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Developing a Culture of Collaboration:

A Departmental Exploration of Science Literacy at Sunset School

A dissertation submitted in partial satisfaction of

the requirements for the degree

Doctor of Education

by

Tamara Jill Miller

2012

ABSTRACT OF THE DISSERTATION

Developing a Culture of Collaboration:
A Departmental Exploration of Science Literacy at Sunset School

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Doctor of Education

University of California, Los Angeles, 2012

Professor William Sandoval, Co-Chair

Professor Eugene Tucker, Co-Chair

This paper presents the results of a study that examined the effects of using an action research process to explore science teachers' views on science literacy as well as improve collaboration among department members. Data were collected by documenting the action research process and interviewing teachers at a suburban K-12 school in Southern California. Findings suggest that teachers' views of science literacy vary more by context than by individual, and that collaboration seems to be useful in expanding teachers' beliefs about science literacy.

The dissertation of Tamara Jill Miller is approved.

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University of California, Los Angeles

2012

Dedication

I dedicate this dissertation to my wonderful husband, Jeremy. I could not have done any of this without your love and support. Thank you!

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VITA

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Chapter 1: Introduction

American students are less scientifically literate than students in most industrialized nations (Bybee, 1995; Kolsto, 2001; Miller, 1998; Sadler & Zeidler, 2009). Specifically, the U.S. is not producing and training enough scientifically literate students and technically proficient people to satisfy American economic and defense needs (Shahn, 1988). The lack of public competence in science and technology has severe social and economic consequences (Mejlgaards & Stares, 2010). As Americans, we need to take a closer look at the effects of scientific literacy on public policy.

Scientific literacy is defined as the ability to read and write about science (Miller, 1998). Similarly, Shen (1975) defined science literacy as the level of understanding of scientific terms and concepts necessary in order to read the newspaper, understand the news, and understand competing arguments in a scientific controversy. Greenwood and North (1999) argued that the growth of U.S. scientific enterprise over the past decades is at risk of being compromised if the scientific community does not turn its attention to promoting better science education of our youth. “As a whole American youth are not learning science well” (Greenwood & North, 1999, p. 2073). American science achievement and science literacy scores have dropped according to national assessments such as PISA, TIMMS, and NAEP and many of the best students are choosing alternate career paths. Even children who do well in science are not necessarily scientifically literate. They may acquire science knowledge and demonstrate this knowledge on Advanced Placement (AP) exams, the American College Test (ACT), and Scholastic Aptitude (SAT) II tests, but awareness of the implications of science is not the same as the acquisition of scientific information. The evidence suggests that this national issue of scientific illiteracy may also be a concern at many public and private schools around the country.

For the purpose of my study, science literacy is defined as the science skills and knowledge that one needs to navigate through life and fully participate in the democratic process. This includes the ability to make good health choices, vote responsibly and knowledgeably on science related matters, to elect officials that support progress on issues such as stem cell research, biodiversity, sustainability, and climate change, and understand science in the media. Science literacy is the ability to use one's science knowledge to solve problems and analyze real issues.

In this study, I brought together a group of science teachers to elicit beliefs about science literacy, and to measure those beliefs and perceptions over time as we collaboratively worked together to discuss curriculum that enhanced the level of science literacy of the students, and how we could assess this level of literacy. A major goal of my study was to develop competency-based assessments, in collaboration with members of a science department, at a secular private school in Los Angeles.

The following research questions guided my study:

- (1) What are science teachers' views on science literacy?
- (2) How do science teachers' views on science literacy manifest across different contexts of teaching: planning, instruction, and assessment?
- (3) How does collaboration around the context of planning, instructing and assessing for science literacy influence teacher's views on the nature of their work?

Statement of the Problem

Scientific Literacy has not been well-defined since the introduction of the concept almost sixty years ago (Hurd, 1958). While science literacy is one of the goals of science education and the new idea behind science reform, it is still vague to many educators and policy makers.

Science became a part of the school curriculum in the 19th century because of the requests made by the scientists themselves, in order to add the "inductive process of observing the natural world and drawing conclusions from it" (DeBoer, 2000, p. 583). These scientists felt that if the people had an attitude of independence they would be protected from the "excesses of arbitrary authority" and they would be able to participate more fully within the society (DeBoer, 2000). John Dewey further supported the view that science knowledge gave individuals the power to act individually. "Whatever natural science may be for the specialist, for educational purposes it is knowledge of the condition of human action" (Dewey, 1916, p. 267). By the 1930s peoples understanding of science was important for effective living, human progress, and also as a cultural force (DeBoer, 2000).

After the launching of Sputnik in 1957 the public attitude in the U.S. about science changed. Rather than being concerned about science literacy, people became more concerned about content knowledge. Very few people were concerned about science as it related to the daily life of the students. It became a race to achieve in order to put the U.S. country back on track both economically and militarily (DeBoer, 2000). John Dewey believed that the application of science is the change that overshadows and controls all others. "That this revolution should not affect education in some other than a formal and superficial fashion is inconceivable" (Dewey, 1902, p. 9).

According to Hurd (1970), it was crucial that the relationships between science, technology and society be as important as the processes of science for citizens in our democracy. By the 1980s, the National Science Teachers Association (NSTA) had adopted a position statement called *Science-Technology-Society (STS): Science Education for the 1980s*. This paper summarized the need for science education to prepare students for their everyday lives by

contextualizing the material and preparing them to make decisions about science-related social issues. Unfortunately, the many critics of the NSTA STS position on science education felt that science would lose out to technological issues. "Social issues do not convey any real understanding of the structural integrity of science and the basics simply don't get taught" (Kromhout & Good, 1983, p. 649).

Science content versus science-based social issues has been a major issue since the inclusion of science in the educational curriculum. There have been multiple reform efforts to either improve what students know or how they can apply what they know to live in a democratic society. Project 2061's *Science for all Americans* was published by the American Association for the Advancement of Science (AAAS) (1989) in an effort to revive science literacy by clarifying the goals of science education. The themes presented in this new reform included retraining teachers with the appropriate skills needed to teach science, revamping textbooks to match current science objectives, and changing the system to recognize the importance of science education for our youth. The learning outcomes proposed included five criteria: (a) Does the content enhance one's long term employment prospects and the ability to make long-term decisions? (b) Does the content help one to participate intelligently in making political decisions involving science and technology? (c) Does the content present aspects of science mathematics and technology that are so important in human history or so pervasive in our culture that a general education would be incomplete without them? (d) Does the content help people ponder the enduring question of human existence? and (e) Does the content enrich children's lives at the present time regardless of what it may lead to in later life? (AAAS, 1989; cited in Deboer, 2000)

Similarly, in 1996 The National Science Education Standards (NSES) were created to clarify the goals of science education. These goals were an expanded version of the learning outcomes presented by AAAS.

Science 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. (NSES, 1996, p. 22)

The National Institute of Health (NIH), the National Science Foundation (NSF), the National Academies of Science (NAS), and the Public Understanding of Science (PUS) have also explored criteria to improve national levels of scientific literacy. Ultimately, the consensus among the sources listed above is that a scientifically literate individual would be able to evaluate the quality of scientific information based on its source and the methods by which it was collected. Furthermore, science literacy includes the capacity to use evidence appropriately when evaluating arguments.

The Problem in a Local Context

While there are varying assessments to measure science literacy among adults, there are only a few tests that examine high school students' level of scientific literacy. Of those tests that measure high school students' science literacy, such as the PISA exam, none of them take into account the multi-dimensional construct of science literacy, which includes the vocabulary of science, an understanding of the process of science, and an understanding of the impact of science and technology on individuals and society (Miller, 1998)

There are no assessment instruments for measuring the level of scientific literacy among high school students in the U.S. Sunset School prides itself on being an academic institution that

matriculates all of its students to colleges and universities and prepares them sufficiently to participate in the democratic process. Science policy will undoubtedly be a major focus of our technologically advancing society. Therefore, Sunset School wants to make sure that it is preparing its students for the science literacy required for civic discourse. It is important that the curriculum and coursework are truly preparing students for their future. Currently, the science department has no tools to measure the level of scientific literacy that the students have attained in their three-year science sequence.

As the number of public policy issues involving science and technology increases, it becomes even more critical that students attain an adequate level of scientific literacy (Miller, 1998). Most schools focus on science knowledge acquisition, and a disconnect remains between the teaching of science and actually preparing students to be consumers of science.

Need for the Study

The purpose of this qualitative action research project was to engage a group of science teachers in a collaborative action research project to measure their beliefs and perceptions about science literacy and ways to assess this literacy among the population of students. Ideally, thinking about assessment differently would lead to a different type of instruction and improved scientific literacy at Sunset School and beyond. There were several parts to this study. The first part of the study allowed me to collect pre-test data on science teacher beliefs about science literacy. The second part was an ongoing measurement of these beliefs and how they have changed over time. An ongoing part of the study was collaborative work and the creation of competency-based assessments, which measured the science literacy of the students.

Study Site

I conducted my research at Sunset School, which is located in Los Angeles, California. There are 12 science teachers in the upper and middle division science department. There are approximately 115 students per grade level in the upper division (grades 9 to 12). The mandatory science sequence is physics, chemistry, and biology. Approximately 90% of students take more science courses than are required for graduation.

Sunset School was the sponsor of this action research project. The school fully supported my collaborative action research study, which engaged teachers in discussions about science literacy as well as activities to create new assessments.

Data Collection

I met with the members of the science department during the August 2011 in-service and continued meeting monthly through December 2011. Final interviews took place in December 2011 and January 2012.

Public Engagement

Hopefully, the data gathered during the course of this action research project will be used to inform Sunset School and other schools on how to best engage a group of science teachers in an action research project designed to expand beliefs and perceptions about science literacy and create competency-based assessments to measure the level of science literacy. Ultimately, this study was in an effort to improve a science program and practice by having teachers collaborate around the context of science literacy.

Chapter 2: Literature Review

Introduction to Literature Review

The sudden appearance of Sputnik in 1957 catalyzed an enormous national effort to win the space race and improve mathematics and science education in the U.S. Within 12 years, the U.S. had landed on the moon. Unfortunately, the U.S. has not sustained this intensity in science education. According to the National Assessment of Education Progress (NAEP) in 1996, less than one third of Americans scored at or above the proficient level in science. The PISA exam, which tests for science literacy, the ability to identify and explain scientific phenomena and use scientific evidence, displays almost equal results. Fifteen-year-old students in the United States had average scores on the combined science literacy scale that were slightly lower than the Organization for Economic Cooperation and Development (OECD) average scores. U.S. students scored lower in science literacy than their peers in 16 of the other 29 OECD jurisdictions and 6 of the 27 non- OECD jurisdictions (PISA Results, 2006). Over the past 30 years, the United States has not seen an improvement in these scores.

Science reform efforts, as a means to improve science literacy have been ongoing for the past century. Unfortunately, redesigning curriculum has had limited success due to the conflicted meanings of scientific literacy. There are several recurring themes in the literature on science literacy.

This literature review explores the history of science literacy in the U.S. as well as examining multiple perceptions and definitions of science literacy. In addition, I discuss the different ways that science literacy is measured nationally and internationally, and how schools can begin to assess their own students' levels of scientific literacy.

The literature review also discusses science teachers' beliefs about the nature of science and how these beliefs influence science instruction and assessment. Furthermore, it will discuss science teachers' level of science literacy and its impact on their students' level of science literacy.

My research questions address the importance of action research as a process to improve department engagement and ownership of competency-based science literacy assessments. Because of the nature of action research, it is possible to create sustainable change when individuals at a site create and implement their own ideas rather than accept and implement the ideas of others (McNiff & Whitehead, 2007). Action research works on the premise that individuals actively working in an organization are the best source of knowledge. Thus, action research at my site begins the process of sustainable change through awareness and acceptance of the issue of scientific literacy.

Assessment of the Problem

Multiple books and journals have addressed the issue of the lack of scientific literacy in the U.S. over the past several decades. Furthermore, there have been many studies that explore ways to measure the level of scientific literacy within and between populations. Miller (1998) created a civic scientific literacy measure to estimate the percentage of adults who were very well informed, moderately informed, or uninformed on issues involving science. Ryder (2001) synthesized thirty-one studies, categorized by discipline and setting, of the scientific knowledge needed by individuals to function in their daily lives. Ryder's analysis of the studies was guided by the question, "What knowledge of science is relevant to those individuals not professionally involved in science?" Specifically, each study examined what specific science knowledge did the individual need to apply in that setting or discipline in order to make an accurate life or

behavioral choice or engage with the science. Ryder (2001) stated that in many of the studies the individual needed more than just empirical data to interpret the event; they needed knowledge sources that came from being able to analyze sources and data (scientific literacy).

Similar to Ryder, Carl Wenning (2007) developed a physical science inquiry test based on the assumption that science inquiry is a strong component of science literacy, and that if the main goal of science education is the attainment of science literacy then there needs to be a way to accurately measure scientific inquiry. His framework included the different stages of science inquiry according to intellectual maturity of the student. Students could develop increased understanding through successively more complex forms of inquiry (Wenning, 2007).

The Scientific Inquiry Literacy Test (SciInqLIT) was developed by Carl Wenning in 2007 using his science literacy framework. Forty multiple-choice questions were generated by several physics teachers who were familiar with the science literacy framework. The test was piloted to 425 high school science students at five different high schools in Illinois. The test was given under pre and post-test conditions and served as a diagnostic tool to assess weaknesses in student understanding, improve instruction, and measure program effectiveness. Wenning (2007) acknowledged that the SciInqLIT had limitations due to its multiple-choice format, paper-pencil aspect. He stated that a more authentic measure of science inquiry would be one that utilized manipulatives. The assessment, if created well, could have huge impacts on curriculum design and instructional practice (Wenning, 2007).

The Programme for International Student Assessment (PISA) exam is given every few years to 15-year-old high school students throughout the world in order to measure their level of scientific literacy. Sadler and Zeidler (2009) explored the PISA exam in their study on the Assessment for Progressive Aims of Science Education. They examined the PISA exam through

the lens of the Socioscientific Issues movement (SSI). The PISA and the SSI seem well-aligned in general terms; however upon closer inspection, many of the PISA questions seem quite removed from the goals of the SSI movement. The PISA exam does not reflect the progressive nature of science, which is one major goal of science literacy (Sadler & Zeidler, 2009).

The PISA exam approach to testing science literacy is through examining mastery of science processes normally taught in school, which all students should be familiar with (Bautier & Rayou, 2009). "But can literate competencies be reduced to what has been learned in school?" (p. 359). Bautier and Rayou (2009) examined the ways in which culture and socialization revealed themselves in student responses on the PISA. After their analysis of student responses as they related to cognitive competencies and ways of being in the world and in knowledge, Bautier and Rayou were able to establish profiles of students for whom literacy competencies were only one component. Many times students performed better on the PISA exam because of their life experiences and opinions, rather than their application of science knowledge. The conclusion of the authors is that the PISA exam does not necessarily measure what it is supposed to measure with regards to science literacy.

Definitions of Science Literacy

The term scientific literacy emerged in the late 1950s when Paul Hurd used it in his article *Science Literacy: Its Meaning for American Schools* (DeBoer, 2000). Hurd suggested that the science curriculum needed to be "culturally based and in harmony with the contemporary ethos and practice of science" (Hurd, 1997, p. 407). He also emphasized the importance of closing the gap between the wealth of scientific achievement and the poverty of scientific literacy in this country (DeBoer, 2000). Since then science literacy has been defined in many ways by various interest groups. Because there have been different meanings and uses of the

term science literacy since its inception, there have been mixed approaches in science reform, science education, and science assessments (van Eijck & Roth, 2010). Deboer (1991) and Roberts (1983) tried to consolidate the public understanding of science literacy in their works by creating a database of interpretations of scientific literacy. By the late 1960s, science literacy became known as an umbrella term for everything in science education (Laugksch, 2000). Feinstein (2011) created a useful framework to organize the different definitions of science literacy into three broad categories. He used the science literacy categories SL-rhetorical, SL-logical, and SL-empirical to taxonomically group the definitions. In order to understand the groupings, it is important to define the categories.

SL-rhetorical.

The SL-rhetorical supports definitions, which discuss conceptual change, mental models, and progressions. It accepts, a priori, the relevance of particular constructs or skills, but the descriptive question of "What does science literacy look like" is asked rhetorically, without any supporting evidence of its useful nature (Feinstein, 2011). This category includes definitions that support conceptual change in science. This model does not really answer what science literacy is, rather suggests that particular skills and concepts taught will contribute to whatever science literacy may be. It is not clear whether the skills taught using this model are even useful beyond an educational setting. This model is frequently seen in education when teachers teach a science course from a book and hope that at the end the students are scientifically literate, even though there is no starting definition, and no clear path to achieve literacy. Research articles on conceptual change and mental models in science education fall in this category because they fail to prove that a particular construct will even be useful beyond the classroom.

SL-logical.

The SL- Logical category supports science literacy in the form of argumentation, nature of science, and socio-scientific issues. It logically deduces the knowledge and skills that can be attributed to science literacy, and it accepts a particular description of science. The SL-logical model provides a clear, more-detailed than the rhetorical description of science literacy and this description is connected to the usefulness of science in a students' daily life.

One component of SL-logical model of science literacy is scientific citizenship. Scientific competence is both the objective knowledge of scientific information, and subjective interest in science related themes. A lack of this public competence can have severe social and economical consequences. A democratic society, where everyone has equal opportunities, needs to support adequate knowledge of science and technology. A lack of public interest and understanding of science makes it difficult to keep economic pace because we can no longer sustain and develop "systems of innovation" and the new technologies on which our economy is based. The new and evolving science programs are those that increase public participation rather than public competence (Mejlgaards & Stares, 2010). This can be described as the people "speaking back" to science rather than a traditional one-way dissemination of facts and information (Gibbons, 1999). All citizens need to participate in all aspects of scientific and technological debates (Jasanoff, 2004).

