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Scientific Literacy and Purposes for Teaching Science: A Case Study of Lebanese Private School Teachers

Danielle Dani
Ohio University, USA

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In the United States and around the world, calls for educational reform stress the need for a scientifically literate population, prepared for the twenty-first century workforce. These calls have translated into new curricula, which in isolation, are not enough? Teachers play an essential role in the development of scientifically literate citizens. Their purposes for teaching science act as filters for acceptable learning and teaching activities. This paper examines the congruence of eight private school teachers' purposes for teaching science, and aspects of scientific literacy in the Middle Eastern country of Lebanon. Findings are discussed in light of contextual factors that inform the operationalization of scientific literacy in practice.

Key Words: Scientific literacy, orientations to teaching science, social context.

Introduction

In the United States, calls for educational reform stress the need for a scientifically literate, prepared twenty-first century workforce (Bybee & Fuchs, 2006). Scientific literacy consists of the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. The National Science Education Standards define it as:

> Scientific Literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (National Research Council, 1996, p. 22).

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The spirit of the reforms has transcended national and geographic boundaries, promoting scientific literacy as a major goal and outcome of science education in various countries around the world, one that is "essential to full participation of citizens" (Bybee, 2008, p. 566). The Program for International Student Assessment (PISA) in 2006 targeted scientific literacy, and assessed how well prepared 15 year-old students from over 80 countries were for life beyond the classroom. Current definitions of scientific literacy place individuals on a continuum that ranges from less developed to more developed scientific literacy (Bybee, 1997; Koballa, Kemp & Evans, 1997). These definitions propose four dimensions of scientific literacy: nominal, functional, conceptual and procedural, and multidimensional. So, for example, an individual with a less developed scientific literacy is able to recall scientific information, and classify knowledge as scientific. An individual with the highest level of scientific literacy understands the history and nature of science, the relationship of science to other disciplines, and the interrelationship of science, technology and society.

Scientific Literacy and the Lebanese Science Curriculum

The current Lebanese science curriculum was implemented in 1998 (National Centre for Educational Reform & Development, 1995). The curriculum consists of general objectives (goals), introductions, objectives, instructional objectives, and activities. It provides common science content until grade 10. In grade 11, students opt to pursue secondary studies in the humanities or science streams. The science stream is further split into general science or life sciences in grade 12. All courses within a stream are pre-determined. While students at all levels take science, the number of sessions of science that students take per week varies by level and stream.

BouJaoude (2002) conducted an analysis of the Lebanese science curriculum to investigate the balance of scientific literacy themes within it and its potential to prepare scientifically literate citizens. He developed and used a framework of scientific literacy for his analysis based on (a) the four aspects of scientific literacy: knowledge of science, the investigative nature of science, science as a way of knowing, and the interaction of science, technology and society (Chiapetta, Sethna & Fillman, 1993), (b) personal use of science to make everyday decisions, solve everyday problems, and improve one's life and the impact of science related moral and ethical issues (Hurd, 1998), (c) domains of curricular science (Koballa et al., 1997), and science as one way of knowing rather than the only way (Shapin, 1998). BouJaoude concluded, " the Lebanese curriculum emphasizes the knowledge of science (Aspect 1), the investigative nature of science (Aspect 2), and the interactions of science technology, and society (Aspect 4) but neglects science as a way of knowing (Aspect 3)" (2002, p. 153). BouJaoude further argues that the emphasis on the interaction of science, technology, and society in the curriculum holds the potential for the development of citizens and decision makers who use scientific knowledge meaningfully in their lives. However, he cautions, "Teaching, assessment, and the quality of textbooks used are also important factors that need to be considered if students' experience with science is to be complete and fulfilling" (BouJaoude, 2002, p. 154).

Framework for the Study

Teachers' purposes for teaching science (sometimes labeled 'orientations'), serve as filters for acceptable learning and teaching activities (Clark & Peterson, 1986; Richardson, 1996). Given that contemporary theory and research emphasizes the central role of *purpose* on human thought and action (Wertsch, 1998), and because teachers are considered the most influential factor in educational reform intended to promote student learning (Duffee & Aikenhead, 1992), identifying teachers' purposes for teaching science is critical for understanding the status of scientific literacy in any context. For these reasons, the purpose of this study was to use BouJaoude's (2002) framework for scientific literacy as represented in Table 1, to investigate the congruence of eight teachers' purposes for teaching science and aspects of scientific literacy in the Middle Eastern country of Lebanon. The study also aimed to elaborate the contextual factors that influence teachers' operationalization of scientific literacy in practice.

