Formal operational reasoning patterns and scholastic achievement in genetics. *Journal of College Science Teaching*, *8*, 156–158.
Yang, F. Y., & Anderson, O. R. (2003). Senior high school students' preference and reasoning modes about nuclear energy use. *International Journal of Science Education*, *25*, 221–244.
Zeidler, D. L. (Ed.) (2003). *The role of moral reasoning and discourse on socioscientific issues in science Education*. Dordrecht: Kluwer.
Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of Elementary Science Education*, *21*(2), 49–58.
Zeidler, D. L., Walker, K. A., Ackett, W. A., & Simmons, M. L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas. *Science Education*, *86*, 343–367.
Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching*, *39*, 35–62.
Zoller, U. (1982). Decision-making in future science and technology curricula. *European Journal of Science Education*, *4*(1), 11–17.