Scientific citizenship as defined by Irwin (2001) is a two-dimensional interplay and balance of both participating in science and having the appropriate knowledge of science. Scientific competence allows for greater participation in society (Irwin, 2001).

Continuing within the SL-logical category, Pella (1966) summarized the scientifically literate person as one who understands the "interrelationships of science and society; the ethics

that control the scientist in his work; the nature of science; the difference between science and technology; basic concepts in science; and interrelationships of science and the humanities” (p. 44). Similarly, almost 25 years later, *Science for all Americans* (AAAS, 1989) defined a scientifically literate person as

One who is aware that science, mathematics, and technology are interdependent enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. (AAAS, 1989 p. 4)

Pella's conception of science literacy was aligned with the SL-logical model and differed very little from Hurd's conception of science literacy.

SL-empirical.

The SL-empirical approach to science literacy focuses on nascent traditions of science in everyday life. It identifies skills and attributes based on "in situ" study, defines science literacy based on how science is useful in everyday life, and supports it with evidence. Under this model, there has been consensus that scientific literacy is something that can be "spotted in the wild," specifically nature and the environment that we share with others (van Eijck & Roth, 2010). This type of science literacy involves real world problems that are solved in the context of the specific problem, such as having a child with Downs Syndrome, where the parent must simultaneously understand the disorder, the implications, and the treatment.

Progress in Science

Progress in science depends on the public's perception and support of science education and research (Laugksch, 2000). Many demands are placed on citizens that require a deep understanding of scientific knowledge. How scientific literacy is defined depends largely on the conception of how researchers think about learning science.

Throughout the 1970s and early 1980s, science literacy began to follow the SL-logical model and became much more related to science in its social context. It became increasingly important that the interrelations of science, technology and society be emphasized and not just the content and processes of science (Gallagher 1971; Hurd, 1970; NSTA 1982). However, such interrelationships were controversial because they emphasized the social issues and not the disciplinary content.

The National Science Education Standards (1996) were the government's approach to science education reform and literacy and included a section outlining specific content standards for attainment of scientific literacy. The document highlights the following goals for science literacy:

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. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (National Science Education Standards, 1996, p. 22)

According to the SL-empirical concept, science literacy involves inferring meaning from text as well as interpretation, analysis, and evaluation. It is dependent on what the reader brings to the task. It is also important to note that students who score well on tests of science knowledge do not necessarily do well on tests that measure their capacity to interpret science in the media and to decipher between strong evidence and unsubstantiated claims made by an author (Norris & Phillips, 1994; van Eijck & Roth, 2010). Furthermore, there has been a push by some scientists to "salvage" science literacy by helping students become competent consumers of science via connecting their science education to real life experiences (Feinstein, 2011). It is

argued that most science education today shows little evidence of helping people live better, happier lives, yet one should still reflect on the usefulness of science in daily life. In fact, Feinstein (2011) focused his analysis on the "usefulness" aspect of science in his definition of science literacy. He argued that science education should help people solve personally meaningful problems in their lives, influence their political decisions, help them gain security and material items, and guide their behavior.

Feinstein's push is to transform science literacy from a bunch of political slogans to something tangible and worthy. His study presented two questions "What does science literacy look like?" and "What must people know or be able to do to be science literate?" (Feinstein, 2011, p. 3). The first question is inherently descriptive, while the second question is prescriptive. The connection between the two involves taking a backwards approach of looking at a program and seeing what kind of science literacy it produces. This type of empirical approach is rare in science education. The descriptive and prescriptive questions can be used to categorize most science education into the three categories: SL-rhetorical, SL-logical, and SL-empirical. Science educators do not promote all science literacy practices with equal energy, but rather support certain practices that emphasize socially valued ends (Feinstein, 2011; Norris & Phillips, 1994).

How science literacy is defined is quite important because if it is defined as only concepts, facts and processes (as many texts and authors define it) there is a large portion of the interconnectedness of science to society that is lost. Furthermore, it can be argued that science literacy can be spotted "in the wild," which refers to real world uses of science. Therefore, if the purpose of science education is to create a scientifically literate population, we must improve the SL-framework to increase scientific literacy in everyday life.

Science illiteracy is a national problem. If a large percentage of the population is not scientifically trained, our country's technical and defense needs will be adversely affected (Hurd, 1970; Lederman, 1998; Miller, 1998; Shahn, 1988). But more importantly, people who are science illiterate are deprived of their wider citizenship roles, including their ability to understand our increasingly technological world, make informed health and environmental decisions, and think clearly (Shahn, 1988). Therefore, "literacy" as the ability to understand is different than literacy as knowledge. More emphasis needs to be placed on the students' development of higher-level cognitive skills and the process necessary to acquire these science literacy skills. Science literacy requires the ability to relate to strange phenomena, make use of the language of science, and sometimes the mathematical reasoning process. Once literacy is defined, its meaning can drive curricular change and provide a basis for assessment (Shahn, 1988).

Research on Science Literacy

Science Literacy has been the focus of multiple research studies over the past 50 years. "The science community must take advantage of growing public dissatisfaction with the current education system and ask how science teaching and learning can be transformed. In short, scientists must mount the next campaign" (Lederman & Malcolm, 2009, p. 1265). According to a survey created by Jon Miller (1998), vice president of the Chicago Academy of Sciences, only 1 in 11 Americans is well enough informed to participate in a dispute involving a scientific issue. As Americans, we need to take a closer look at the effects of public policy on scientific literacy. Greenwood and North (2009) argued that the growth of our scientific enterprise over the past decades is at risk of being compromised if the scientific community does not turn its attention to promoting better science education of our youth. Also, the high school science books are

inconsistent as is the preparation of science teachers (Brossard & Shanahan, 2006; Laugksch, 2000). “As a whole, American youth are not learning science well” (Greenwood & North, 2009, p. 2073). American science achievement scores have dropped according to national assessments (PISA, TIMMS, NAEP) and many of the best students are choosing alternate career paths.

Experience and education, both formal education and informal acquisition of knowledge, provide people with a lens through which to perceive the world around them. As the scientific and technological influences on society become more prevalent, it will become increasingly important to help the citizenry develop a scientifically sharp lens to the world. (Greenwood & North, 1999, p. 2074)

American schools have witnessed a decrease in academic performance in all subject areas. In comparison to other countries, US academic performance ranks low.. In 2007, the International Mathematics and Science Study (TIMSS), was conducted with a cross-sectional study of 50 countries (TIMSS, 2007). The results from the science and math study of 12th graders from each country placed U.S. students near the bottom. The results of the study comparing the students in advanced placement physics and advanced placement math ranked U.S. students near the bottom as well, indicating that even our most gifted and talented students are not well served by our education system (Fensham, 2009; TIMSS, 2007).

Assessment of Scientific Literacy

The ways in which science literacy has been measured have varied since the term's inception in the later 1950s. Historically, there have been three main interest groups: sociologists of science or scientific educators using a sociological approach to science literacy, social scientists and public opinion researchers, and mainstream science teachers (Brossard & Shanahan, 2006; Laugksch, 2000). The assessments measured by the sociological approach have used standardized questions and survey methodologies to observe people's understanding of scientific constructs. When the respondent's knowledge matches what the experts deem

important, they are called scientifically literate. The main way to assess this type of literacy is through qualitative methods, such as case studies that use participant observations, interviews, focus groups, and questionnaires on specific issues. The method of assessing scientific literacy from the public opinion researchers differs from the sociological approach and has been termed the "deficit" model, which measures what people do not know. These researchers use large-scale samples, standardized questions, and survey techniques to obtain their data about the ability of the participant to describe and compare trends with respect to content knowledge and attitudes toward science. The benchmarks for science literacy that were proposed by the AAAS are often used as a representative set of questions to assess this knowledge. The third interest group, science educators, has not measured science literacy in a composite manner.

Building and expanding on the necessary knowledge identified by the AAAS, Miller (1998) created a set of basic scientific constructs that are important for understanding contemporary issues and yet still have the durability to last, as opposed to specific terms. The "nature of science" (NOS) is associated with Miller's third component of science literacy, the impact of science and technology on society. This is closely related to the STS movement.

A very important characteristic of a test instrument is its ability to measure what it is intended to measure (Laugksch & Spargo, 1996). The NSF's scale is the most widely cited public scientific literacy instrument based on the U.S.'s most current approach to scientific literacy. Broussard and Shanahan (2006) stated that there were 31 terms that are commonly used in the media, and that rather than solely using the NSF assessment, they decided to create their assessment on the basis of the collective social decision making of the media. Another criteria for creating a strong assessment is the degree to which it can be applied in cross cultural settings (cross cultural validity) (Mejlgaards & Stares, 2010).

In one international study cited by Mejlgaards and Stares (2010) in the Public Understanding of Science, the authors tried to construct solid indicators of participation and competence in science. The quantitative study posited that there was an association between survey items and two elements of scientific citizenship, participation and competence. The authors used the association between survey items to hypothesize the latent variables that lay beneath the survey questions. This latent variable approach was useful because it empirically allowed the data to speak for itself. However, this method can be problematic because the relationship between survey items becomes probabilistic rather than deterministic, which can increase the possibility of measurement error. The five types of competence were: very interested and very well informed, very interested and moderately well-informed, moderate to all, moderately interested, poorly informed, not at all interested, poorly informed. Interestingly, the authors concluded that efficacy follows interest. They questioned whether having an interest in science leads to being well informed in science. (Allum, Sturgis, Tabourazi, & Brunton-Smith, 2008). This is a key point when examining high school functional science literacy. Science departments may find that the students who score higher on the instrument of assessment have a higher vested interest in science. And if so, should departments be focusing on what is interesting and relevant in the classroom as a means for increasing literacy? The authors indicate in their discussion that finding a set of indicators for scientific citizenship would need many more in-depth assessments involving both quantitative and qualitative approaches. Ultimately, Mejlgaards and Stares (2010) determined that there were two categories of scientific citizenship: highly participatory and highly competent (mobilized citizens); and the detached citizens who are neither informed nor interested in participating in science, thereby rendering them marginalized in the knowledge society.

Similarly, another study conducted in 2008 constructed a meta-analysis of the science attitudes and knowledge across cultures. Their study yielded similar data to Mejlgaards and Stares' study in that there was a positive relationship between general attitudes towards science and general knowledge of scientific facts. Furthermore, they found that this relationship varied little across cultures. The impetus for this study was to understand why science was becoming less of a "force for good" in America and Europe. The authors posited that the skepticism of science among the public and officials is one contributing factor to major cuts in funding for science and technology programs.

Early findings of previous studies indicated that the low level of basic textbook knowledge about science lead to the decrease of a scientifically literate public. This was seen as the "deficit model," which was defined by Sturgis and Allum (2001) as the resistance to science and technology supported by ignorance, superstition, and fear. As examples, they argued that the public's doubts about nuclear energy and genetic engineering stemmed from citizens' inability to grasp the science upon which they are based. Interestingly, empirical evidence from most of the studies points to a weak correlation between knowledge of scientific facts and processes and positive attitudes toward science. Sturgis and Allum stated that the link is even weaker for technologically related topics. Citizens' perception of the "riskiness for society" of medical applications and biotechnology is also determined by their understanding of the underlying science. Overall, attitudes about science are more positive when individuals are more scientifically literate (Allum et al., 2008; Mejlgaards & Stares, 2010; Miller, 1998).

Another approach to assessing science literacy was done by using a 12 year ethnographic study of citizens and scientists approach to solving a community resource dilemma . The problem presented by the study transcended any one discipline of science and involved a

collective endeavor of individuals to solve the problem. This case study approach treated scientific literacy as a dynamic multi-faceted process rather than sets of knowledge contained in one individual (van Eijck & Roth, 2010b). In this study, the resource problem was solved; however, it could not be pinpointed to a single individual. Van Eijck and Roth (2010) concluded that scientific literacy was the outcome of a collective process in which the scientists spoke so that the residents could understand and the residents spoke so that the scientists could understand. Each side had to communicate in a common public discourse. This is described as the emerging scientific literacy, which is situational in nature. These authors cited another example of a seminal study where the navigation crew of a US navy vessel had to coordinate their actions to do what would be nearly impossible for them individually. "The ultimate navigational knowledge involved computational and cognitive properties that were much larger than any single individual" (Hutchins, 1995; cited in van Eick 2010, p. 186). In the same way that the crew could not navigate individually, neither do individuals in society. The knowledge of experts, and residents are necessary for the mobilization of scientific literacy, and scientific literacy is achieved through the group rather than just the knowledge of the individual.

National and International Assessments of Science Literacy

There are several national and international assessments aimed at measuring science literacy. On closer inspection of these assessments, it is clear that they primarily measure the knowledge/content-based material, and in some cases the process of science literacy as well. It is estimated that 90% of all standardized tests focus on the recall of science information (Shahn, 1988). Some of the assessment scores mirror the government's and public's decry of scientific illiteracy, indicating that American students are falling behind other industrialized nations, while

other assessments say American students are proficient. It is also possible that some of the international measures do not accurately measure literacy.

The National Assessment of Educational Progress.

The National Assessment of Educational Progress (NAEP) was recently updated in 2009 to reflect recent developments in science, curriculum standards, assessments and research. Because the new assessment is so different from past NAEP assessments, results cannot be compared to previous results. The NAEP is similar to other international assessments in that it has a series of multiple-choice questions that assess student knowledge of science and technology. The NAEP test also includes nature of science themes and hands-on performance tasks, which require students to perform experiments and analyze data.

Thirty-four percent of fourth-graders, thirty percent of eighth-graders, and twenty-one percent of twelfth-graders performed at or above the proficient level, demonstrating competency over challenging subject matter. Seventy-two percent of fourth-graders, sixty-three percent of eighth-graders, and sixty percent of twelfth-graders performed at or above the Basic level in science in 2009 (NAEP, 2009). Of all seniors who took the exam, those having taken physics, chemistry, and biology did better on the assessment than those students who took fewer courses and less advanced coursework.

The PISA exam.

The Program for International Assessment (PISA) exam compares educational levels of reading, math and science literacy across nations. The target population is 15-year-old students. It is considered to be one of the most comprehensive assessments because it asks students to apply their knowledge to real-life situations (Bautier & Rayou, 2009). The recent release of the 2009 scores has been highlighted by the Obama administration as an example of the U.S.'s

mediocrity in science education. While other countries have shown significant recent improvement in scores, the US has continued to stagnate, ranking 17th out of 34 industrialized countries.

The TIMSS exam.

The Trends in International Mathematics and Science Study (TIMSS), similar to PISA, measures the science learning of students in grades 4, 8, and 12, in specific disciplines. The written examination is composed of multiple choice, essay, drawing, graphing, and numerical manipulation. The TIMSS identifies knowing, applying, and reasoning as the three cognitive areas that are measured (IES, National Center for Educational Statistics).

The results of these tests put American students at roughly the middle to the bottom in comparison to other industrialized nations. It has been argued that the U.S. science curriculum is a mile wide and an inch deep and that any international assessment that asks for any depth of subject matter will yield abysmal results. Furthermore, science teachers are not equipped with the knowledge base to teach the material at the depth required for good teaching and student learning (Abd-El-Khalick & BouJaoude, 1997; Hashweh, 1985).

It is debatable whether the international and national tests designed to measure science literacy actually measure what they are intended to measure. It is clear that the U.S. is in the middle to the bottom of the ranks of other industrialized nations. Therefore it is important to look at factors that contribute to students' literacy, such as teachers' levels of literacy and teachers' beliefs about the nature of science.

Science Literacy Levels of Teachers

Strong teaching requires a deep knowledge of the content being taught (Bishop & Denley, 1997). Teachers that are supposed to teach for a high level of scientific literacy among

their students need to be highly literate themselves (Abd-El-Khalick & BouJaoude, 1997; Ball & McDiarmid, 1989; Willcuts, 2009). The process begins with a comprehension of the material, followed by a transformation of the material into forms that are understandable by their students. After comprehension and transformation, instruction begins. The methods of instruction are dependent on teacher knowledge and understanding of the material. The next step is evaluation, which also requires a firm understanding of the material. Finally, the teacher can reflect on the lesson and assessment, which also requires content specific analytical knowledge (Abd-El-Khalick & BouJaoude, 1997). Inadequate pedagogical knowledge of the teacher leads to learning difficulties of students and deficits in teaching strategies (Bozkurt & Nafiz Kaya, 2008).

Research suggests that a teachers' body of scientific knowledge serves as a framework to teach, answer students' questions, clarify information, and learn the process of science. This body of knowledge should be part of every science teachers' preparation (Anderson, 1987). Teachers that are lacking in their knowledge base due to inadequate preparation hold naïve views about the nature of science, and do not understand the structure, function, and development of their subject (Abd-El-Khalick & BouJaoude, 1997). Furthermore, the years of experience, the grade levels that they teach, and their level of education do not always have a direct relation to their knowledge base. This suggests that teacher preparation programs are not helping teachers develop their knowledge base.

Professional Development

In an effort to improve science teachers' practical knowledge of science, professional-development programs need to be implemented and sustained. Improving teaching and learning depends on sustained high quality professional development (Darling-Hammond, 1997). Teachers' practical knowledge includes the teachers' beliefs and knowledge about how they teach

and what they teach, and this practical knowledge is largely dependent on experience (van Driel, Beijaard, & Verloop, 2001; Willcuts, 2009). The types of professional development strategies that have been most successful in creating lasting change are network learning, peer coaching, collaborative action research, and case studies. Furthermore, reform projects need to be documented to enhance the chances of successful implementation for future science teachers (van Driel et al., 2001).

