Observation Three Critique: Historical Debates

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Section One: Introduction

Bertrand Russell (1925) stated, “a certain percentage of children have the habit of thinking; one of the aims of education is to cure them of this habit (p. 378).” Although nearly a century has passed since Russell’s ironic statement, it remains as true today as it ever was. As opposed to becoming dependent on others for learning that occurs when education curtails children’s thinking, the ability to think for oneself and develop independence as a result of teaching (Hawkins, 1974) should be the aim. To achieve that end, it not only is important for students to comprehend the “what” related to the discipline of science itself but equally important is the “how” (Schwab, 1962) of the process that yielded the information that they were taught.

For students to fully understand the what as well as the how of science to be capable of appreciating the discipline in its entirety, there must have been an effective educator in the lives of students whose teaching methods implemented were successful as a result of giving much consideration and effort to the development of appropriate strategies and techniques. Such useful methods are determined from guidelines that have been established from the available evidence-based literature.

The guidelines for science education have undergone revisions throughout history that have seen many significant improvements being made that resulted from the contributions that were provided by many scholars in a variety of fields that were related to science education. Assessment and reassessment of what has been done, analysis of the results, and determining where there is room for improvement are all steps involved in reformation. Also, keeping what works while abandoning what does not is also part of the evaluative process that is involved in
reform, which traditionally begins by making observations followed by critiquing what was observed.

**Critique Overview**

The author approached the present assignment in the traditional spirit of reform. As a result of observing either a set of live or recorded classroom, the author provided a critique of the recognizable and recommended activities from the literature that were related to science education. This critique, which comprises the author’s analysis, results from the identification of both teaching strategies and techniques that were recognized from the recommendations as found in the text of the works of eminent scholars in the literature. Once the activities were identified and supported through attribution with citations, any implications of the identified techniques and strategies were elaborated on and discussed.

The analysis conducted was based on Observation 3, which was a prerecorded video source of fifth graders from Turtleback Elementary School. The observation three video was comprised of activities in which both students and teachers were engaged that reflected their understanding of some of the greatest historical debates known to humankind. Writing, delivering, and critiquing short stories were just a few of the processes that these children acquired as skills that were related to the activities involved in the observation. The students were required to collaborate with one another once formed into heterogeneous groups to work together to develop their best arguments. Then, once they had obtained the appropriate information using a variety of technological media, such as computers, the internet, hands-on learning, and iMovie, they were asked to present a demonstration that incorporated what they had learned from their teachers concerning the History and Philosophy of Science (HPS).
With the goal of developing and substantiating an argument for what science looks like in the classroom, this paper will be structured in a logical manner and contain citations to substantiate the claims made. The paper will proceed from the more general contextual information to the more specific information related to the activities. Beginning with the presentation of some of the historical background concerning education in science that provides the reader an overview of some of the relevant periods, problems, and themes through which science education has passed. By doing so, the author facilitates the reader’s ability to make connections between the year in citations and the decades during which particular themes and thoughts from the context were involved. Activities identified or implicated in the activities according to the transcript of the observation will be commented on incorporating citations that refer to the specific action, behavior, or skill required to complete the task. Ultimately, the author considers the implications of the identified activities through their relationship in satisfying the content or goals as mentioned in the original documents of the National Science Education Standards (NSES), Frameworks for K-12, Common Core State Standards (CCSS), and Next Generation Science Standards (NGSS).

Including this Introduction Section, there will be a total of three main sections each of which has been devoted to a purpose. The remaining portion of the current Introductory Section will establish the context for the critique by presenting a broad overview of some important events and periods from which the evidence-based literature used in citations comes. The next section will be the Body of the Paper, which is comprised of the actual analysis of the transcript concerning the activities related to observation three. Activities that were observed as well as those involved or implied in the transcription that have been suggested in the literature or the national standards as recommended practices will be discussed. Since not every activity or
category on the HPS worksheet rubric was involved, only relevant topics and citations from the literature and national standards will be provided that apply to the activities involved.

Following the Body of the Paper, there will be a final section entitled Conclusions. In the Conclusions, it will be discussed in what way the activities identified addressed the rubric categories. Moreover, how any of the identified activities correlated with the National Science Education Standards (NSES) or Next Generation Science Standards (NGSS) for fifth-graders will be considered, as well as their implications on teaching practice and student learning. Any conclusions will be premised on the text from the works of the scholars that were encountered taken on an implicative argument from authority (Machi & McEvoy, 2016). The author believes that organizing the paper in this manner will make it easier for the reader to follow the progression of the critique by referring to the sections that were previously encountered to substantiate conclusions drawn.