Table 1. Aspects of Scientific Literacy

Aspect	Components
The knowledge of science	Facts, concepts, principles, laws, hypotheses, theories, and models of science
The investigative nature of science	Using methods and processes of science such as observation, measuring, classifying, inferring, recording and analyzing data, communicating using a variety of means such as, writing, speaking, using graphs, tables, and charts, making calculations, and experimenting
Science as a way of knowing	Emphasis on thinking, reasoning, and reflection in the construction of scientific knowledge and the work of scientists Empirical nature of science Ensuring objectivity in science Use of assumptions in science Inductive and deductive reasoning Cause and effect relationships Relationships between evidence and proof Role of self-examination in science Describes how scientists experiment
Interaction of science, technology, and society	Impact of science on society Inter-relationships between science, society, and technology Careers Science-related social issues Personal use of science to make everyday decisions, solve everyday problems, and improve one's life Science related moral and ethical issues

Methods

The purpose of this qualitative study (Bogdan & Biklen, 1998) was to examine Lebanese teachers' purposes for teaching science against the backdrop of BouJaoude's (2002) framework of scientific literacy. Specific research questions were:

1. Do participating Lebanese science teachers' purposes for teaching science correspond with aspects of scientific literacy?
2. What contextual factors do participating Lebanese science teachers cite as underlying factors for their purposes for teaching science?

The Lebanese Context

Lebanon consists of a multicultural, pluralistic Arab society (Bahous & Nabhani, 2008). Even though Arabic is the official language in the country, science is taught in a second language - French or English.

The educational system in Lebanon is centralized under the Ministry of Education and boasts public and private schools in urban, suburban, and rural settings. The structure of the educational ladder of public and private schools in Lebanon is divided into three levels, nursery, basic education (grades 1-9), and secondary education (grades 10-12). Basic Education is further divided into two stages, elementary (grades 1-6) and intermediate (grades 7-9).

The Ministry and its National Center for Educational Research and Development (NCERD) oversee the country's national curriculum, textbooks, national examinations, and all matters related to public schools. For example, the Ministry of Education requires public schools to use locally produced textbooks that are aligned with the national curriculum. While private schools in Lebanon are required to address the national curriculum, they are not bound to the public texts in science, many choose to use them. The Ministry of Education recruits public school teachers from the graduates of the Lebanese University only, while private schools recruit graduates of private universities where the standards of teacher preparation programs are more rigorous than in the Lebanese University in course content, foreign language proficiency, and internship experiences (Jarrar, Mikati & Massialas, 1988). One caveat though, is that private school teachers need not be graduates of teacher preparation programs, and usually hold at least a Bachelors degree in the discipline they will teach or a closely related subject.

Participants

Participants consisted of eight intermediate and secondary Lebanese science teachers, five males and three females. The intermediate and secondary grades were chosen because the author's licensure grade band and expertise spans grades 7-12. All participants taught at private schools where science was taught in English. Schools were selected based on convenience and willingness to participate in the study. Public schools and teachers were purposefully excluded due to the centralized approval process necessary for gaining entrée to schools and classrooms. Names used to describe participants and report findings are pseudonyms. While all participants had undergraduate degrees in scientific or related disciplines, only four had Masters Degrees in these disciplines (Atef, Bassima, Randa & Hannan). Two of the teachers, Bassima and Wissam were officially licensed to teach science through the American University of Beirut and The Lebanese University respectively. Wissam additionally had a Master's and Doctorate Degree in Science Education. Bassima and Randa regularly participated in science education workshops sponsored by the American University of Beirut's Science and Mathematics Education Center (SMEC). All teachers participated in general pedagogical training workshops sponsored by the National Center for Educational Research and Development (NCERD) focusing on the new curriculum, structure, and use of the national textbooks in the years following between 1998 and 2002. Participants teaching experience ranged from two to 36 years, with a median of 12.5.

Data Collection and Analysis

Data sources for the study consisted of interviews (two per participant), classroom observations (three per participant), and artifacts such as lesson plans and classroom handouts. Data was collected over a period of six weeks. Only one interview protocol was used to elicit teachers' beliefs and knowledge of the purposes for teaching science. The interview protocol consisted of 17 questions and was adapted from Grossman's (1990) Conceptions of Teaching Science instrument and Richardson and Simmons' (1994) Teachers' Pedagogical Philosophy Instrument (TPPI). The interview was conducted in two one-hour sessions; before and after classroom observations. Sample questions include:

- Tell me about what you see as the reasons for studying science in middle and high school. What are your goals for your students? [Probe for conceptions of teaching, process skills, content, nature of science, inquiry]
- What learning in your classroom do you think will be most and least valuable to your students outside the classroom environment?