Teachers' knowledge plays a role in classroom instruction and assessment. Brickhouse (1990) found that there was a link between teachers' views of the growth of scientific knowledge and the way in which they helped students construct their own knowledge of science. The three forms of content knowledge are the pedagogical content knowledge, curricular knowledge, and subject matter knowledge, and the key to understanding the knowledge base of teachers is examining the areas where content and pedagogy intersect (Shulman, 1986). The substantive knowledge describes the connections and interrelations of concepts to one another within a discipline, while syntactical knowledge is the methodology used to construct knowledge within a discipline. Teachers vary in their conceptions of scientific processes and scientific theories and how the two are related. Furthermore, some teachers view the process of observation and experimentation as an inductive process while others view it as theory-driven. Brickhouse (1990) found that these teacher-held views determined the way that their students learned science.

The current state of professional development for teachers is not ideal. It has been documented that a significant number of teachers have little to no professional development opportunities; the opportunities that do exist are in the form of workshops and short courses that do not really give the teachers time to apply what they have learned; and the professional

development is applied to the individual teacher rather than the organization (Loucks-Horsley, Hewson, Love, & Stiles, 2003). However, while it can be argued that teachers' knowledge of content and pedagogy are the key factors in creating a scientifically literate population of students, it is not the only factor. It is also important to consider science teacher beliefs about the nature of science (NOS).

Science Teacher Beliefs About Nature of Science

Science teachers' beliefs about science literacy are significant in creating the quality of the educational experience and the type of learning environment that students receive. Their beliefs and attitudes affect their pedagogical decisions (Yerrick, Parke, & Nugent, 1997). One research study included a discussion of human decision-making as it relates to the development of cognitive models of the scientific enterprise, and the selection and order of instructional techniques used by the teacher (Duschl & Wright, 1989). In the article, teachers with low-level sections of science tended to teach the learning process of science (basic skills), such as measuring, describing, reading, writing, and language development, that would be used to understand vocabulary, definitions, and identifying. The objectives tended to be teacher-identified outcomes. In science classrooms with high ability students, there was a large focus on learning the content of the discipline (physics, chemistry, biology) through higher-level instructional processes, such as problem solving, reduction and construction of systems, and analysis. The source of the objectives came from set state standards and curriculum. Teacher objectives and assessment of learning outcomes were directly related to the perceived ability of the student. Thus students in higher-level classes tended to learn to think like scientists (Duschl & Wright, 1989)

Teaching is complicated in both the task and the environment in which it takes place. The classroom can be a busy chaotic place with multiple forms of stimuli entering at any given time. Teachers must constantly construct "models of reality" to effectively lead labs, lessons, and instruction. Most of these constructs are based on the teachers' beliefs about what is important and valuable. The teacher is the ultimate decision maker, but these classroom decisions are based on select components of their environment.

The goals that teachers set and their beliefs about the subject matter are critical in determining the decisions that they make in the classroom about what is taught and what is learned. It is teachers' knowledge of science and instruction as well as their views on teaching that directly influence their curriculum (Gess-Newsome, 1999). In an empirical study, which explored the correlation of science education and beliefs about science education, the beliefs and attitudes of science teachers and scientists were measured using a pilot study (Pomeroy, 1993). The study concluded through correlation analysis that there was a linkage between beliefs about science and science education. This association reinforces the notion that there needs to be a component of the philosophy of science embedded in science teacher preparation (Duschl & Wright, 1989; Gallagher, 1971; Pomeroy, 1993).

In one case study conducted in 1990 with 74 pre-service teachers (Lederman, 2007), surveys were given with open-ended questions about the nature of science, teaching of and learning of science. The analysis of the data showed that most teachers in the study believed that science was a body of knowledge that consisted of facts, observations, and explanations. The teachers were evenly divided on their role of science teacher as "dispenser of knowledge" and "guide/mediator of knowledge." The conclusion of the study was that pre-service teachers did not "possess adequate conceptions of the nature of science" (Lederman, 2007, p. 841).

The research on teacher decision making in the late 1970s and early 1980s (Duschl & Wright, 1989) suggested that teachers constructed models of reality in their classroom based on small/select parts of the environment that they taught: they did not teach toward objectives but rather taught toward activities; their planning and decision making was based off of the content and instructional texts; their behaviors and thinking were guided by beliefs which were based in the environment that they taught in; and finally, teachers' beliefs guided their decisions, which affected their behavior .

Educational philosophy plays a large part in how teachers make decisions. Some of the theories that have guided science instruction in the past have been classical empiricism, positivism, world-view, realism, and neo-empiricism. Scientific theories guide teachers' cognitive models when developing instructional tasks and assessments. The teachers' beliefs are the basis of the implemented curriculum. In one triangulated study about teacher beliefs and classroom instruction and assessment (Duschl & Wright, 1989), the authors answered research questions about teachers and their view of the roles that theory played in the selection, implementation and development of instructional tasks, the factors that teachers' used to develop instructional tasks, and the benefits that might be gained if the nature of science and its theories were used to develop instructional tasks. The study was carried out over 16 weeks in the science department of a suburban high school. Thirteen science teachers, with an average of 12 years of teaching experience, and varied instructional duties, were observed during this period. The observations during the 16-week observations were only considered valid if the interviews, documents, and surveys all corroborated the observations. The data collected from the study revealed that there were three lesson-type categories: organizational process skill lessons, cognitive and scientific process skill lessons, and objective lessons. Organizational processes

were the strategies that teachers used to orient the learner to the rules and routines of the school and classroom. The organizational processes could take two forms: classroom-teacher (i.e., keeping a notebook, labeling papers) or science-scientist (i.e., writing lab reports, conducting scientific investigations, using equipment). Teachers in the study spent a good part of the month engaging in this type of organizational processes teaching, which was highly redundant from year to year. One example that the authors gave was that teachers in the science department spent anywhere between 3 days to 2 weeks on metrics in grades 9 to 12, across all disciplines. The metrics unit example supported the idea that there were three decision-making constructs at play: teacher accountability, teachers' inattention to redundancy, and teachers' independence in selecting instructional material. The question that arose was whether there was a conflict between developing knowledge of science and developing skills for success in the science classroom (Duschl & Wright, 1989).

Cognitive and scientific processes are the types of instructional tasks that lead to students thinking like a scientist. Duschl and Wright (1989) found that the teachers in high level chemistry, physics and biology could pinpoint the time in the year when their students could begin to think like a scientist.

Alternatively, critics of this argument state that teachers' beliefs about nature of science do not necessarily result in differences in teaching (Lederman, 1998, 1999, 2007). There are multiple factors at play, including number of years of teaching and especially perceptions of students. Students' understanding of the nature of science is critical in their development of science literacy. In a multiple case study of science teachers in an upper school, the relationship between teachers understanding of NOS and classroom practices were observed in order to understand factors that enhance or impede instruction (Lederman, 1999). The analysis of the

data revealed that teachers' conceptions of science did not necessarily determine classroom practice. The other factors that were found to be really important were teachers' level of experience, intentions, and perceptions of their students (Lederman, 1999).

Reform efforts and reorganization of schools through national efforts have not been successful at the classroom level. The reason for this is that participants in reform efforts tend to maintain their entry-level beliefs about the nature of science, teaching, and ways to measure and assess scientific literacy. One study, conducted over two weeks in 1995 (Yerrick et al., 1997), with middle school science teachers, attempted to understand the process of making lasting change and changing deep-rooted beliefs about science teaching and education. The teachers in the study chose to participate in a statewide effort to align their curriculum with the new science framework. The teachers expressed a high level of concern regarding whether it would be difficult to make the philosophical shift from transmissional to transformative teaching of the new course material. The transmissional teachers were those who believed that science was just a discrete set of facts to be delivered, while those teachers who believed that science knowledge needs to be interpreted by the students, and that the knowledge should transform the students, were transformational. The forms of assessment used by the transmissional teachers were usually sets of short questions and answers that ask the students to repeat what they have learned. The transformational teachers asked the students to analyze and interpret information in a way that was not transmitted (Yerrick et al., 1997).

The data collected from previous studies with the same research design and focus showed that the teachers who transformed science education used research based learning strategies with their students at a much higher frequency (Yerrick et al., 1997). During the previous workshop, teachers received instruction and literature on their ability to design curriculum and modify

classroom settings to improve student learning. The basic components of reform that were addressed in the studies were: inquiry science with time for reflection to make sense of the material, depth of content and relevance of material, questioning and meaningful assessment rather than memorization, collaborative dialog to experience the thoughts of others, and teaching that was guided by research based theories (Yerrick et al., 1997). The teachers in the study modified their instruction and assessment to mirror the new reform techniques. Initially, after the professional development, teachers in the study were observed to have altered their assessments to reflect the new pedagogy; however, observations at a later date showed that teachers fell back into the routine of giving traditional objective tests. The authors concluded that the teacher's strong personal beliefs ultimately influenced their course of action in teaching. Furthermore, teachers may walk away from an identical reform effort with varied interpretations of the new science instruction. They further concluded that teachers did not develop their knowledge of teaching through abstract workshops. Teacher learning needed to take place in the context of the classroom, through direct field experience (Elbaz, 1981).

Improving Science Literacy Through Action Research

Action research is a way to study experiences of teachers and improve partnerships between colleagues. It is highly beneficial because science teachers experience professional development through two lenses: that of the researcher/learner and that of the teacher. Learning for science teachers needed to be constructivist in nature, and include an explicit model of nature of science (Willcuts, 2009). Action research can create sustainable change because participants are implementing their own ideas (McNiff & Whitehead, 2006). The process is cyclical and starts with an observation, followed by a reflection, an act, an evaluation, and finally a modification. The research in the current study will include an interactive process of working

with teachers to explore notions of science literacy in an effort to create our own definition. Using a collaborative action research cycle in science departments as a vehicle to create curriculum and assessment has proven to be successful. In one study, by Parker and Coble in 1997, science teachers were grouped and their dialogue was continuous with other members of their department as well as university science professors as they developed curriculum materials to promote scientific literacy among their students. This approach "supported teachers to become architects for change through building upon their current conceptions instead of attempting to remediate them" (Parker & Coble, 1997, p. 785).

Conclusion

Science literacy (SL) has been defined by many and agreed upon by few. The term according to Feinstein (2011) has three broad categories by which it is defined: SL-rhetorical, SL-logical, and SL-empirical. Most definitions of science literacy can be grouped into these three broad categories. Achieving science literacy in our high schools is and has been a major focus of scientists, teachers, politicians, and schools. Factors such as teachers' beliefs about science and teachers' content knowledge affect the science literacy levels of their students. It is important for teachers to have a clear definition and understanding of science literacy. Furthermore, it is essential for science departments to have instruments to measure the level of science literacy among their students. Schools cannot know if their students are scientifically literate if they have no means for measuring this knowledge. An action research cycle will help to illuminate teacher beliefs and create knowledge and theory as a result of the action (van Driel et al., 2001).

My study aims to improve the science literacy level of students at Sunset School by engaging science teachers in a collaborative action research cycle. Such collaboration will

hopefully encourage discussions about science literacy, improve planning and instruction around the context of science literacy, and ultimately improve assessment of science literacy.

Chapter 3: Methodology

Introduction

As noted in the previous chapter, American students are less scientifically literate than students in many other countries. This lack of scientific literacy will undermine people's abilities to participate in a democratic society and meet other 21st century demands. Such demands require individuals to understand and engage with scientific research, understand rapidly developing technologies, and practice sustainability (Murcia, 2007). Having a scientifically literate population requires a clear definition of science literacy, knowledge about how it can be developed, and, finally, an understanding of how it can be assessed.

My research focused on high school science literacy in the U.S., and more locally at Sunset School in Los Angeles, California. The purpose of my dissertation was to engage a group of science teachers in a collaborative action research project to observe and elicit their beliefs and perceptions about science literacy and find ways to assess this literacy among the population of students. In the process of answering the question, "What are science teachers' views on science literacy?" I also answered some of the embedded questions, such as how do Sunset faculty think about science literacy as it relates to instruction and assessment, and how did collaboration influence the way they thought about their work. A significant part of my dissertation was looking at how teachers thought about science literacy and how they measured the scientific literacy of their students, as well as how their beliefs and perceptions changed over time after participating in a collaborative action research project.

Research Design and Questions

I used a qualitative action research design for this study. The goals of the study were to measure science teachers' beliefs about science literacy using action research. I also looked at

how teachers' views on science literacy manifested in their assessment, instruction, and planning. In addition, I examined how their perceptions may have changed over time. Finally, I looked at how collaboration influenced their work.

My research design was driven by the following questions:

- (1) What are science teachers' views on science literacy?
- (2) How do science teachers' views on science literacy manifest across different contexts of teaching: planning, instruction, and assessment?
- (3) How does collaboration around the context of planning, instructing and assessing for science literacy influence teacher's views on the nature of their work?

Rationale for Qualitative Research

A qualitative research design helped me answer the "what" and "how" of my research questions by capturing the participants' individual and collective voices. It involved collaborating with the participants interactively and ultimately shaping the themes that emerged (Creswell, 2009). Because I conducted my research with a small science department of 11 people, interviews and reflective journals were an appropriate form of data collection.

Transcripts from each discussion session and the interviews as well as reflective journals allowed me to collect rich, thick, detailed information about teacher beliefs and practices. Group session interviews and reflective journal prompts were appropriate ways to capture the changing beliefs of teachers over time because participants were asked to write their initial beliefs and discuss their beliefs at the conclusion of the study. I collected pre- and post-data to compare results from the beginning to the end of the study. The process allowed me to clarify my questions, follow up on answers, and ask participants to expand on their ideas in a productive and pragmatic way.

The small sample did not lend itself to a quantitative study. This holistic account allowed me to identify all the factors involved in the process of qualitative action research (Creswell, 2009).

My research design stemmed from a social constructivist worldview. The assumptions of this worldview are that individuals in the science department would seek to understand the different views on science literacy that exist in the world and especially within the department (Creswell, 2009). The views were diverse and varied among members and this lent itself to deep discussions and interactions during each session's collaborative group work. The goal of my research was to elicit the participants' views of science literacy as well as study the interactions and influences among department members, which might have shaped their final beliefs and perceptions.

Rationale for Action Research

Action research is an approach to research that involves both taking action and creating knowledge or theory as a result of that action (McNiff & Whitehead, 2006). According to Bolman and Deal (2008), organizations will look for ways to "engage and empower" various stakeholders in making choices. Action research is a way to create change because participants are actively involved and implementing their own ideas (McNiff & Whitehead, 2006). The process is cyclical, begins with an observation, and is followed by a reflection, an act, an evaluation, and a modification.

This type of research required the involvement and observation of the teachers and students at Sunset School. Because teachers behave in a sort of "collective autonomy," it is important that all members understood the shared vision of the school and could act accordingly (Sagor, 2000). According to Nolan and Vander Putten (2007), teachers who conduct research at their site are reflective practitioners who aim for instructional improvement. There are three

main principles for working with human subjects: respect for persons, beneficence, and justice (Nolen & Vander Putten, 2007). Because of the nature of action research, it is possible to create sustainable change when individuals at a site create and implement their own ideas rather than accept and implement the ideas of others (McNiff & Whitehead, 2007). Action research works on the premise that individuals in the organization are the best source of knowledge. The act of embarking on action research at my site will undoubtedly begin the process of sustainable change through awareness and acceptance of the issue of scientific literacy.

Description of Intervention

My action research project involved a pre- and post-analysis of teacher beliefs about science literacy as well as the facilitation of an intervention to expand teacher beliefs about science literacy. The goal was that teachers would begin to think more comprehensively about science literacy, how they taught, and how they assessed science literacy in their classrooms. The interest in qualitative research was in the process rather than just the outcomes (Maxwell, 2005). Teachers in this study each had a laptop computer that was provided by the school that was used to respond to journal prompts and activities within each session.

Phases of Implementation

Implementation of the science department intervention took place from August 2011 through December 2011. There were two hours of scheduled meetings during the August in-service time allotted for departmental professional development. Subsequent meetings took place on four Monday afternoons during faculty meeting times, and lasted an average of one hour. The final interviews lasted between 20 minutes and one hour. See Appendix A for a timeline of the project.

Site Selection

The site for my study was Sunset School, located in Los Angeles, California. Sunset School is a K-12, medium sized private school (1200 students) predominately serving a small community of families in Santa Monica, Sunset, and Pacific Palisades. Sunset School opened in 1972 as a co-ed 7-12 school and in 1994 opened a K-6 elementary school on a separate campus one-half mile down the road. The population of students is mostly white. Ethnic minority students make up 20-25% of the students in any given grade level. It is an appropriate location to have completed the study because of the reputation of the school, the caliber of the students, the emphasis placed on education, and the tremendous involvement of the teachers. All of the science teachers have had significant teaching experience with the exception of two new teachers.

The type of instruction ranges from very traditional, content-oriented instruction to very student driven conceptual and process-oriented teaching. The structure of the school allowed me to look at vertical articulation, which was the sequence of courses and their connection to each other, across six grade levels (7-12). There was quarterly professional development time set aside for science teachers to meet during a common meeting time. The Sunset School supported this type of study in order to improve curriculum and practice. AP scores and SAT 2 scores are high in the sciences and there is a 90% passing rate for the students each year on AP exams. Teachers are expected to teach a great deal of content as prescribed and expected by the College Board. Because of the rigorous program, it was expected that science literacy would be at the forefront of conversations among science teachers. Although this school and the findings from my study are unique, the action research methods used may be helpful to other schools that are interested in understanding and possibly expanding teacher beliefs about science literacy.

Population

Science teachers were the designated population to study in order to answer the research questions. To develop a climate of trust and sharing during the process, it seemed appropriate to include faculty but not administrators or students in the group sessions. Science teachers were the population designing and adhering to the curriculum. They were also the population that held strong beliefs about science literacy and how it should be measured.

Sampling

Sunset School has three divisions of science teachers: lower (K-6), middle (7-8) and upper (9-12). The middle and upper division science teachers work on the same campus, while the lower school science teachers teach at a different site. Therefore, every teacher in the middle and upper division science departments had an equal opportunity to be in my study. There are four science teachers in the middle division who teach seventh and eighth grade life science and physical science, respectively, and there are eight upper division science teachers. Three teachers teach ninth grade physics, three teachers teach tenth grade chemistry, and three teachers eleventh grade biology.