**Brief History and Context**

By the middle of the 19th century, after a long history in which science and science education had been traditionally the result of individualized approaches, there was a lack of solid theoretical foundation and consistently effective practices. The noticeable effects from a lack of organization and efficiency had taken their toll leaving educators frustrated. However, the absence of a unified voice in public education would soon change with the open invitation of Thomas Valentine, then President of the New York Teachers Association, to form a national teachers association, which would lead to the founding of the National Education Association in 1857 (NEA, 2017).

The NEA consisted of educators from around the country, which included an African-American founding member named Robert Campbell (NEA, 2017). These educators were
unified in both voice and vision for meaningful education and teaching. Those who joined had dedicated themselves to ensuring that their collective wisdom and experience would be utilized to the fullest extent.

Among the issues that they faced early on was student learning and transitioning to higher education, which suffered from a lack of consistency. With the desire to remedy the problem, the NEA assembled The Committee of Ten in 1893, which was chaired by the former President of Harvard University, Charles Elliot (Deboer, 1991). The Committee comprised a composite group of ten educators responsible for developing time-lengths, subjects, and methods that would achieve the goal of easing the process of transition from high school to college (Deboer, 1991). Together with their counterpart, the Committee on College-Entrance Requirements (CCER), the effort that was placed into making science education beneficial for all students irrespective of ultimate individual educational aspirations was commendable. Nevertheless, the solidification of the importance of incorporating science education into the curricula for all students resulting from the Committee’s efforts was insufficient to address all the issues facing the secondary educational system.

Society had apparently changed yet secondary education was unable to keep pace (Deboer, 1991). While practical in its approach to providing a basic foundation in science for all students regardless their educational goals in college, the Committees had completely overlooked the fact that not everyone would desire to continue education beyond high school. For this group of students, such a science foundation was not practical. Moreover, from a social utility perspective, this meant that some additional changes were still in need.

The formation in 1911 of The Committee on the Articulation of High School and College Education (later referred to as the Commission on the Reorganization of Secondary Education
[CRSE]) by the NEA was intended to address the issue and would ultimately be remembered for its development of subject-subcommittees (Deboer, 1991). The task of legitimizing the basis for its involvement in the curriculum is what science, like all other subjects, was required to do. The approach to establishing legitimacy would be argued from the standpoint of the social utility of the topic of science with respect to the Cardinal Principles of Education (NEA, 1918). The restructuring by CRSE and social relevance approach is what allowed for both nontraditional subcommittees to be formed alongside those of the classical subjects.

In a matter of little more than three decades, the shift that had occurred was from a logical approach to one of psychological (Deboer, 1991). Making such a transition meant that science education would no longer be treated as simply an impersonal, indirect, and recreational experience. By recreational, the reference is to the emphasis that was placed on science laboratories for instruction through simulation and recreating conditions for learning science about the real world instead of going outside to interact with it. Because of this lack of real-world experience, the learning by trial-and-error involved in acquiring mental shortcuts for rapidly judging and problem-solving characteristic of heuristics (“Heuristics | Definition of Heuristics by Merriam-Webster, 2017”) was nonexistent. Thus, since simulations in the lab would never be as experienced in the real world, it became a question of external validity (Martella, 2014).

The absence of a heuristically oriented aspect of the curriculum had begun to be appreciated. When research conducted by Thorndike (1901;1924) on the effect of augmenting specific mental abilities on the others, which addressed experimentally whether the general transfer of knowledge could occur, many educators were persuaded to abandon the possibility of that such a thing was likely. By the 1920s, educators were broadening their conception of
general knowledge acquisition or what it meant to have it transfer. Advocacy for the psychological aspects involved in personal, direct, and actual experiences in the natural world that were of social relevance to the student were what many claimed facilitated the acquisition of knowledge. Such psychologizing to which Dewey (1934) referred, allowed for students to learn in the own terms by having unique and individual educational experiences that relied on their personal ones.

The depression on the 1930s and the impending war of the 1940s, the impetus to effect necessary alterations in science education was increasing. Many scientists had abandoned academia for employment with the government and the private sector that resulted in a personnel deficit that impacted science education efforts (Deboer, 1991). The threat of war looming forever altered how science was perceived and the view regarding the importance of science education to society. Once the war had ended, the creation of the Presidential Scientific Research Board, which subsequently established the National Science Foundation (NSF), marked a turning point for science. Nonetheless, as such organizations were created underscoring the importance of science, the 1950s brought with it what would be described as an anti-intellectual nature that characterized society and threatened what science was attempting to achieve. It was around this time that the attack on science would prompt the NSF to fund projects that looked into the construction and development of Mathematics (1952) and Science (1956) courses (Deboer, 1991). These courses designed by scientists were different from what was available in that these were to be student-centric emphasizing comprehension of the true nature of the principles of the disciplines.