All interviews were audiotape-recorded and transcribed. To answer the first research question, field notes, interview transcripts, and artifacts were subjected to content analysis using the components and subcomponents of the aspects of scientific literacy described by BouJaoude's (2002) framework. To answer the second research question, data sources were examined through a process of analytic induction and constant comparison (Patton, 1990; 2002). Once emerging, researcher-constructed, themes were established, logical analysis (Patton, 1990) was conducted using identified purposes for teaching science and emerging contextual factors. During all levels of analysis, data sources were searched for discrepant information that might run counter to emerging patterns and themes.

Research Findings

The participants' purposes for teaching science reflected the four aspects of scientific literacy to varying degrees. All eight teachers cited purposes for teaching science that were aligned with "the knowledge of science," "the interaction of science, technology, and society," and to a lesser extent "the investigative nature of science." Only three of the eight teachers cited purposes for teaching science that were aligned with the "science as a way of knowing" aspect of scientific literacy. The following sections describe participants' purposes for teaching science, followed by a description of the underlying contextual factors that emerged from the analysis.

The Knowledge of Science

Participants in this study overwhelmingly indicated that one of their main purposes for teaching science consisted of equipping students with basic knowledge. They believed that a breadth and depth of scientific knowledge allows students to understand the world. Scientific knowledge further constitutes the bedrock on which future science learning will be built. For example, Bassima stated, "I need them to know the basic academic knowledge and when you study Science you have a lot of information that's constant, which is relevant to their health, relevant to basic natural phenomenon around them." Randa indicated that "I want them to take the basics with them … you build on the basics." Similarly, Nabil affirmed:

> My goal is to give them information about their bodies, the body of the animals surrounding them, the plants that surround them... After all they live in an ecosystem. My basic goal is to teach them life; the differences, the processes that happen, the anatomy and so on.

Observed classroom sessions addressed content from units on the immune system (two participants), electricity, atoms and molecules, gaseous state of matter, oxidation and reduction reactions (two participants), and plant structure and growth.

Interaction of Science, Technology and Society

Participants consistently cited careers and the personal use of science to make everyday decisions, solve everyday problems, and improve one's life as purposes for teaching science. For instance, Randa stated, "I always tell them, maybe chemistry even physics, it should help you to improve your life. Not your own life, life in general." Ziad indicated, "As much as I can, I try to link the subject to life. Maybe something they use at home, maybe something they see every day, maybe something that people use at work or a job." Hannan likewise pointed out:

> In the case of immunology and I noticed that when someone had a common cold, she ran to me and said that, "I have a common cold and I am going to spread the disease." So they started talking about it. They are aware of it. Being aware is really good. And sometimes they go and discuss this with their parents. And if something happens they come and tell me and explain. So that's the importance of science.

Participants further cited the ethical use of science as one of their goals. For example, Randa stated, "In life science you can use cloning for different purposes. So I hope that my students will be able to value when to use this technique and when not to use it." Participants' emphasis on the interrelationship of science, society, and technology was apparent in their teaching also. Observed classroom sessions included discussions and demonstrations of technologies and technological systems such as the extraction of latex, car batteries, and vaccines among others.

The Investigative Nature of Science

Participants listed the methods of science as a goal. For example, Bassima affirmed, "I want students to view science as a way of investigating." Wissam stated, "I want the students to have the capacity for problem solving, ability to formulate questions, to seek answers, being able to observe," and Nabil declared, "I like them to look at things. They will deduce certain things from table or figures or whatever, and then we will piece the picture together." Similarly, Kamal and Hannan indicated respectively:

> After teaching the scientific method to my students, this is an excellent way to see if the students are being able to analyze. First analyze what is the objective of the certain experiment. Then they are able to formulate certain hypothesis somewhere on that objective. Third and very importantly, is they know how to design a certain experiment; to try to prove that hypothesis true.
>
> One of my goals is for students to be able to make observations and inferences and some conclusions related to the topic. So they can read a document on precious stones and make observations and conclude that as cations change, color of precious stones change.

Participants' practice emphasized science process skills. Observed classroom sessions included instances of measurement, observation, inference-making, prediction, and controlling variables. For example, pointing to a table representing three measurements of voltage and intensity, Ziad asked students to infer a pattern and predict the next value. In another classroom, Kamal asked his student to think of an experiment they can do to prove that gas has mass. Randa's class was discussing which variables to control and how to make volume measurements before a titration experiment.