The Science Department

The Sunset School consists of a lower, middle, and upper division. Each division employs its own teachers. The science department members do not teach in multiple divisions. As a result of the separate divisions, communication and collaboration had been limited over the years. Prior to commencing my study, the middle and upper division science department met only twice a year, with no real agenda.

Eleven members of the science department participated in the study, including a summer school biology teacher. Because of health reasons, only one member did not participate in the

study. Although I was a full participant and facilitator at all meetings, I did not include my own data in the findings. Data were collected from 11 teachers over the course of the study. These teachers represented a cross-section of grade levels and years of experience. In order to protect their confidentiality science teachers were assigned pseudonyms taken from famous male scientists. Seven of the participants taught in the upper school, while 4 of the participants taught in the middle school.

Science teachers in the middle and upper division ranged from 26-years-old to 61-years old. All but two of the science teachers had been teaching at Sunset School for a minimum of 5 years. All of the middle school teachers had backgrounds in both physical and life science. The upper division science teachers varied in experience and background.

The sample was selected from the members of the middle and upper school science department (see Table 1). Because my study was qualitative, I did not attempt to generalize to the entire population of science departments. I studied people purposefully because they shared the common characteristic of teaching science. Therefore, the conclusions that I have drawn from my study may not be generalizable to other science departments nor can they be generalized to members of the department who did not participate in the study. There was a range of teachers in the department, and this may be common among other science departments at other schools. With 11 members from the science department over a period of 6 months with six group sessions, there was enough information to reach saturation and understand the phenomenon I was studying.

Table 1

Teacher Demographics at Sunset School

Teacher	Number of years teaching at Sunset School	Subjects Taught	Higher degree in Science or Education (Masters or higher)	Race/ethnicity	Gender
A	5-9	7th and 8th	Yes	White	Female
B	5-9	7th and 8th	Yes	White	Female
C	10-14	7th and 8th	No	White	Male
D	10-14	8th	Yes	White	Male
E	25-30	Biology (H) Anatomy Zoology	Yes	White	Male
F	1-4	Chemistry (H and AP)	Yes	White	Female
G	5-9	Chemistry (H) AP Environmental Science Forensics	No	Asian	Female
H	20-24	Physics Chemistry	No	White	Male
I	5-9	Physics	Yes	White	Male
J	15-20	Biology Astronomy	No	White	Female
K	1-4	Biology Chemistry	No	White	Male

Access

To gain access to my site I discussed my study design with the administration at the school. I explained my rationale for studying the science department, how I would collect the data, and the type of feedback that the school would receive after I analyzed the data. I built my study upon a Western Association of Schools and Colleges (WASC)-mandated recommendation that the faculty would create a process for the articulation of the academic program across

multiple divisions. This included a scope and sequence document with specific content, objectives, skills, and assessments.

To encourage teachers to participate in my study, I set up a realistic timeline (Appendix A) for each group session that allowed department members to have adequate time to process information between meetings. I emphasized the confidentiality of the participants in the signed consent forms and the memorandum of understanding (Appendix B). I also removed myself from the teacher evaluation process during the year of my study while remaining department chair. The project was time consuming for the teachers involved. I emphasized the use of already allotted professional development time to help gain access from the teachers. Generally, their participation in this study did not force them to spend much additional time outside of the pre-scheduled and pre-allocated meeting times set forth by administration. In meeting with both administrators and science teachers, I introduced my project, provided an overview and timeline, outlined participation requirements, asked for questions and discussed contact information.

Data Collection Methods

In order to answer the research questions and maximize external validity and reliability, I employed four modes of data collection: group sessions (Appendix C), interviews (Appendix D), sample work, and electronic reflective journal prompts (Appendices E and F). According to Creswell (2009), multiple forms of data collection are essential in qualitative research and were used to triangulate my findings. See Appendix G for the Data Analysis Matrix I developed to guide the process of data analysis.

Group Sessions

One of the purposes of my action research study was to begin creating a culture of collaboration among science department members. I facilitated group sessions as a means to

create authentic and purposeful collaboration around the issue of science literacy. My study yielded results on what departmental members thought about science literacy, as well as how beliefs influenced their assessment and instruction. The focus of several group sessions was centered on group-generated science competencies and how assessment, instruction, and planning could be aligned to these competencies.

By the end of the group sessions, each group member had the opportunity to identify competencies, assessments that measured those competencies, as well as plan instructional goals that maximized student competencies. We continued to discuss science literacy through the creation and reflection of competencies.

The tape-recorded group sessions began during in-service week in August of 2011 and continued through December of 2011. I held five group sessions that allowed individual participants to write down their initial definitions of science literacy, compare individual definitions to the group, and generate more holistic definitions of science literacy. Science teachers were grouped heterogeneously between subject and division and asked to generate competencies for the department. Subsequent sessions focused on department member created assessments that measured the group-generated competencies. I audio-taped all group sessions and asked for explicit permission from each member to record their voices and transcribe their words. Each group session lasted approximately one hour. Details regarding each of the sessions are in Appendix E.

Electronic Reflective Journal Prompts

Before and sometimes after group sessions, I emailed an electronic journal prompt to each member of the group asking them various questions about the day's discussion. This was one way to obtain honest feedback from individual members who may not have been

comfortable sharing in a group setting. At the end of the first session, I had pre-data I had baseline data to measure teachers' expansion of ideas about science literacy over time. I also had a simple framework for what my department thought about science literacy as well as a set of questions that members had written down.

After the first group session, I selected a peer-reviewed journal article for each member to read before session 2. The article was by Paul Hurd, *Scientific Literacy: New Minds for a Changing World*. This was an introductory article that summarized the history of the science literacy movement in this country. Hurd (1997) defined science literacy and discussed the importance of teaching science for non-science majors. He pushed for a socially responsible and competent citizen through improved science instruction that recognizes shifts in culture. I chose this as an article to read because it nicely summarized and defined science literacy in a way that would be familiar to group members. The article was a strong springboard for discussion about basic science literacy.

Interviews

In addition to the other modes of data collection mentioned above, I briefly interviewed each member of the department at different stages through the process in order to clarify any group session questions, and expand on their electronic journal prompts. The interviews were especially helpful in answering research question 3, which asks about how collaborative processes influence change in beliefs. Interviews were open-ended and incorporated questions based on observations (Maxwell, 2005).

Data Analysis Methods

Transcription and coding.

I began the process of coding almost immediately after I collected data in all forms. I coded and analyzed the initial and final definitions of science literacy as well as identified the recurring themes. I also documented the process over a 6-month period as well as collected assessment items from teachers as they created them during this process.

Each group session was digitally recorded and a verbatim transcript was prepared for all sessions. This process ensured that science teachers were heard and documented accurately in order to decrease threats to validity by incorrect documentation of data. I used Microsoft Word and Microsoft Excel to code and organize the data from the transcripts into categories. The data collection and data analysis occurred almost simultaneously. Participant responses to questions were sorted under broad headings such as definitions of scientific literacy, feelings about assessing literacy, value in collaboration, and most important competencies.

The goal after coding was to identify themes and connections between them. Finally, the themes were analyzed within the theoretical framework to form my conclusions. This ensured credibility. I also collected pre-group session data and post-group session data in order to answer research questions 1 and 2. It was only through comparison of pre- and post data that I was able to understand how beliefs about science literacy change over time through a collaborative action research project.

Data analysis matrix.

I developed a data analysis matrix (see Table 2) that specified which methods were used to answer each research question and how I analyzed the data collected from each method to answer each question.

How I coded my findings.

I used a coding scheme based on Noah Feinstein's (2011) science literacy categorizations. Feinstein described three categories of science literacy: rhetorical, logical, and empirical.

The rhetorical category includes definitions, which do not actually link the knowledge that students acquire to any usefulness in their lives or in context of any real societal issue. Rather, the rhetorical definition makes the claim that knowing physics and chemistry is useful, without supporting the claim with any evidence. These are the definitions that claim something is important, without a justification for why. Usually these definitions include content from the book or the curriculum that have an a priori acceptance of their importance. An example of a rhetorical definition might be: *Science literacy is when students have a thorough knowledge of the terms and concepts of physics, chemistry and biology. The science literate students will be able to use all terms correctly.*

The logical category of science literacy describes definitions, which include the usefulness in students' lives, socio-scientific issues, argumentation, and nature of science definitions. A person whose definition falls into the logical category might say, "science literacy is making a connection to what is taught in the classroom and how it can be applied to daily life, and understanding that life is science." This definition falls into the logical category because it makes the link between science and its usefulness to daily life.

The final category is the empirical category. This category supports definitions that include real world problems or issues, or in-situ studies. The empirical category supports definitions, which include their usefulness to everyday life and support it with evidence. Another way to think about the empirical category is to look at science being a way to explain naturally occurring phenomena. An example of this might be a definition, which states that

science literacy is being able to solve a real world problem such as the obesity epidemic or how to reduce carbon dioxide emissions that contribute to climate change.

In summary, the rhetorical and logical categories supported definitions and sample questions where a "situation" is created for the purpose of kids using their science knowledge to explain it, while the empirical category asks students to place themselves within naturally occurring, timely issues and asks them to use their science to explain or solve a problem.

While I was able to categorize each of the definitions and artifacts, I also was able to look at participants and mentally place them on a continuum based on their degree of rhetorical, logical, and empirical. Rhetorical definitions varied in degree. Some participants shifted their thinking from pure rhetorical, to rhetorical-logical, to logical, logical-empirical, and finally empirical. It is useful to think of science literacy along this continuum, because even if individuals do not seemingly change categorization, they may still have shown growth in my study.

It is also important to note that the empirical categorization is the ideal in science education. Using these categorical definitions of science literacy I coded multiple artifacts that teachers produced during the professional development sessions. These included the written definitions each teacher wrote during the first session, sample test questions they wrote prior to the second session, sample performance assessments written for the third and fourth sessions, and final definitions elicited in individual debriefing interviews following the last PD session.

Ethical Issues

There are always ethical considerations when doing work at one's site, such as whether my department members felt coerced into participating in the action research and the creation of assessments and lessons. I did not directly supervise department members during the period that

my research was conducted; however, I was involved in informal evaluations during each member's first 3 years of employment. There were only two teachers who were in the department fewer than 3 years. I made it very clear that participation in the study was optional. I ensured that teachers had a safe and respectful environment to share beliefs and perceptions.

Several safeguards were put in place to address ethical considerations. First, I developed an informed consent document, which described the purpose of my research, the potential risks of participating in the study, the benefits for the participants and the time commitment. I clarified expectations to ensure confidentiality. Each group session was recorded and notes were taken; however, when writing up the notes pseudonyms were used to ensure anonymity. Results of the study were shared with my department and my administration; however, individual names were not used. This ensured that teachers had a safe place to share their beliefs and ideas. I also asked for individual feedback after each group session so as to decrease "group think" or pressure to conform.

Reliability and Validity

The focus of my research questions addressed science teachers' beliefs, perceptions and attitudes about science literacy and science literacy assessment. The credibility and reliability of my study primarily rested with the responses in interviews, group sessions, reflective journals, and actions provided by the participants in my study. I repeatedly used respondent validation to confirm with my interviewees my conclusions drawn from the interview transcripts (Merriam, 2009). In this way, I made sure that I did not misinterpret their words because of my own biases. In addition to collecting authentic data from my participants, I was also continuously aware of my own biases, and how these biases could have been perceived by department members, thereby influencing their responses.

Reliability is the extent to which my research findings can be replicated (Merriam, 2009). My study measured science teachers' beliefs and perceptions; however, human thoughts and behavior are never static. Therefore, while I may not yield the same results if I repeat the study with another science department, the results should remain reliable. The last sentence is awkward. The most important issue is that my results are consistent with the data collected (Merriam, 2009).

Management of my role.

For the purposes of my research project, I wanted to be perceived as a graduate student and a facilitator first and foremost. Of course, I had worked with the members of my department for several years and I was inevitably seen as a colleague and a department chair. My goal was to increase collaboration among the department members through the process of creating competencies and assessments. I tried to remain neutral and un-reactive at all times. Furthermore, comments shared in the action research group were not shared with the administration, thus emphasizing my role as a graduate student rather than the department chair.

Trustworthiness and credibility.

To ensure credibility of my study I needed to be conscientious of my own biases. I have been teaching high school science for 15 years and have developed opinions regarding the knowledge and processes in science that are worth knowing and that students should be able to discuss. Furthermore, I have gained tremendous insight during the process of reading journal articles and books on the topic of science literacy. As I presented research to the department I needed to be cognizant of the entire department's opinions and the faculty's independent research on the topic of science literacy. As the science teachers created competencies and assessments, I learned about the value placed on certain types of knowledge.

I needed to deal with issues of reactivity and not share my own beliefs so that my department members could share theirs freely. All opinions and beliefs were deemed legitimate. Furthermore, because the sample was small, the reader can determine whether the extent of this study can be generalized to his/her setting.

Summary

Science literacy has been the focus of educators, public policy-makers, and scientists all over the country. There is a growing body of literature on this widely debated topic; however, there has been neither discussion nor collaborative work at Sunset School in the past decade around the issue of science literacy.

In this chapter, I discussed the rationale for both the need for this study as well as why a qualitative action research study was the best method to answer my research questions. It is my hope that the process of the study as well as the results from the creation of assessments and competencies will improve collaboration among department members, as well as expand the department members' definitions of science literacy. Finally, the science department will have some form of assessment that accurately measures the type of science literacy that is valued by the school's academic community.

Chapter 4: Findings

Introduction

In this study I set out to answer three questions: What were participating teachers' views of science literacy? How were these views manifested across contexts of planning, instruction, and assessment? Finally, how did collaboration around science literacy affect teachers' view of their work? This chapter answers these questions in turn.

In analyzing the various artifacts teachers produced during the study, it became clear that the answer to the first question was really to be found in the answer to the second question. That is, teachers' apparent views on science literacy seemed to vary by the contexts in which such views were elicited. The first section of this chapter, then, presents my findings for the first two questions together. Following that, I present teachers' views of their collaborative work over the course of the study.

Landscape of Science Literacy

The first group session took place during in-service week. I asked participants to write down their initial views on science literacy, as well as write down some sample test questions that could measure the scientific literacy of their students. I used Noah Feinstein's (2011) classification of science literacy to create my own categories to group science department members' definitions. Feinstein defined rhetorical approaches to science literacy as those that simply assert that knowing science concepts or skills (such as doing experiments) are important for people to know. Logical approaches to science literacy are those that logically deduce the knowledge and skills needed by students to engage with science in the world. Crucially, for Feinstein, neither of these approaches has empirically tested whether their suppositions held for people in the world. Therefore, Feinstein defined an empirical approach to science literacy that

was grounded in examinations of the ways in which people actually encountered science in their lives and induced the science people needed to know to meet their own goals in such encounters. To these three categories of definitions, I added a fourth, fifth, and sixth, rhetorical-logical, rhetorical-empirical and logical-empirical, to capture ideas proposed by study participants that were ambiguous with respect to the two base categories (see the previous chapter for full discussion).

All of the responses that participants constructed to the tasks I used here as data sources could be placed into one of these six categories. However, Feinstein (2011) placed these definitions on a continuum that can, simplistically, be thought of as something like abstract to grounded. In his view rhetorical was the low end, because the value of knowledge/skills was merely asserted. Logical approaches, according to him, at least put forth arguments for the value of certain knowledge/skills. The problem is that these arguments are logical rather than empirical. So the continuum from bad to good would be Rhetorical–Rhetorical/Logical–Logical–Logical/Empirical–Empirical. The rhetorical-empirical category skips the logical component all together. The methods section includes detailed explanations and examples of each type of category on the continuum.

Teachers' Views of Science Literacy

Teachers' views of science literacy were not consistent across time and context. In this section I will elaborate on those views using the categories described above. I will discuss the major themes associated with their views on science literacy (RQ1 and RQ2).

Teachers' views of science literacy, as manifested in each of these contexts, are summarized in Table 2. If a teacher listed several components to their definition, I categorized each component. If they listed a hybrid assessment question or competency-based assessment, I

listed them both. If teachers listed multiple assessment questions and listed multiple competency-based assessments, I included each of the categories in the chart. Sometimes, teachers listed four or five sample assessment questions yet only the distinct categories represented by teachers' artifacts are shown in the table. For example, if a teacher prepared multiple sample test questions that were in the same category, that category is listed in the table only once.

Table 2

Teachers' Science Literacy Views as Manifested Across Contexts

Teacher	Initial Definition	Sample Test	Competency Assessment	Final Definition	Overall category assignment
Pasteur	R	R/L	R/L	R/L	R
Bohr	R	E	L	L	L
Kepler	R	L/E	L	R	R/L
Heisenberg	R/E	L/E	L/E	L/E	E
Galilei	R	R	L	R	R
Watson	R/E	L/E	L/E	E	E
Mendel	R/L	R/L	L	R/L	R/L
Crick	R/L	R, L	L/E	R/L	R/L
Salk	R	R/L	E	R/L	R/L
Archimedes	R/L	E	L	R/L	R/L
Planck	L	R/L	R/L	L	L

(R = rhetorical, R/L = rhetorical-logical, L = logical, L/E= logical-empirical, E = empirical).

Teachers' views varied across context.

The major findings for research question one were that most participants initially defined science literacy with a rhetorical component in their definition, according to my a priori categories, which were based on Noah Feinstein's (2011) science literacy categorization. Also, between their initial and final definition, nearly half of the participants' beliefs about science literacy partially changed toward a more logical or empirical definition. Finally, I assigned a rhetorical and rhetorical/logical categorization to most participants based on their categorization

across multiple contexts during the study. These multiple contexts included their beliefs (what they said) and practices (artifacts, sample work, and behaviors). Ultimately, the way the science teachers defined science literacy varied more by context than individual. Sample test questions and competency-based assessments were more logical and empirical than initial and final definitions.