Science as a Way of Knowing

Only three of the participants cited science as a way of knowing as a purpose. These teachers valued the empirical nature of science, as well as thinking and reasoning. Wissam declared, "Another goal is to teach them a way of thinking scientifically and to have a scientific approach for them to act in one way or another like a scientist." Randa elaborated, "What I want to develop is their critical thinking and to reflect on what is presented to them and to decide whether it could be acceptable or not." Similarly Bassima stated, "I want them to look, I want them to defend. They have to be skeptic [sic], they have to inquire and they have to be scientists."

Contextual Factors

Two contextual factors emerged as a rationale for participating teachers' purposes for teaching science, namely (a) the national textbooks and exam, and (b) the Lebanese social climate. The following sections describe these factors and their relationship to the participants' purposes.

National textbooks and exam. Participants indicated that providing students with basic knowledge and understanding of science was necessary to help students supplement the national textbook, and pass the official exam. They critiqued their textbooks indicating that they did not contain enough information to help students understand, and remember content:

> The book has documents. And each document contains messages. They contain information. Our books today are different from before. The chapter is divided into activities similar to sections. And each activity does not have just pure information. Each activity has like 20-30% information. And the rest has tables, drawing, graphs. And to these documents, that's the information. Not enough to pass [the test].

The textbook and the exam are characterized by documents that present a problem, figure, chart or graph followed by a series of questions that invite students to make observations, analyze data, and arrive at conclusions. An excerpt from the tenth grade biology textbook can be summarized as follows:

- A figure representing a strip of cortex that was recently removed from a tree.
- Question 1: What does the swelling above the marked band indicate?
- Question 2: Indicate the direction of the liquid mentioned in the answer from #1.
- Question 3: If you make holes through the bulged section a viscous liquid drops that tastes sweet, what does this indicate?
- Question 4: Is this the crude sap? Why or why not?

Participants further highlighted the need for the methods of science to appropriately interpret the textbooks and pass the official exam. For example, Atef stated, "I focus on memorizing, reading skills, analytic skills, and interpretation skills. [On the test] One part is knowledge, what you know. Second part is reasoning, and the last one is communication." Similarly, Nabil indicated:

> Now the purpose of these books is that the students should work on each document and extract out the information. And this is what I do in the class for them. In the class, many times, I have students to work in pairs or on their own or in groups of 4 or 5 and give them questions about certain documents to analyze, to interpret, to conclude and so on. And then to extract the basic information. That is very impor-

> tant, and 60% of the exam or test is done this way. We give them documents and the same process. It's a good way.

Social climate. Participants indicated that the country's social climate, represented by political and religious plurality, was at the root of their "interaction of science, technology, and society" purpose for teaching science. They acknowledged that this plurality results in various, sometimes conflicting, points of view. Participants highlighted the importance of acquainting students with the differing points of view and promoting respect of the differences. To illustrate, Kamal stated:

> For instance about the surrogate mother or about artificial insemination, about abortion. These have many attitudes and beliefs that govern them. We had a debate in the classroom whether they are for or against let's say abortion, and religion came into it. You know the usual stuff. So, in science, you try to let them accept and know the other points of view; the other views of other people. And of course, you cannot make them come out of their culture. For instance, if I am for abortion, let's say and I'm looking at a newborn who is going to be handicapped, but maybe some religions do not go for that. So you have to respect these things.

Six of the participants considered it their responsibility to engage students in an examination of consequences and implications of science and technology in an effort to develop in students a sense of environmental stewardship that they felt was lacking in the socio-political context of the country. For example,

> I assign the person dates which they should present the environmental projects and this seems to be effective. I motivate students. You have a job at hand; you have a job to do. You are part of society. Because in Lebanon the government is unaware. TV does not raise awareness. Everywhere we don't have it. You have to visit your community. Only way to visit is by individual efforts. I want them to see that science is a tool. The goal is to use it in life, in the community. (Atef)

Social climate also emerged as a rationale for the three participants who listed "science as a way of knowing," as one of their purposes for teaching science. This subgroup of participants viewed the social climate as problematic because it did not boast any scientist role-models for students, nor did it model reasoning like a scientist. For example, Wissam stated,

> I do not think that in our culture they actually sense the scientific approach. We do not have those scientists. We do not hear of them, probably we have them. We do not hear of the technologies that we have in the industries. This isn't approachable to the students, not like it is in the American society.

This subgroup further indicated that the social climate did not model the identification and questioning of assumptions. They claim that modeling self-examination and skepticism in their science classrooms will ultimately engender more informed decision-makers. For example Bassima stated:

> It's also to inform them of other points of view. Maybe they will adopt it later, but scientifically not haphazardly whether because I belong to that sex or to that I don't know what and this is what it should be.