Initial definitions of science literacy.

It turns out that research question one was difficult to answer because individual definitions varied across context. Participants could have a definition that I assigned into the rhetorical category, while still having an assessment that I assigned into the logical or rhetorical category. Initially, 10 of the 11 participants in the study listed a definition of science literacy that included a rhetorical component. An example of a rhetorical definition was:

We want our kids to be well versed in the Big Three disciplines (Phys/Chem/Bio): (1) key concepts and applicable formulas, mechanisms, (2) know and use the important vocabulary of each discipline, (3) be able to “talk” science, and, integrate the concepts from the three disciplines. (Pasteur, initial definition)

Specifically, Pasteur posited that knowing the vocabulary and the formulas and being able to integrate them would contribute to the science literacy of the student. This was a rhetorical claim because it stated that knowing something was important without giving evidence for why it was important. This above example was representative of many other rhetorical definitions listed by teachers, who mentioned the importance of experiments and knowing all three disciplines.

Three of the 11 participants also included a logical component to their rhetorical definition. An example of the logical and rhetorical definition can be seen in Crick's initial definition:

Science literacy is the process of discovery. In my classroom, it means open-ended questions that allow students the ability to follow the scientific approach to a conclusion. This allows students the means to provide evidence to support their theories and opinions in a competent, mature manner. It also means being able to take information and make it applicable to life experiences.

The above definition represented both the rhetorical component as well as the logical component. The rhetorical component of Crick's definition was when he wrote that students should follow the scientific approach to a conclusion. Yet he also included the logical component, which was that students should be able to take information and make it applicable to life experiences.

Two of the 11 participants (Heisenberg and Watson) included an empirical component to their rhetorical definition. An example of this can be seen in Watson's sample assessment:

Science literacy is knowing the basics of how the world works (why are there seasons, for example). It's the ability to read an article out of the science section of any newspaper and understanding the methodology used and being able to weigh the accuracy of the results. Science literacy is being able to comment intelligently on that article or the news. It's also the ability to design and redesign as necessary a lab experiment to answer a set of questions or curiosities.

The empirical component of science literacy definitions, above, is easy to spot because it is usually some type of real world problem or case study in which students can use their knowledge to help solve that problem or issue. In the above example, Watson stated that a student should be able to read the science section of the newspaper, and understand the methodology used as well as the accuracy of the results. It is implied that reading the science section is the "thing" in which the knowledge of science will be useful. Furthermore, Heisenberg included in his definition that a student would be able to explain why they wash their hair twice, or why otters do not get bogged down in oil spills. Both of these examples were real life scenarios in which a student could use their knowledge of science to explain the scenario. Only one participant listed a purely logical definition of science literacy.

Scientific literacy equals being able to take the general theories and laws that govern general science and being able to apply them to new ideas or more complicated topics. Having a connection between what taught in the classroom (which may be hard to grasp as many laws or theories are esoteric) and how it can be applied to daily life, understanding that life is science. (Planck, initial definition)

Planck's definition falls into the purely logical category because it connected what was taught in the classroom to the daily life of the students.

Initial to final definitions.

In Table 2, moving across rows from initial to final definitions, there were more instances of logical and empirical in the final definitions. Initially, 10 out of 11 participants expressed instances of rhetorical, with four instances of logical and two instances of empirical. In the final definitions, there were seven instances of rhetorical, eight instances of logical and two instances of empirical. An example of this change can be seen in Watson's initial and final definitions. Initially, Watson listed a rhetorical/empirical definition, while his final definition was purely empirical.

Variation between sample test questions and initial definitions.

During the first group session, I asked participants to give examples of questions that measured the science literacy of their students. Most teachers gave several example questions. Similar to the above categorization theme, teachers could list questions that were placed into more than one category. An important finding was that sample test questions included more instances of logical and empirical than teacher's initial definitions, as seen in Table 3. Sample test questions included eight instances of logical and five instances of empirical, compared to initial definitions, which included only four instances of logical and two instances of empirical. Eight participants listed at least one sample test question that was consistent with their initial

definition of science literacy. An example of this can be seen with Mendel. He listed a rhetorical definition,

In my classroom, the emphasis is on evidence and how to use evidence to draw a logical conclusion. The difference between observation and inference is key to building understanding that is supported and testable. The simplest and most elegant explanation is the most inspiring.

His example question was also rhetorical, "Cell city: Kids will construct an analogous cell based on the function of the individual organelles." The definition is rhetorical because it assumes that being able to use evidence is important without supporting why it is important. The sample test question is also rhetorical because it is assuming that constructing organelles for the cell city is also important, without justification.

Most participants wrote several types of questions that fell under two or more categories. Seven participants included questions that fell under the rhetorical or rhetorical/logical categories. Examples of questions that were rhetorical included Heisenberg's, "In biology the kids must show competency in microscope work and identify phases of mitosis or tell the difference between protozoans," and Salk's, "One particular question asks students to determine if there is a relationship between the solubility of gases and elevation from looking at a table of data."

These questions were rhetorical, because they assumed that the task was important, without any evidence to support the usefulness in the student's daily life. Furthermore, these examples did not include any real world situations that the students could use their knowledge of science to answer.

Two participants, Bohr and Archimedes, listed purely empirical questions. Examples of these empirical questions written by Archimedes include: (a) Some scientists believe that the Earth's magnetic field is weakening, what kinds of effects could occur if this theory is true? (b)

Hypothetically, a catastrophic event altered life on Earth changing the current climate and atmosphere. Which type of cell would have a better chance at surviving and why? While Bohr listed the following sample empirical questions:

I obtained a copy of a nutrition label from the back of a food product and put it, along with several questions pertaining to the label, on a test. They had to tell me the ratio's of protein to lipids, lipids to carbs, protein to carbs, etc., as well as tell me how many kilocalories (not Calories), sodium, and fiber that was in the product. I feel besides knowing the molecular makeup of a living cell has only four main constituents, it is important to know that all the food we eat also has the same four constituents that have a HUGE impact on our health and well being. (Bohr, sample assessment)

The above examples illustrate the empirical categorization because they listed the real world problem and then asked students to solve that problem using their understanding of science.

Two other participants, Kepler and Watson, listed multiple questions that were empirical and logical.

(1) Design and perform an experiment that evaluates the various clean-up methods following an ocean oil spill. (2) Design or remodel a practical ""green"" house for urban Los Angeles taking into account the availability of space, cost of materials, etc. (3) Design and perform an experiment so that a student can identify an unknown cation in a sample. (Watson, sample assessments)

In Watson's example above, students were asked to evaluate various methods to clean up an oil spill. This was considered empirical because this question was assigned shortly after the Gulf oil spill, it was clearly a real and present crisis that existed, and the students were asked to use their science knowledge to solve this problem. In the second question, students were asked to design a greenhouse, which may have some useful application, as it asked students to consider costs, space availability, and other factors.

Using a map of an island with geographical features and information, which energy sources would be best suited to implementation here? Justify your answer. Using figures of two different water rockets, which of these rockets would fly the highest? Justify your answer using rocket motion and aerodynamics concepts. (Kepler, sample assessment)

In Kepler's example above, he presented students with an island and asked them to use their understanding of science to explain the best energy sources based on island features (empirical). His second question asked the kids to use the science to explain the rocket's movement as an example.

Developing Competencies and Assessments

In Table 2 there is a column titled competency-based assessments. It is important to note that the competencies listed in Table 3 were developed by the teachers during the course of the study. The assessments to measure those competencies came after the development of the competencies. During the second group session, participants were grouped heterogeneously to develop competencies for the science department. The task was to determine what our Sunset students should be able *to know and do* when they graduate Sunset School.

Each group of four teachers was asked to generate three competencies. Most groups were able to generate one or two competencies, which over time were refined to eight competencies. The proximate purpose for generating these competencies was to move teachers further along the continuum of rhetorical to empirical, and to foster collaboration. The ultimate purpose of generating competencies was to align the 7-12th grade curriculum. By generating competencies, I was hoping that teachers would begin to think of science in terms of practical skills and content that students should show mastery over, rather than just science content, out of context (*rhetorical*). Developing competencies gave teachers the opportunity to collaborate, which in turn, allowed them to think about their work differently. This was an important task in order to answer research question 3. I did not look at individual participants' contributions toward generating their group competencies, although I did ask about the process of developing these competencies during my final interviews. These competencies, alone, could not be

categorized along the continuum of rhetorical to empirical, however, the competency-based assessments were categorized as seen in Table 3.

Competencies were difficult to create.

The task of creating competencies was challenging for most groups. Salk stated, "the challenge was not necessarily in working with the group, but the challenge was in ... for me, anyways was to ... was to think about what was specific to science." Some said it was easy but could not develop more than one. Archimedes illustrated this idea by saying, "We thought it was gonna be easy, but once we would put one down, we would say well hold on here . . . number one, it's too general . . . it's too big. We need to really make it a little bit more specific."

Some groups focused more heavily on the content rather than the skill/content combination. Eventually, several competencies were generated and agreed upon by the whole group. However, different participants ranked some competencies as being more important than others. The ranking of competencies will be discussed later in chapter four.

Table 3 shows the refined competencies that were created by participating teachers. These competencies were generated during the PD/group sessions over the course of two months. Teachers understood that if they could decide on what students should know and be able to do before they graduate, then there could be a common thread through the curriculum regardless of the content in each course.

Table 3

Group Generated Competencies

By the end of grade 12, Sunset students should:
1. Demonstrate an understanding, through writing, speaking, and creation of models, that science is an on-going process.
2. Be able to seek, create, manage and organize scientific information, using appropriate educational and computer technology.
3. Be able to read media reports of science or technology in a critical manner so as to identify their strengths and weaknesses.
4. Be able to effectively communicate science and the nature of a controversy in multiple ways including conversation, debate, written expression.
5. Be able to use various forms of evidence (books, technology, humans, research, experiments) to find answers to questions and then use those sources to develop their understanding.
6. Be able to construct their own explanations of phenomena using their knowledge of accepted scientific theory and linking it to models and evidence found in books, the Internet, experts, research journals.
7. Be able to design a scientific experiment, starting with the formulation of a question that can be investigated, continuing with appropriate methods and materials, and finally collecting and evaluating data to develop a conclusion.
8. Be able to understand the language of science and apply the knowledge to qualitative and quantitative problems.

Towards a Logical Assessment

As mentioned above, these competencies in Table 3 were used to generate competency-based assessments. The competency-based assessment was also important in categorizing teachers' views of science literacy as logical, empirical, or rhetorical. The assessment piece was different than the other pieces of data used to categorize teachers because the assessment was generated with a competency in mind. Furthermore, the competencies were generated as a group. This is significant, because the data produced was much more logical than any of the other assessment questions that teachers generated.

Ten out of 11 teachers created an assessment that was logical in nature. An example of this was seen in Archimedes' assessment, where students were asked to locate a current event in an article and decide which statements were facts and which were inferences.

Four out of 11 teachers included an empirical component to their assessment. An example of an empirical assessment involved Bohr's students going out into a field or naturally occurring terrestrial biome and discussing the types of organisms and plant species that could and could not live there and to hypothesize what would happen if one of the plants or organisms was to be wiped out (as occurs often in nature due to human impact), and think about the ways in which the biome could continue to thrive or not thrive as a result.

Only two out of 11 teachers included a rhetorical component to their competency-based assessment. An example of this was seen in Watson and Galilei's element web design project, where students were asked to create a website for their element by researching their element and then listing the important facts about it.

An important finding was that in developing a competency-based assessment, teachers were able to come up with a more logical and empirical piece of work than they did when they wrote science literacy definitions and sample questions on their own. Perhaps the scaffolding and specific directions provided in the assignment allowed for this type of work. This will be discussed in chapter 5.

Consistent Versus Inconsistent Views

It is helpful to look at Table 2, specifically across the rows to see the consistency or inconsistency in the way participants were categorized. Ten out of 11 participants expressed the same categorical views in their initial and final definitions. Furthermore, nobody expressed the exact same view across all four contexts. The different contexts elicited different aspects of

science literacy views among all participants. Participants' initial definitions were mostly rhetorical, yet their competency-based assessments were mostly logical. The variation was mostly context based, not people-based.

Overall Category Assignments

To assign each participant an overall category, using Table 2, I looked for consistency in each element across the row. I assigned the categorization that appeared most often across contexts. Five out of 11 participants were assigned a categorization that was more logical or empirical than their initial definition. Six out of 11 participants maintained a categorization that was consistent with their initial definition.

There was change over time for five of the participants, from the beginning of the study to the end of it, according to my categorization. An example of this can be seen with Bohr, who listed a rhetorical initial definition, an empirical sample test question, followed by a sample assessment that was logical, and a final definition that was logical. Similarly, Kepler's initial and final views were consistently rhetorical, while his sample questions and sample assessment were both logical. His final categorization was more logical than his initial categorization.

Participation in the Process

The above findings illustrate the outcomes by context. Another piece of data that was not included in the tables above, yet revealed teachers' views on collaboration, was their participation in different aspects of the study. All teachers were participatory during group sessions. All of the teachers worked in their groups to discuss science literacy and develop competencies. However, the work that was assigned outside of the group sessions was not always completed. None of the 11 participants completed the assessment without a great deal of prodding by the facilitator. Eventually, six of the 11 participants sent an email with the

competency that they were assessing for, as well as a summary of their assessment. Only one of the initial assessments contained a rubric or scoring guideline, even though the rubric was requested. Participant feedback given during informal interviewing (after the due date for competency assessment had passed) included their difficulties and challenges in creating a competency-based assessment. The three chemistry teachers faced the biggest obstacles, citing that their curriculum was very content and math driven. Several teachers did not know how to create a rubric or a competency-based assessment. They tried to move there with the assessment, but they did not have enough training to create this on their own.

Designing Competency-Based Assessments was Challenging

During the third group session, participants were asked to reflect and write about how the effort to design an assessment for one of the competencies influenced their ideas about assessment. Several participants cited that the process of creating competency-based assessments was difficult. Kepler wrote,

Designing activities to address the group-generated competencies is difficult! Traditional assessments and assessments of traditional competencies fit within our grading scheme very easily, while holistic or formative assessments (which are often best-suited to the group-generated competencies) are trickier. Not surprising.

Good assessments are not only hard to design they are hard to assess. Also, assessments do not need to be in the form of a test or a quiz or major project. Once there was discussion about alternative forms of assessment, teachers realized that assessment could take many forms and it did not need to be after every unit along the way. Archimedes wrote,

We are assessing our students at EVERY step of the educational forum. It also makes me realize that maybe it isn't as important to have major unit tests count so much towards a final grade. If our assessment points are aligned to the competencies, then maybe we accomplish the goal in small chunks, not major ones!

Others stated that they could assess competencies through conversation. Crick wrote,

It is much easier for me to create a lesson with the ideas I want to get across to the students than it is to create/write a formal assessment for that lesson. I feel that through conversations I can assess whether the kids understand the material (orally) but to come up with a rubric that applies to that "conversation" is difficult for me to do.

It was clear through the interviews that teachers knew what they wanted their students to know and be able to do, but the challenge was in coming up with a good way to measure it.

Competencies, Current Assessment and Future Assessment

During the final interviews, I asked participants about the competencies that we developed as a group. I asked them to look over the competencies and determine which of the eight competencies were most important in creating a science-literate student. It was helpful to ask teachers about the competencies that they deemed important in order to elicit their views about science literacy in the context of current teaching and assessment as well as future planning (research question 2). In order for teachers to assess students for these competencies in their classroom, they needed to assess and instruct in a more logical and empirical manner. Therefore, their responses were indicators of what they perceived to be important and what they will possibly assess for in the future. The competencies listed in Table 4 are in the order that participants circled them on their paper. The actual written competencies can be found in Table 3.

Table 4

Competency Rankings by Teacher

Name	Competencies that are important	Competencies that they assess for	Competencies to assess for in the future
Kepler	7, 3, 5	6 5	3
Watson	7	4, 3	Don't know
Plank	1,5,7,2	7,2	5,7,2,1
Crick	2,4,1	7	1
Salk	7, 3	6 (a little) 5	3 and 6
Pasteur	3,5,8	3 8 5	7
Galilei	2,3,5,8	2,5,8	3
Bohr	7, 2, 4	2	6,4
Heisenberg	3, 6, 7	3	Maybe 6 and 7
Mendel	1,6,3,5,7,8	1, 7,8	5 6
Archimedes	5, 7,4, 3, maybe 7	5 4 3 7 (a little)	8

The first column in Table 4 shows the competencies that each teacher thought were important. The second column shows the competencies teachers thought that they currently assessed for. The third column shows the competencies that teachers thought they might assess for in the future.

One finding is that teachers developed these competencies as a group and agreed on them as being important, during their development. However, when asked individually, teachers did not think all of the competencies were important, as seen by the data in the first column of Table 4. Furthermore, teachers did not state that they would want to assess for all of the competencies in the future.

As seen in Table 4, more than half of the participants ranked 7, 5, and 3 as being the most important for developing the science literacy of Sunset students. Eight out of 11 participants circled number 7; Sunset students should be able to design a scientific experiment, starting with the formulation of a question that can be investigated, continuing with appropriate methods and materials, and finally collecting and evaluating data to develop a conclusion, as one of the most important competencies. Crick elaborated on how he used competency 7,

I am trying to look at our labs that we do and pose a question, and then have the kids kind of come up with their own ideas. Here are the supplies I'm going to give you. I'm not going to tell you what they're used for, because you already know what a test tube is or a graduated cylinder is for. We've talked about the process, we understand why it's important with our earth processes, and now I want you to create a convection current with these materials.

Similarly, Salk mentioned that 7 was important "so, that they have an understanding of how it's done . . . and I think the only way to do that is to have experience doing it." Watson also explained that so much of his course depends on students understanding how one would go about testing something.

Seven participants ranked number 3 as important. Crick said,

There's so much BS that's put out there. I want them to be able to calmly, directly debunk it, or ask the right questions so that they can see this is valid; this is not valid; this makes sense, it's an interesting question; the way they went about proving this was wrong.

Salk affirmed this,

If they're gonna critique and make decisions based on what they read in the media, well, they have to have an understanding of how the science is done, and be able to ask the important questions, and-and think critically about it.

Six out of 11 participants ranked competency 5 as important. Archimedes posited, "it's like connecting all the pieces, all, you know, use your background information. If you don't

have it, then ask somebody else." Interestingly, he finds it the hardest to assess, even though it is important,

Number five is the toughest one for me, I think. If you want to ask the question, how do we give them those tools to find the answers and use those sources? That's the hardest one maybe to assess.

Three participants felt that competency number 4 was also important because students should understand the nature of a controversy and not always just passively agree with one side or the side that the teacher supports. Crick illustrated this when he posited,

I mean they've got to be able to understand both viewpoints, not just their own, but they have to at least be able to think about somebody else's opinion and through debating and things, that forces them to learn both sides. I think this is so important after graduation and in college, because this is how people communicate on a global aspect.

Interestingly, some people circled certain competencies as being very important without ever assessing for them. Kepler circled number 3, but did not assess for it. Furthermore, participants started to discuss how they assessed for certain competencies, but after they tried to verbalize how they assessed for it, they realized that they really did not. Kepler mentioned,

Kids should be able to design an experiment, but...you can't assess that, precisely. You have to get them to do that but you can't, I mean, if I let a kid loose, I say, like, you know, 'Here's some materials, here's a question -- have at it.' And if they're not able to do it, I don't think they should...that shouldn't be impacted by their grade.

Current assessment.

For the most part, science department members assessed for one or more competencies that they felt were important throughout the school year. However, exceptions to this practice were Watson and Crick. Watson stated that 7 was really important; however, he currently assessed for 3 and 4. Crick stated that competencies 2, 4, and 1 were the most important, but he only assessed for 7.

Future assessment.

When asked which competencies department members would assess for in the future, most listed one or two competencies that were consistent with the competencies that they deemed most important. Only Pasteur listed a competency to assess for in the future (7), which was different from the ones that he deemed most important.

Making Room For Science Literacy

Teachers' beliefs, stemming from collaborative work, were generated from what teachers said during group sessions and in final interviews. Their practices came from artifacts (competencies, sample questions, assessments, revisions of assessments) that they submitted. During group session two, I asked teachers to think about any topics, themes, skills, processes, or assignments that they could eliminate or reduce in their curriculum to make room for greater depth of other topics/themes/skills/processes/assignments that lend themselves to creating a more scientifically literate population? Teacher's responses varied from "everything can be reworked" to "nothing can be eliminated."

Pasteur wrote that he could do "less lecture, more discovery, more inquiry-based labs." Salk wrote, "Our curriculum is already fairly deep and not very wide. Our textbook has eight or ten chapters related to chemistry and we barely get to chapter six. It is truly process driven and not content driven. " Galilei also felt that there was room for change by

introducing more topics/assignments that require hands on activity and shifting away from lecture models. Specific topic areas are constantly being tweaked in order to accomplish this. At the moment, we will introduce a pendulum lab via simulation on computer as well as building the actual pendulum in real time.

Archimedes felt that "most of the material where a student is to memorize and regurgitate information is an area where we can cultivate better assessments/assignments to foster science literacy in that area." Kepler wrote

Every year we look at the curriculum and think about what worked best or fell flat last year. Almost always the things that we eliminate are those, which were driven by overly broad content without experiences to connect them to the world, and what worked best were the activities that were most engaging to the students.

Other teachers implied that they had begun the process of narrowing their curriculum to make room for greater depth as a means of improving the science literacy of their students.

Heisenberg wrote,

I've streamlined Astronomy over the years to only include necessary and valuable material. In Biology I've just tried to get through as much of the material as possible, while being able to ALWAYS go off on a tangent if a student asks a great question—that is when the class gets engaged and we go deeper. Each year I add new activities/experiments to get the kids to think and test what we're doing in class.

Similarly Watson wrote,

We reworked the chemistry curriculum for this year which I think will allow for more connections with the real world to be made. I would like to reduce the emphasis on such topics as tectonic plate movement, hazardous waste managements, and many other things to focus more on energy and biodiversity in environmental science. \

Only a couple of teachers felt that they could not eliminate material to improve science literacy. Planck wrote

I believe that scientific literacy comes from years of knowledge. If we drop the traditional core of chemistry to focus on reality, then when they get to college they are going to be freaked because they never learned the boring math.

I also asked a similar question, "When you reflect on your curriculum, instruction and assessment, are there ideas that don't lend themselves to creating a scientifically literate population of students? Six out of eleven teachers said no, while four teachers said yes, and one teacher did not reply. Of the teachers that wrote no, some elaborated why they said no.

Archimedes wrote,

I think every area of curriculum, instruction and assessment in our 7th grade program can lend themselves to creating a scientifically literate population of students. The real challenge is how we adapt the need to cover content, with the goal of making the material

personally relevant and fun. Material that students can connect with will ultimately be the material that the student remembers.

Similarly, Crick stated, "I feel like our curriculum is based on having a good working knowledge of science hopefully reflecting experiences/life lessons the kids have had or will have in the future."

Those teachers that said yes to teaching some curriculum that does not lend itself to the science literacy of their students gave various reasons ranging from curriculum being set by the college board to concepts and connections that could be made stronger. Some teachers mentioned that the material was mandated by the College Board for AP and SAT tests. External hierarchical pressures tended to influence teachers decisions on the material taught and the assessments given. Teachers were only willing to admit that parts of their curriculum were not necessary if those parts were mandated by an external party.

Views on Collaboration

Teachers' views on collaboration came from a planned source, the final interview at the end of the study. These interviews represented expressed ideas, both positive and negative. A second perspective on teachers' views of collaboration could be gleaned from their participation. There were inconsistencies between what they said the value of collaboration was and their actual work. I will discuss the findings from the interviews first, and then address the collaborative work that teachers did and did not do at the end of this section on collaboration.

In answering the question, how does collaboration around the context of planning, instructing and assessing for science literacy influence teacher's views on the nature of their work, I found that all teachers felt that collaboration was useful. The degree of usefulness varied from teacher to teacher. The value of collaboration was validation, growth, perspective, brainstorming, sharing the work, and conveying the teachers' program.

Furthermore, most teachers believed the school could facilitate collaborative work by creating more in-service days, as well as meetings dedicated to departments. Finally, teachers believed challenges to collaboration included time restraints, inflexibility, and the un-changeability of participants, personality differences, and dislike of meetings.

In this section, I describe teachers' views on collaboration. Their views came from a planned source, the final interview at the end of the study. These interviews represented expressed ideas, both positive and negative about the value of collaboration. A second perspective on teachers' views of collaboration can be gleaned from their participation in the study. After 5 months of collaborating participants were interviewed to find out if their assessment and instruction had changed, as well as how they felt about the collaborative work. I also asked them if the group-created competencies influenced the way they thought about assessment. Finally, I asked them about how the school could address any of the challenges in continuing the collaborative work. These questions helped me to understand their views on the nature of their work.

Collaboration is useful.

All teachers conveyed that collaboration was useful to some extent. Answers ranged from very useful and integral to the success of the science program, to useful at times, and for very specific purposes. Kepler articulated,

I think it's useful. Just talking about it . . . even if nothing else happens, just talking about it is gonna make things a little bit better. . . . because, like I said, you know, this is stuff . . . we were thinking about in a totally abstract way all the time . . . and that reflects in our teaching.

One of the things I noticed immediately after the first two sessions was that science teachers were communicating more through email, which was an initial step in collaboration outside of the group sessions. Watson sent various emails about science topics with links to cool

science sites. Salk also sent a series of emails about getting kids to program in science courses. Overall, there was an increase in the number and types of emails sent to the science teachers.

Value in collaboration.

During the final interviews, I asked teachers in what ways it was useful to collaborate with other science teachers around the issue of science literacy. Teachers' responses varied; however there were five main themes that emerged from this question.

Validation.

Approximately half of the teachers stated that hearing that other teachers were doing the same type of work or that they had similar issues in their classroom was validating. Archimedes said,

It validates that what you're doing it, you know, we're constantly trying to grow in the classroom. I'm doing some things way different this year than last year, even though the content might be similar . . . and when I hear from somebody, you know, one of the competencies we want are these and I'm like ah, I know we're achieving it right here. It's validation for one!

Similarly Crick emphasized,

I think just hearing from other people, having the time where we're sitting down and we're talking all about the same thing and brainstorming, I mean like . . . like I had no idea that Kepler and I thought the same on so many things, I never have conversations with him about science because I never see him.

Growth.

Four participants also felt that they experienced growth as a result of working together. Growth included hearing new things from other participants, or having new ideas thrown around, or even just thinking differently about assessment or instruction from listening to others talk about their lessons. Archimedes stated,

It's like showing areas to me of further growth. Like I know I need to assess this better. Or I'm going to do a project different next year just from talking with you, when you're interviewing me, I know I'm going to actually do something like, because I see a better

way to do it. So validation, and growth and also articulation . . . whether it's a curriculum or if it's just a common kind of values and language that we're using."

Similarly, Crick stated,

you can feel confident in what you know now and you will continue to grow in that way." And for an inexperienced teacher, growth meant new ideas for him to try. "For me it was useful, because I'm new at this, so hearing people, . . . someone who's been at this for a long time, whether or not I agree with, you know, it's interesting . . . and it's very helpful for me.

Sharing work and brainstorming together.

I grouped sharing work and brainstorming together because that is how participants listed the two activities. By brainstorming together, teachers felt that they could share in the work that needed to be done and also divide the tasks. Seven participants cited that there was value in collaboration because work could be shared, labor could be divided, and there was a lot of brainstorming in the group. Crick stated, "being able to . . . to brainstorm, I mean I brainstorm with Mendel and Archimedes all the time.... I think that's what makes us a strong group."

Similarly Pasteur said,

There's so many studies that prove, you know, five-five brains get you there quicker than one, but and I'm okay to sit down and problem solve together. If there's an ideal curriculum that we're seeking, getting together and talking about it is the only way we're gonna get close.

While Mendel stated, "I liked seeing the compilation of everyone's results because I – I think my colleagues are super smart, and it's so nice that they're so willing to share.

Awareness of the program and articulation.

Three participants felt that collaboration was useful in conveying the academic program at Sunset School and sharing expectations, as well the articulation of courses. Watson explained,

I think it would be helpful for them to see what our expectations were. Like yeah, I think they have the topics that we cover, but I don't know that they have even just a list of things we would expect them to at least have heard. 'Cause when I talk about models of

the atom, that's the first time they've even heard about protons, neutrons and electrons for some of them . . . and that seems odd to me to get that the first time in 10th grade.

Crick also felt the same way, "It'd be valuable knowing what's happening in each classroom."

Similarly, Pasteur claimed, "I think us doing that is-is really valuable, 'cause we find out one where-where are we as a whole. You know, where-where is each individual." Mendel summed it up by stating,

I find that besides building like collegiality and all that, I really think that it's important for us to know what – what you're doing, – what – and what you need from us, and what we can get from you, and how we can . . . I really strongly believe in the spiraling curriculum that spirals back and back and back, even though some people do not. I think that that is the most effective way for students to learn.

Collaboration was not valuable to all.

Four of the participants stated reasons why a portion of the collaborative work was not valuable. The reasons ranged from participants not having time to prepare assessments before group sessions, or that participants left early before group work was complete. Kepler exemplified this, stating,

I see people who very clearly didn't think about any of it for even ten seconds before the meeting. And . . . just how they have things that are more important to them. And after the meeting, talk about how lame it was or how we didn't do anything .

Other reasons why collaboration was not useful were because members got sidetracked and caught up in sidebar conversations or on topics other than science education. Salk mentioned, "It was not as productive as . . . because we didn't . . . we got . . . we got caught up in conversation, and-and caught up in maybe a tangent here or there, and then I think we . . . it was a lot that we were being asked to cover." Some members stated that there were so many meetings at Sunset School that it is sometimes hard to be productive in all of them. Also, a couple of participants stated that the value of collaboration was lessened if they were grouped with someone who did not process information the same way or at the same speed. Crick stated,

"I mean Sunset loves meetings, and we have a lot of meetings where I don't get anything out of them. Um, and I have to say that science falls in that category." While Heisenberg explained, "When I'm paired with people who are very detailed oriented or are able to link together a series of ideas very quickly, and I need more time to absorb it, so that kind of hinders me."

Challenges in collaborating.

A theme that emerged during all final interviews was the challenge of collaboration. The most common responses included time restraints. Most participants found that meeting times, which were scheduled at the end of the day, conflicted with childcare responsibilities or team practices. Archimedes commented that "time constraints and family obligations . . . the end of the day is hard for some of us. I'm sometimes fried, and you know, maybe I'll have a sports practice." Furthermore, the end of the day was when most participants felt least likely to engage in worthwhile discussion and conversation.

Other participants explained that every minute of their day was packed with activity and teaching, and that spending time in meetings was taking away from valuable lesson planning and grading. Planck expressed, "I mean, at least for me. I don't have a spare minute. I feel like I don't have a spare minute during the day to go to the bathroom, or get lunch." The timing issue was frustrating for participants who were willing to forsake other commitments to be at meetings while watching their colleagues skip meetings for less significant commitments. Galilei commented,

I think just getting everybody together at the same time without having you know 'oh I can only stay five minutes, I've got to you know, I got this going on so I'm just going to go.' So I guess the timing is the biggest thing.

It was clear from the interview data that teachers needed more time in their day to complete their required tasks as well as come to after school meetings.

People do not change.

Many participants also commented that, "people don't change," and that this type of collaboration would not make a difference if people were not willing or able to change. The reasons given for not changing included teachers' place in their career, not feeling that change was necessary, and that people got stuck in what they are doing and even if they wanted to change, it is too hard. Salk illustrated this idea with his comment "some people are set in their ways . . . and they're not willing to change, because what they have done has worked, and it's easy." Similarly, Watson also expresses this concern,

I think they want to meet on paper. But once you put them all in a room together, people are so stuck in what they're already doing that we can talk about it a whole lot, but I don't know that a lot would actually change.

Pasteur self reported that at this point in his career it was hard to process this type of change, and in fact, he fought against it to preserve his long-standing and unwavering beliefs about science education.

In the twilight of my career . . . like I said earlier about figuring out if I can find time for processing it . . . if I can find time for that aspect of what our kids need. I used to always kind of fight it, because, you know, content is crucial in life sciences. I will go to my grave believing that.

Planck further acknowledged that people are set in their ways and do not see the point in collaborating around science literacy, especially if they are not going to alter their practice.

Too many mandatory meetings.

Another sub theme that came out of the challenges of collaboration was that people have a deep dislike of mandatory meetings. Planck, Bohr and Pasteur all commented on the fact that at times, they dreaded the after school meeting because there were so many required meetings. Pasteur states, "Ugh, don't make me do this [meeting] again. And yet I get it why we do it."

Similarly, Bohr emphasized that "there's not enough reason . . . I mean, just for us to want to come together in the groups."

Personality differences.

Several teachers noted the personality differences in the department. These teachers thought that the challenges to collaboration were, in part, due to the different types of participants in the study. Some participants were more assertive, others less assertive. "Some people didn't talk, and some people talked too much" (Planck). It wasn't always the most experienced teacher who was the most vocal. One participant did not feel like his views resonated with the other middle division teacher views. Bohr emphasized,

Other cons like, it might not even be the—the most experienced teachers or the smartest one throwing the group around, it might just be the most vocal one. You know, it's just—it's easier to follow someone that's trying to lead the way.

Facilitating more collaboration.

Five of the participants discussed ways that the administration could facilitate more collaboration through in-service or professional development days, and more regularly scheduled meetings. Mendel stated, "Monday afternoon faculty meetings . . . even starting once a semester, I think is a good place to start because I think we used to do that and I really valued those meetings . . . we need to meet once a month at least." Participants acknowledged that time constraints were a considerable issue that could be alleviated with better planning on the part of the administration.

Furthermore, many felt that the hour or so that we met for each group session was not nearly enough time to complete meaningful work. Several participants suggested that upwards of 5 hours to meet and spend time in each other's classrooms and labs would be beneficial. Galilei mentioned, "tweak the schedule in the day so it creates a block in which there are no

classes, no kids; it's during the day so there are no sports, no nothing and then you have the time blocked." Alternatively, in-service days at the beginning of the year, rather than at the end of the year when department members are burnt out, would be helpful.

Other suggestions were that teachers could spend more time observing each other's classes as a form of collaboration. This could be encouraged by the administration by providing substitute coverage. Kepler mentioned that having a better teacher evaluation system in place would motivate teachers to collaborate. Finally, Planck mentioned that bringing in a specialist to come speak with the department about topics of interest might also foster collaboration.

What they said was different than what they did.

The above findings illustrate the responses that teachers gave during interviews about the value of collaboration. However, when looking at teachers' actions during the project, the data looks a little different. Teachers often did not complete the collaborative work and teachers often did not attend all sessions, or stay for the entire session when they did attend. All teachers attended the first two meetings during in-service week. Only ten attended the third session, and three teachers left early. Three teachers did not attend the fourth session, and two left early. Eight teachers attended the fifth session and stayed the entire time. All teachers participated in the final interviews, although several teachers were noncommittal and changed dates and times.