Discussion

The first purpose of this study was to investigate the degree of congruence between participating Lebanese teachers' purposes for teaching science and aspects of scientific literacy as per BouJaoude's (2002) framework (Table 1). The results of this study show that participants' purposes for teaching science correspond with "the knowledge of science," "the interaction of science, technology, and society," and "the investigative nature of science" aspects of scientific literacy described by BouJaoude. Furthermore, in response to the second purpose of the study, all participants identified the national textbooks and exam as contextual factors that facilitate the operationalization of their "knowledge of science," and "investigative nature of science" goals because of the strong emphasis of these documents on these two aspects of scientific literacy. These findings reflect the aspects of scientific literacy emphasized in the Lebanese science curriculum as reported by BouJoaude (2002). A majority of participating teachers was not licensed to teach science, and lacked any formal preparation in science education. The non-licensed teacher-participants and their licensed peers had common experiences with respect to the national curriculum, textbooks, and associated NCERD facilitated professional development programs. Non-licensed teachers seemed to solely rely on the national curriculum, textbooks, exam, and associated professional development programs to guide them with respect to what to teach and why. Since these national documents and initiatives only emphasize three of the aspects of scientific literacy, it is not surprising that the same three aspects would be the focus of participants' goals (the *only* focus for the non-licensed participants') and would translate into their practice.

While the Lebanese science curriculum does not address the "science as a way of knowing" aspect of scientific literacy (BouJoaude, 2002), three of the participating Lebanese teachers cited this as a purpose for teaching science. Interestingly, Bassima and Wissam were both licensed secondary science teachers with extensive post-baccalaureate experience in science education either in the form of a graduate degree or professional development workshops through the Science and Mathematics Education Center (SMEC) at the American University of Beirut. Although Randa was not licensed in secondary science, she also boasted extensive post-baccalaureate experiences in science education through SMEC. An implication of this finding is that teacher preparation or professional development is a necessary condition for the development of "science as a way of knowing" purposes for teaching science. Since neither is mandated for private school teaching, it is recommended that science teacher preparation become a mandated prerequisite for teaching, or that mandated inservice professional development be provided.

Unfortunately, even though the three professionally prepared participants listed science as a way of knowing as a purpose, this goal did not translate into their practice. While this finding may be an artifact of the limited number of classroom observations completed for the three participants, it implies that while teacher preparation and professional development may be necessary conditions for the development of purposes for teaching science that are aligned with all aspects of scientific literacy, they are not sufficient. Several studies document efforts to promote teachers' understandings of the nature of science (NOS) (Lederman, 1998; Abd-El-Khalick & Lederman, 2000). While these efforts have been successful at times, the research reported here suggests that teachers' understandings of the NOS do not directly translate into their practice. Because it is accepted that teachers cannot teach and evaluate that which they do not understand, it is important to provide science teachers with a functional understanding of the NOS (Lederman, 1998). The research literature recommends the use of explicit and reflective instructional processes to promote understandings of the NOS in both teachers and students (Lederman, 1998; Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002). Therefore an implication of this study is that Lebanese teacher preparation should rely on such processes to promote teachers' functional understanding of the "scientific ways of knowing" aspect of scientific literacy.

Finally, participants identified the Lebanese social climate as a contextual factor that informs their purposes for teaching science. Participants' experiences within Lebanon's pluralistic society seemed to facilitate the operationalization of their "interaction between science, technology, and society" goals as evidenced by their push to promote an awareness and respect of the diversity of viewpoints with respect to the social, ethical, and moral issues in science. Some participants' socio-political experiences seemed to further prompt purposes for teaching science that emphasize community activism that starts with local environmental stewardship. These findings are in line with and support Mueller and Bentley's (2007) call for pluralism in science education and Roth and Barton's (2004) environmental stewardship conceptualization of scientific literacy. Interestingly, participants' experiences within the Lebanese social climate seemed to hinder the operationalization of their "science as a way of knowing" purposes for teaching science. The society's lack of value for and recognition of science, technologies, and scientists produced and operating in Lebanon conflicts with participants' beliefs regarding how to teach about the nature of science and functions as a barrier to the translation of this purpose into practice. Findings imply that the development of Bybee's (1997) multidimensional level of scientific literacy is predicated on place-based (Bowers, 2001; Sobel, 2004) culturally-responsive, education in Lebanese science teacher preparation programs and science classrooms.

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Author

Dr. Danielle Dani is an assistant professor of science education at Ohio University. **Correspondence:** Department of Teacher Education, Ohio University, 252 McCracken Hall, Athens OH 45701, USA. E-Mail: dani@ohio.edu