Initially, the group sessions were supposed to include more material and more collaborative activities. In between sessions, participants were asked to modify competencies, design competency-based assessments, work collaboratively to modify their competency-based assessments, and give the assessments to their students. I had planned for teachers to create and give assessments and return to the group sessions with data on how their students performed on the assessments. I was going to have teachers pair up and observe each other's instruction in a

non-evaluative way to give feedback on how their instruction aligned with their assessment. The professional development was supposed to include the creation of multiple competency-based assessments, as well as peer observations as a means to improve instruction and align assessment to instruction.

Beginning with the reading assigned after the first group session, many teachers did not complete the task. After the second group session, teachers were asked to create an assessment based on any one of the competencies that we generated, and then send me the competency number and their assessment before the third group session. Not a single participant had completed the task 3 days before the group session. I met with teachers individually and helped them to think about the assignment and ways to complete it. By the third group session most participants had created some type of assessment. Only one of the assessments turned in had any type of grading scale or rubric attached. This was an assessment that was created during the past year by two teachers in the study. It partially assessed for one of the competencies. All of the other assessments were only partially complete, and were not true assessments, because there was no way to measure student mastery of the competency.

By the fourth session, teachers spent more time developing their competency-based assessment as seen by the added details and partial rubrics; yet again, the work was only completed as a result of multiple emails and check-ins by me to keep the process moving.

Ultimately, only one-third of my original professional development plan was completed during the course of the study. Because teachers did not complete tasks in my timeframe, subsequent tasks could not be completed.

Summary of Findings

Science teachers' views on science literacy were initially mostly rhetorical according to my categorization. However, these rhetorical definitions changed and included more logical components for half of the participants over the course of the study. Teachers' views on science literacy did vary by context: instruction, assessment, and planning. Teachers were able to develop competency-based assessments that were more logical in nature than their initial and final definitions of science literacy.

Collaboration was useful and helpful for most teachers, although the degree to which teachers collaborated varied by context and session. Generating competencies was challenging for teachers, and developing assessments to measure those competencies was even more challenging for all participants in the group. Finally, most teachers did not assess for competencies that they deemed important, although they would like to in the future.

Chapter 5: Discussion of Findings

Introduction

The purpose of my study was to determine teachers' views on science literacy and the way that their views influence different contexts of their teaching: planning, instruction, and assessment. Subsequently, I sought to understand how collaboration influenced the way that teachers felt about the nature of their work. This chapter begins with a brief summary and discussion of the findings; then relates them to the theories and previous research presented in the literature review. I then go on to discuss the limitations of this qualitative research and my reflections on this work. Finally, I present my conclusions and make recommendations to improve assessment and instruction at Sunset School, as well as facilitate more collaborative work.

Summary of Findings

Evidence found in this study indicated that most participants initially defined science literacy with a rhetorical definition. Furthermore, after participating in the study, half of the participants' views about science literacy changed to include a more logical component. Also, participants' definitions varied across context (test questions, competency based assessments, definitions). None of the participants held consistent views across all four contexts. This variation was more context-based than participant based. Most teachers produced competency-based assessments that were more logical than their rhetorical initial views on science literacy. Teachers also said that they wanted to assess for competencies that they deemed important, even though they did not currently assess for those competencies.

By the end of the study, all teachers said that collaboration was useful, although the degree of usefulness varied from teacher to teacher. The value of collaboration was validation,

growth, gaining perspective, brainstorming, sharing the work, and conveying their program.

Ultimately, teachers believed that schools could facilitate collaborative work through in-service days, and dedicated department meeting times. Finally, while teachers said that collaboration was important, their actions, which included not completing collaborative work and not attending group sessions, implied that it was relatively less important than other demands on their time.

Discussion

Below, my discussion is broken up into five sections that describe my major findings and why they are significant. Where appropriate, I tie in some of the existing literature. Following my discussion of the findings, I describe some of the contextual considerations of my study. Specifically, I describe the challenges of this type of study in a small, private, high-performing school.

Predominance of rhetorical definitions.

The first finding was that science teachers' definitions of science literacy were rhetorical in nature, according to my categorical assignments. Most teachers wrote down initial definitions that were science oriented (rhetorical), but these definitions were not supported with evidence as to why they were useful (logical), and they did not include complex real world situations that students needed to understand (empirical).

I expected this finding because for the most part, science education has always been a series of facts and concepts that teachers teach because the book contains the information, and because the information is on the standardized tests that teachers are preparing their students to take. How science literacy is defined matters. As cited in chapter two, Miller (1998), defines science literacy as the ability to write and read about science. This is also a vague and rhetorical definition, because what does it really mean to be able to read and write about science? Teachers

follow curriculum in the science books, and they use test banks, which are provided with the books. Because there has been no consensus on science literacy since the introduction of the concept over fifty years ago (Hurd, 1958), it is not surprising that the science teachers in my study included vague and rhetorical definitions.

Many teachers still feel that science is a set of terms and facts and ideas, and that putting the science into science-related social issues dilutes the pure science. However, even Dewey in the early 1900s realized that learning must occur through engagement in real-world problem solving and that teachers and students alike need to apply their intelligence to complex and dynamic issues (Dewey, 1902, 1930).

Another aspect is that teachers may articulate their definition a certain way, and when given more time to think about it and reflect on it, they may have an expanded definition that is more inclusive of what they actually think science literacy is.

Beliefs expanded for many participants.

Almost half of the participants' beliefs about science literacy changed between their initial and final definition to include a more logical and empirical definition. Even though participants still maintained in part their rhetorical definitions, five showed a positive change. One of the goals of having discussions about science literacy was to expand teacher beliefs about science literacy. It is not clear whether the discussions about science literacy, the collaboration over creating competencies, or the creation of new assessments were the cause for this positive change. It may be a combination of all three factors that created the more logical definitions. It is also important to note that while some teachers' beliefs expanded, others did not. Of those that articulated change, those changes may have been a result of all three factors. Of those that did not articulate change about beliefs, it may have just been the context in which I asked them.

Variation was context based.

If you look across rows in Table 2, for most participants the initial code and final code are almost the same. Yet, the sample questions and competency-based assessments are more logical and empirical. This suggests that when you ask a teacher to define science literacy, they define it in a very science discipline centered way, which will often sound like the chapters in their science book. "We want our kids to know key concepts and vocabulary, formulas and mechanisms" (Pasteur, initial definition). However, when you ask them to give sample questions their responses are more logical. "Have kids write on a real life situation and see how they apply their knowledge of science" (Pasteur, sample question).

This leads me to conclude that there is more variation between the context in which participants defined science literacy rather than the individuals themselves. Teachers do not have a uniform or stable view of what science literacy is. These views vary depending on what I asked them to do. It is also possible that their definitions reflect views that are not tied to their practice. Meaning, they could say one thing and do another thing that was inconsistent with what they said they were doing. However, the only data that I collected were their assessments and sample questions, and I can only infer that teachers were inconsistent between what they said and the two artifacts that I collected.

In terms of student outcomes (science literacy), it matters what teachers do in the classroom more than what they say about what they do. So even though teachers could not necessarily write a logical or empirical definition, they could write a logical and empirical assessment, and this was a positive finding.

Collaboration was valuable.

All teachers conveyed that collaboration was useful. The climate of the meetings was congenial and pleasant. Teachers felt that they had a better understanding of their colleagues and their instruction. It was important that science teachers collaborated to generate science competencies so that they felt some ownership over them. This also helped teachers feel validation about their own work. Those teachers that came into the meeting feeling overwhelmed by the content prescribed by their discipline, felt validated after the meeting because they could eliminate some of their content to make room for lessons that contributed to the science literacy of their students.

Participants also mentioned growth as one of the ways in which collaboration was valuable. By sharing ideas, teachers could expand their own repertoire. The inexperienced teachers especially seemed to benefit from the group sessions. One teacher mentioned, "I'm new at this, so hearing people . . . is very helpful for me." It makes sense that veteran teachers should be sharing the successes and failures of their practice with new teachers. Even teachers who have been teaching for many years can benefit from the insight of their colleagues. "I'm going to do a project different next year just from talking with other teachers about this" (Archimedes, final interview). Clearly, the collaboration is useful, but there are challenges to collaboration that will be discussed in the next section.

One of the things I noticed immediately after the first two sessions was that several science teachers were communicating more through email, which was an initial step in collaboration outside of the group sessions. As mentioned in chapter 4, Watson and Salk began sending emails with links to interesting sites. Other teachers also began sending group emails about technology, interesting professional development opportunities, and labs. I did not code or

analyze the emails, rather, I noted that the frequency had gone up from zero emails to several a week from various participants.

Challenges to collaboration.

One of the findings that emerged was that there was value in collaboration and doing meaningful planning. However, there was an agreement among teachers that there was not adequate planning time and that the time that was allotted for teachers was not at the right time and did not foster group work. Teachers felt that if there in-service days which were specific to this kind of curricular change, it would be helpful. Furthermore, the time of day seemed to impact the type of work that teachers were able to do. Many of the participants in the study had extra-curricular commitments, which took them out of group meetings and made staying after school impossible. The most convenient time to work was done when we met in the mornings during in-service week. This morning time made it so that teachers were not rushing out of the meetings for other commitments. Also, having meetings on days when there were no classes in session alleviated some of the teachers' workload.

Contextual Considerations

In this section I speculate on some of my findings and how they tie into the climate and culture of the school. I discuss why there may not be incentive to change practice and why participation in the project may have been inconsistent.

Lack of incentives for change.

I think that one of the underlying themes that came out during group sessions and interviews was that there was not always incentive to change the way teachers assess and instruct because all kids seemed to be achieving at Sunset School. The system did not appear to need fixing if all of the students scored well on standardized tests and went on to great colleges.

Teachers may have felt that time and energy was better spent attending to other problems within the school. There may not have been an immediate perceived need for this kind of work.

Discussions and group work were inspirational and motivational; however taking the next step of changing current styles of instruction and assessment, or revealing practice to colleagues, may have been a daunting and time consuming task for teachers. Furthermore, the school's administration, parents, and students were not asking for any change in practice. At the time this study was conducted, there was no formal evaluation system in place that measured teachers' practice. Furthermore, student outcomes in science were undefined. There was no consensus or documentation about what students should know or be able to do before they graduate. Taking into account all of these factors, the results of my study are not that surprising.

Unfreezing beliefs.

It is important to understand teacher belief systems and how teaching and learning take place. Even when presented with different ideas about what it means to be science literate, teachers will not always change their teaching because of the complex interplay between their ego, perceptions, and attitudes, as well as the school culture and group norms. Schein (1995) described the process of change as a painful unlearning, and difficult relearning. By merely adding a driving force toward change, an immediate counterforce (restraining force) will be produced to maintain the equilibrium. The only way to move forward with change is to remove the restraining forces (Schein, 1995), which in the case of Sunset School, may be teachers' tightly-held beliefs and perceptions, and group norms that are woven in the organizational structure.

Teachers did not complete the tasks.

When I began the project, I created a series of group sessions that were each dependent on a task to be completed between the group session. Unfortunately, most teachers did not complete the tasks that were asked of them, in the time frame that I had originally planned for. The first task after group session one was to read an article about science literacy. This was given to each science teacher after the first group session. Only a handful of participants read the article over the two-day period between group sessions. During group session two, I asked the teachers to reflect on the article as well as on the first group session. Teachers were energized and participatory during the first two sessions, which led me to believe that they would eagerly complete the assignments to improve assessment and instruction. This energy and enthusiasm stemmed from meetings being held before the school year started and during a time when they were expecting to meet. Unfortunately, once the school year began, teachers may not have had the time to spend on extra work outside of their regularly scheduled courses, advisory periods, mandatory meetings and personal lives.

The first major assignment asked teachers to pick one of the competencies, which they developed collaboratively during the second and third sessions, and design an assessment, which would measure one of the competencies. They were also asked to give that assessment and see how the students did. They were given a month to complete the task. Unexpected by me, none of the teachers completed the task. Two things may have been going on: the first was that they did not actually know how to create an assessment that differed from the traditional assessments that they gave in their class; and second they could not balance the demands of work and personal life with my added tasks. Creating a competency-based assessment required teachers to know what types of questions and activities could be used to measure the competency. I think it

would have been valuable, if there were time, to create a sample assessment with the teachers. This was a shortcoming in my study. I did not allocate more time to certain tasks that may have needed further clarification. Another possibility was that the resistance stemmed from teachers not feeling secure enough to open up their practice to colleagues. In asking them to create assessments and share them, I was asking them to generate something new that applied their knowledge rather than just consume information from another scholar.

I met with teachers one on one to discuss their obstacles in completing assignment one. I noticed a similar theme in many of the conversations: creating a competency-based assessment was difficult to do. Multiple teachers expressed that they did not really know how to make an assessment that tied in with their content. They also stated that it was hard to assess the assessment. Crick said, "it is easier to create a lesson with the ideas I want to get across than write a formal assessment for that lesson." Based on this finding, I would recommend that significant professional development time be allotted to teaching teachers how to authentically assess, with competencies in mind, as well as create rubrics and grading scales.

Ultimately, teachers were able to come with activities for each competency, but they could not come up with a sophisticated way to grade these activities. This was evident in the third session. Some teachers teamed up and turned in activities that did not include any way to measure the students' understanding of the material or mastery of the competency. I asked teachers to include some form of rubric to grade the students' assessment by the fourth session, although I did not specify how to create the rubric.

By the fourth session, several teachers were able to modify their assessment to include a point system. However, the point system was not justified with criteria for each point value. Teachers knew that they would be awarding points, but they were unsure of how to assign those

points. An example of this was seen in Galilei's assessment rubric where he wrote, "video posted on time 0-1-2-3; video is related to unit- 0-1-2-3; video is engaging-0-1-2-3." In discussion, teachers realized that they needed to improve their assessments, but in the end most did not.

As mentioned above, teachers said they valued collaboration, but their actions were inconsistent. Session 4 (department meetings by discipline) was cancelled, and deemed optional by the administration for logistical reasons, and when I tried to reinstate the meeting, teacher by teacher, I found that only a handful of teachers were willing to attend. The handful of teachers who did attend the meeting were participatory and fully engaged in the conversations. The teachers that left school early cited reasons for leaving which included being tired, not wanting to meet after school, and feeling sick. Yet, if the meeting was required, I assume they would have been there.

Also, before the fourth meeting I asked participants to modify and refine the group-generated competencies online before we met as a group, and none of them did it. However, what I saw as resistance may have also been a struggle. Teachers may not have known how to put onto paper what their beliefs about competencies were. Also, it may have seemed safer in the group setting to build on each other's ideas. Their thinking seemed to have evolved, but their instruction and assessment were lagging behind. During group sessions, teachers were able to talk about what they wanted to assess for and the importance of each competency, yet in the final interviews, teachers did not circle all competencies, signifying their importance.

Independent schools are not always as vested in reform efforts.

There have been multiple reform efforts to improve science education and change the ways students learn science in the United States, however, independent schools are not as tied to the reform effort. In public schools, there are state mandated standards, which results in a

standardization of teaching. If there is a revamping of standards, public schools are required to adhere to them. In private schools, teachers may use standards to guide their curriculum and instruction, but it is not always mandated.

In the case of Sunset School, teachers choose their own textbooks, curriculum and instruction strategy. In fact the only national science tests that students will take at Sunset School during their science career are the SAT subject test and the AP test. AP tests have not been the standard of scientific literacy. In fact, both the SAT subject test and the AP tests require more reproductive thinking (repeating factual knowledge) rather than productive thinking. Unfortunately, because the major emphasis of the AP science tests is rote memorization of material, this becomes the emphasis in the science classroom (Education & Council, 1988). Science is more than empirical data; it is the ability to analyze data and sources to interpret an event (Ryder, 2001). With a heavy emphasis on science knowledge acquisition, there remains a disconnect between the teaching of science and actually preparing kids to be consumers of science.

Reflections on Interventions

The genesis of this project stemmed from my desire to improve science education at my school. It was important for me to delve into discussions with my department about what truly matters in science education, before we embarked on a WASC-mandated scope and sequence document for the department. My hope was that teachers would shift from a heavy content focus to a competency focus, which required that teachers actually talk about what matters and create competencies. Finally, I hoped that teachers would shift the way they assess students and ultimately change their instruction. I had observed too many classrooms where the focus was on the minutia of science rather than the development of skills and understanding.

The final exams that teachers have been submitting for the past six years, while I have been department chair, have been heavily fact and content-laden with very little room for problem solving or critical thinking. It is not entirely teachers' faults for instructing and assessing this way. After all, the AP science exams and the science SAT subject tests assess in the same way. These tests send a signal to teachers that this is what matters, even if a great deal of literature and the new science framework suggest otherwise.

When I created objectives and outcomes for each group session, I fully expected the department to embrace this type of work and move forward. The first session went very well. Teachers were truly energized and excited to be talking about science literacy. The timing was also perfect. Teachers were refreshed from a summer off and the morning meeting time was ideal. However, once the school year started, teachers were faced with many challenges to completing the tasks. By the second session, almost half of the teachers did not have time to read the assigned article. There is such a scarcity of time and energy in the teaching profession that taking on extra responsibilities can cause anxiety for the teachers, especially when they feel stretched to their limit. The competencies that teachers developed were good, and quite similar to the 21st century skills that are listed in many education books and journals.

Shortcomings of the Study

When I began to think about group sessions and working with teachers, I fully underestimated the amount of time that we would have and need as a group to do this kind of work. Thinking and discussing science literacy is one thing, learning to develop competencies and assessments takes much more time and a lot more training of the teachers involved. The tasks were not easy and they were time consuming. This was not time that teachers could spare

in their demanding jobs. But if, somehow, significant time could be set aside, the work could be done.

Recommendations For Schools

I recommend that science teachers engage in a targeted professional development that builds upon the work that they successfully created during my study. Specifically, teachers were able to create more logical and empirical assessments when they were asked to use competencies to guide them. Therefore, the type of professional development that seems most useful at this time is work that helps teachers develop new models of assessment and instruction that have a competency in mind. It is very challenging to create competency-based assessments and rubrics for scoring student work. Professional development that can scaffold these tasks and make them manageable are critical for teachers who want to teach a competency-based curriculum. Furthermore, it is possible the teachers that are amenable to change can be paired with other teachers that did not show as much growth in the study. Teachers can help other teachers build from their contextual understanding. This could lead to more teachers becoming literate about science literacy.

I also recommend that schools set aside significant time for collaboration and that this collaborative work be expected and encouraged and be a part of the teacher evaluation process. Teachers need ongoing opportunities to have dialogue about their practice (Ingvarson, Meiers, & Beavis, 2005). Having continuous dialogue with other teachers enables them to deepen their own content knowledge (Darling-Hammond, 1997). Private school teachers have a different accountability for their work.

I recommend that teachers and administrators have clear goals and learning outcomes for all students, and that teachers meet regularly to discuss these outcomes and ways to measure

student learning. One way this can be accomplished is through departmental scope and sequence documents that highlight learning outcomes, teaching methods, and assessment types.

My recommendation is that Sunset School create more goal oriented in-service days, in which teachers are fully present and focused on creating new assessments, and aligning curriculum. Ideally, these in-service days would be placed throughout the school year after a weekend, when teachers are rested and have time to do meaningful work.

Recommendations for Further Research

It would be interesting to do this type of research with another school and science department. One where the administration is fully engaged and looking for change in pedagogy among the teachers, or where teachers have more professional development set aside for this type of work. The goal in most interventions and professional development for teachers is that they will lead to some measurable difference in student achievement. While this study's aim was to look at teacher views and teacher collaboration, the end goal is that students are science literate. It would be useful to develop some type of science literacy instrument that teachers give to students before they graduate high school as a means to see how well teachers are doing in preparing the students.

Limitations of Study

While this study presents interesting data about science teachers' beliefs and practices, there are limitations to consider.

Generalizability.

I worked with a small group of predominately white, middle-class teachers at a small private school. Almost all of the teachers had a higher degree in education or science. Participation in my study was voluntary. My sample was diverse in experience and grade level

and representative of the school population; however, it was not necessarily representative of the entire population of science teachers. Therefore, I expect that the knowledge gained from this study can be used to add to the existing literature on science education and collaboration, but it is not necessarily representative of all science teachers. Furthermore, due to the qualitative nature of the research, the data may be subject to different interpretations by different readers.

Reactivity.

There was also potential bias because I am a member of the science department and I work intimately with most of the teachers. As the department chair, my participants may have said certain things in the interview to please me, rather than convey the absolute truth. There is information that I infer from their statements and their actions. Also, some of their willingness to participate more or less fully in the group sessions may have been because of my existing relationship with them. To contend with this issue, I used multiple data sources to determine each teacher's views on literacy, collaboration, and change over time.

Conclusion

Improving the level of science literacy of our students should be the goal of science teachers. However, it is not an easy task. What science literacy looks like, and how it should be taught, is not agreed upon by teachers and schools. Most teachers are still defining it in ways that do not necessarily contribute to the science literacy of their students. Unfortunately, as science literacy decreases, science skepticism increases among the public. This skepticism about science being a "force of good" may be a contributing factor to major cuts in funding for science and technology programs (Mejlgaards & Stares, 2010).

Science departments need to define science literacy, and reach consensus on how they can best measure it in their students. The process begins with a conversation and continues with

consensus building around assessment and instruction. Collaboration is valuable to teachers and needs to be facilitated by schools on a regular and on-going basis.

Appendix A: Timeline of Events

August 23, 2011

- Recruit participants and collect consent forms

- Initial group session

 - Collect pretest data (science literacy definitions, sample assessment questions)

 - Assigned reading

- First journal prompt

August 25, 2011

- Second group session

 - Discuss assigned reading (spend most time)

 - Collect sample assessment questions

- Second journal prompt

September 12-16, 2011

- Third group session

 - Respondent checks

- Third journal prompt

October 17, 2011

- Fourth group session

- Fourth journal prompt

November 17, 2011

- Fifth group session

- Fifth journal prompt

December 5-10, 2011

- Final interviews

- Respondent checks

January 2012

- Final interviews

- Code data

- Write up findings

April 2012

- Write up discussion of findings

May 2012

- Present findings and discussion of findings to dissertation committee

Appendix B: Research Information Sheet Consent Form

August 2011

Dear Teacher,

You are asked to participate in a research study conducted by Tamara Miller from the Educational Leadership Program in the Graduate School of Education & Information Studies at the University of California, Los Angeles. The aims of this research are to study the development of a culture of collaboration among science department members and thereby improve science instruction and science literacy at Sunset School. Your participation in this research will improve my understanding of collaborative planning and teaching. There are no physical or psychological risks to you from your participation in this study.

If you agree to participate in the research, you will be audio taped during six group sessions that will take place during regularly scheduled department meetings. The recordings and electronic responses will be analyzed by the principal investigator (me) to understand how you as a teacher, think about science literacy and how your instruction and assessment are aligned with group generated science competencies. After or near the end of each group session I will send a short electronic journal prompt, which will be a debriefing of the discussion and activities that took place that day. Your email response will take no more than five minutes. After the study, I may conduct a short interview with you to obtain more information about your thoughts on the process of collaboration, peer observation, and teaching. I may also administer an anonymous electronic survey to gather similar information. Participation in the research study will take place simultaneously with the work that we are doing as a department. This time includes the six group sessions, response to journal prompts, creation of new lessons, peer observations, short interviews, and reading of journal articles.

All of the data I collect via group sessions, electronic journal prompts, surveys, and interviews will be kept strictly confidential, and will not be shown to school members or staff.

You have the right to review, edit or erase the research tapes of your participation in whole or in part.

Your participation in the research is completely voluntary and even if you consent to participate you may withdraw from the research at any time. You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you wish to ask questions about your rights as a research participant or if you wish to voice any problems or concerns you may have about the study to someone other than the researchers, please call the Office of the Human Research Protection Program at (310) 825-7122 or write to Office of the Human Research Protection Program, UCLA, 11000 Kinross Avenue, Suite 102, Box 951694, Los Angeles, CA 90095-1694.

If you have any questions or concerns about the research, please feel free to contact me at TMiller@bwscampus.com or 310-666-1258. You may also contact my faculty sponsor, William Sandoval, at Sandoval@gseis.ucla.edu or 310-794-5431.

Sincerely,

Tamara Miller

Graduate Student, UCLA

SIGNATURE OF RESEARCH SUBJECT

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Name of Subject

Signature of Subject or Legal Representative

Date

Please sign **below** this text if you are not sure if you are going to participate because you need more information. I will contact you today or tomorrow and answer all of your questions.

Appendix C: Group Sessions

Session 1 (1 hour)

Guiding questions.

Q1: Please write down your definition of scientific literacy. Please include all of the components of your definition of scientific literacy.

Q2: Please write down two sample questions that you have used with your students that measure science literacy?

Q3: What are similarities and differences between different definitions that are on the board? (Group discussion)

Q4: How can we group these from a taxonomic standpoint? Are any of these groups less content oriented? (Group Discussion)

Activity.

I began the study by asking the group to individually write their definition of scientific literacy on paper or on an electronic word document, and of all of the things that made up their definition of scientific literacy. This gave me documentation of each member of the groups' perceptions before the study began. I collected the papers and electronic submissions from all participants. During the next part of the session, I asked each member of the group session to write two test questions that could be used to assess scientific literacy. These questions could be subject-specific or more holistic. The next step was the "taxonomy game" where group members discussed everyone's definitions according to theme or similar definition. I asked participants what some of the similarities and differences were between definitions, and we had a conversation about science literacy.

Goals.

Pre-test data. The science literacy definitions collected in session one gave me pre-test data to answer research question one. I initially collected their definitions of science literacy and by simultaneously collecting sample questions from each teacher, I was able to determine if their assessment questions mirrored their definitions of science literacy. I was also able to elicit assumptions on science literacy. This marked the beginning of a shared endeavor of collaboration.

After Session 1.

1. Group members were asked to read article one
2. Group members responded to electronic journal prompt before the start of session two.

(These questions were written as the guiding questions in session 2.)

Session 2 (1 hour)

Guiding questions.

(The first three questions were the reflective journal prompt questions. These were also a springboard for discussion)

Q1: How would you describe the type of science literacy found in your article? In what ways was the article similar or different to your current belief about science literacy?

After reading this article, was there anything you might add to your definition of science literacy?

Q2: When you reflect on your curriculum and instruction, and assessment are there ideas that do not lend themselves to creating a scientifically literate population of students?

Q3: What, if any topics themes, skills, processes, or assignments could you eliminate or reduce in your curriculum to make room for greater depth of other topics, themes, skills, processes, and assignments that lend themselves to creating a more scientifically literate population?

Q4: What are the content, skills and processes that our students should know and be able to do before they graduate? (Examples of competencies)

Q5: In your group, can you come up with one to three competencies and write them down?

Activity.

At the second meeting I asked everyone do a "quick write" on their own definitions of scientific literacy. It may have changed since the previous meeting, it may have stayed the same, or it may have expanded. I asked them how the author of their article defined scientific literacy. I opened up a conversation about the different types of literacy mentioned in the journal articles. I then asked teachers to reflect on their curriculum and think about the ideas that do not lend themselves to creating a science literate student. I also asked them to reflect on what might be eliminated from their course to make room for more depth of other topics.

The second part of the session involved the creation of competencies. I grouped teachers into three heterogeneous groups and asked them to come up with competencies. I explained that competencies were defined as what kids should know and be able to do. I gave them some sample competencies and then gave them 20 minutes to work in groups. I collected these competencies at the end of the group session.

Goals.

The goals of this session were to re-examine the initial views of science literacy and reflect on curriculum and instruction. Then the next goal was to begin the process of collaboration by working in groups to generate competencies. Finally, teachers would use competencies to develop competency-based assessments.

After Session 2.

1. Group members were asked to pick a competency from the list that was created in session 2 and develop an assessment for that competency.
2. Group members responded to electronic journal prompts before the beginning of session three.
3. Group members were asked to think about what activities/lessons/projects are standard practice in their science classroom, which contribute to the science literacy of the students. Then they were asked to use something that they had learned from the group and/or research and prepare something new to implement in their classroom.

Session 3 (1 hour)**Guiding questions.**

(These questions were the electronic journal prompt questions as well as our springboard for discussion.)

Q1: How has the effort to design an assessment of one of our competencies influenced your ideas about assessment?

Q2: In what ways does developing assessments for your competencies influence your approach to instruction?

Activity.

During this group session, members engaged in authentic group reflection about their competency-based assessment as well as the challenges of developing the assessment. Group members shared their assessments with the group and the group gave feedback. Not all teachers had the opportunity to share their competency-based assessment, so this activity was continued in the next group session.

Goals.

The goals of this session were to engage each group member in self-reflection as well as critique each other's competency-based assessments. The goals of the activity were that teachers began the process of becoming reflective practitioners independent of one another as well as collectively.

After Session 3.

1. Group members were asked to refine their competency-based assessment and think about a rubric for scoring the assessment.
3. Group members responded to an electronic journal prompt, which asked them to submit their competency-based assessment online as well as their rubric for scoring the assessment.
4. Group members were asked to look at the competencies and see if they should be modified in any way. The competencies were on a group site with collaborative access for all group members.
5. Group members were asked to look at the new science framework.

Session 4 (1 hour)

Guiding questions.

Q1: Based on last week's discussion, has any aspect of your pedagogy changed to reflect new ideas that emerged in last months' session?

Q2: How can our assessments be better tied to our competencies?

Q3: How has your assessment changed over the past month?

Q4: How do we judge a good assessment? Can we think about criteria of a good assessment?

Q5: Do we agree that these competencies are important?

Activity.

The session activities included a discussion of the previous session, and the assessments. We took a step back to think about what the criteria are for a good assessment, looked at the competencies as a group, and refined them a bit more.

Goals.

The goals of the discussion and activities after group sessions were to operationalize the competencies. Teachers would develop lessons that matched their assessments, which measured the competencies. Another goal for the group session was that group members would understand how they think about science literacy, and how those thoughts translate into meaningful lessons. A third goal was that teachers would become more comfortable giving and receiving feedback about their assessment. A fourth goal was that teachers began to share assessment items with the group.

After Session 4.

1. Teachers were asked to continue to work on aligning their lesson to their assessment.

2. Group members were asked to bring several assessment questions to the next session that measure scientific literacy.

Session 5 (1 hour)

Guiding questions.

- Q1: Based on the draft of the new science framework, are we missing anything?
- Q2: What aspects of the framework are consistent with what we are already doing at school?
- Q3: What aspects of the framework are new?
- Q4: How do we link the competencies that we developed to the new science framework?
- Q5: What do you see as the next logical step for the department?

Activity.

This group session was spent looking at the science framework and reflecting on current curriculum and assessment as well as the gaps in the curriculum. The science framework was used as a way to look at the prioritized ideas and see where those ideas could be embedded at every grade level.

Goals.

The goals of this group session were that teachers read the science framework and discussed some of the gaps in the curriculum. Another goal was that teachers begin to think holistically about curriculum, competencies and ways to incorporate big ideas from the framework.

After Session 5.

1. Group members continued creating assessment items that authentically measured scientific literacy.

Appendix D: Final Interview Protocol

1. In the first session we thought about science literacy definitions. These are the definitions that we generated as a group. (Show them the list).

- a. Have your definitions changed?
- b. Looking at these definitions, how do you think differently about assessment. Can you give me an example of what that looks like in your class?
- c. Looking at these definitions, how do you think differently about instruction. Can you give me an example of what that looks like in your class?

2. In the second session we thought about what we wanted our students to be able to do when they graduate. We got into groups and we generated competencies. (Show them competencies)

- a. Was this easy or hard? If easy—what was easy? If hard—what was hard?
- b. When you look at these competencies, which ones seem like they are important? Circle them. Why?
- c. Which of the competencies that you circled do you currently assess for?
- d. How well do you think these assessments are working for you?
- e. Which might you assess for in the future?

3. Collaboration questions

- a. How was it useful for you to work in a group the way we did and to think about science literacy and competencies?
- b. What do you think the value of doing this on a regular basis?
- c. What do you think the challenges would be to do this on a regular basis?
- d. What can the school do to support this kind of work, to increase the value and mitigate the challenges?

Appendix E: Abstract of Journal Article

Journal Abstract

Hurd, P. (1997). *Scientific literacy: New minds for a changing world*. Hoboken, NJ: John Wiley & Sons.

Abstract

From the beginning of modern science in the 1600s, there has been an interest in how to link academic science with the lifeworld of the student. To facilitate this purpose requires a lived curriculum and a range of thinking skills related to the proper utilization of science/technology information. The extent to which students acquire these cognitive competencies determines whether or not they are scientifically literate. The supporting science curriculum must be culturally based and in harmony with the contemporary ethos and practice of science. Never before have schools faced such a rapidly changing landscape calling for a reinvention of school science curricula. This article identifies elements of a curriculum framework and cognitive strategies that seek to prepare students as productive citizens in today's world.

Appendix F: Electronic Journal Prompts

In a short typed document, please answer the following questions. Include details to support your response. Your careful, thoughtful, and thorough response is appreciated.

- Day 1 Q1: Please write down your definition of scientific literacy. Please include all of the components of your definition of scientific literacy.
Q2: What are two sample questions that you have used with your students that measure science literacy?
- Day 2 Q1: How would you describe the type of science literacy found in your article? In what ways was the article similar or different to your current belief about science literacy? After reading this article, was there anything you might add to your definition of science literacy?
Q2: When you reflect on your curriculum and instruction, and assessment are there ideas that do not lend themselves to creating a scientifically literate population of students?
Q3: What, if any topics themes, skills, processes, or assignments could you eliminate or reduce in your curriculum to make room for greater depth of other topics, themes, skills, processes, and assignments that lend themselves to creating a more scientifically literate population?
- Day 3 Q1: How has the effort to design an assessment of one of our competencies influenced your ideas about assessment?
Q2: In what ways does developing assessments for your competencies influence your approach to instruction?
- Day 4 Q1: Based on last week's discussion, has any aspect of your pedagogy changed to reflect new ideas that emerged in last months' session?
Q2: How can our assessments be better tied to our competencies?
- Day 5 Q1: What were some of the assessment items that you brought to group session 5? How were they similar or different from other members in the group?
Q2: Were your questions content based, process based, or based on both?
Q3: Were your questions subject specific or general to multiple disciplines?

Appendix G: Data Analysis Matrix

Research Question	Data Collected	Method for Analysis
1. What are science teachers' views on science literacy?	Written definitions of science literacy (day 1) Written groupings (day 1 and 2) Comments/dialogue (all days) Final interviews	Definitions were grouped into categories that were subdivided further. The goal was to identify themes and connections between different definitions. Written definitions were the units of observation to create the categories. This helped me answer research question 1.
2. How do science teachers' views on science literacy manifest across different contexts of teaching: planning, instruction, and assessment?	Written competencies Written goals Written assessment questions Comments during group sessions	I looked at alignment of assessment questions and specific competencies. I recorded comments during group sessions and transcribed, coded and identified themes, and then compared to teachers' written assessment questions.
3. How does collaboration around the context of planning, instructing and assessing for science literacy influence teacher's views on the nature of their work?	Interviews during and after collaborative action research project	Interview data was coded and grouped by recurring themes. I interviewed each member of the department after the group sessions. The interview data was useful because I relied on their perceptions. I asked them questions that elicited responses about their views and I asked if those views had changed in any way. I asked them about the process. I also had initial views documented in the first group session that used to compare their final to initial views of science literacy. I used field notes and transcripts to look at changing views. Interview data gave me data on how science teachers comprehend their beliefs about the process of collaboration. Interview data allowed me to work out structures and relations not apparent in the text of the written documents. I used all three to triangulate my data.

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