Curriculum reform of the 1950s and 1960s was successful in some of its efforts to push for rigorous courses. A “science is as science does” approach to teaching science, and presented
science in the best possible light as logical and structured. However, it failed in a few ways also
by neglecting fundamental principles in effective curriculum design and instruction, according to
Deboer (1991). For instance, the teaching methods had ignored student interests, did not
consider the student’s readiness for learning, and failed to relate science to general themes as
well as the experiences of the students to develop meaning. There were improvements, but much
more was still needed. As the end of the 1960s approached, the intellectually altruistic basis for
studying science was beginning to be supplanted by the social pertinence perspective of science
as applied in the daily lives of all people (Deboer, 1991).

It was not far off for the transition from advocating science education because it could be
useful in everyday living to the push for an education in sciences because of science being
relevant to students’ lives and issues of social import. The resulting theme was referred to as
scientific literacy (Deboer, 1991) and was one of the socially relevant perspectives. Although a
variety of different meanings and interpretations of the term during forward-thinking attitude and
social relevance of the decades of the 1970s and 1980s, the association between science and
society was reflected in the theme of Science-Technology-Society (Deboer, 1991).

Ultimately, as the iterations in thought and policy continued to evolve over time, it
became evident that it was not about science being a process or product, nor was it about whether
science should be viewed as a disciplinary study or a socially relevant one; it was about setting
aside differences to reach mutually agreed upon goals by employing what research has
determined works. There have been and always will be disagreements regarding how science
should be framed. Nevertheless, science as an enterprise is undoubtedly multifaceted (Fraser &
Tobin, 2012) and cannot be categorized as one thing or another, nor can it mean the same to
everyone. Although there is much more that needs to be accomplished, the guidelines and
standard have done their best to incorporate many aspects of science. By ensuring that educators have the resources in the form of such guidelines based on the latest research, they will be empowered with the tools needed to construct curricula with a well-balanced variety of features that are consistent with the aims of science education. The appropriate implementation of what educators “unpack” (Wiggins & McTighe, 2012) from such standards based on research may result in the development of diverse and effective educational activities for all students of science education, which are similar to those related to the critique of the activities involved in observation three with which Section Two will be concerned.

**Section Two: Transcript Analysis and Discussion**

The activities that were identified relating to the transcript of the observation three recording and notes were those that were supported in the evidence-based literature through their inclusion among the national guidelines for education in science. Guidelines, in the form of Standards, were those of the previous National Science Education Standards (NSES) for grades 5 through 8, and that of the more recent Next Generation Science Standards (NGSS) for grades 5 through 8 as well.

It was most beneficial to conduct the observation and critique according to the rubric provided and cross-reference activities with the literature and NGSS guidelines. The reason that it was beneficial was that the segmentation of the standards allowed particular focus to be given to certain aspects at a time when considering the information gleaned from the observation recording. Furthermore, their breakdown revealed overlap in the relationships among the individual groups of standards. Thus, although some teaching standards may not have been directly observed on the recording for obvious reasons, they could be inferred from what was
contained in the observation transcripts and videos. It was in this fashion that as much information as possible was obtained.

**Rationale**

By asserting activities that may be defended as science inquiry, what is not considered science is implied. The author’s claim for what is science activity or inquiry is accomplished by defining the term, identifying activities from the observation transcript that qualify as such, and substantiating the activity identified by citation to correlate the activities with the standards or the literature that defined it. In this fashion, demarcating that which is and is not scientific activity is achieved most efficiently.

As opposed to what most would think about science, it is actually not purely objective. In fact, science may be described as a unique blend of both logic, and creativity (SFAA, 1989). When the public thinks about science, they believe it involves a discovery that occurs only by proceeding through a formulaic scientific method. Nonetheless, according to Popper (1959), this cannot be true because there is no justification for induction, which implies that there is no stepwise scientific method. Moreover, it may be argued that discovery can be reduced to a criterion of verifiability or meaningfulness (Popper, 1959, p. 52) in which observations are sought within the framework of satisfying theory, which proves nothing. Popper (1959) proposed a critical approach in which a criterion of falsifiability is applied in the hopes of adequately challenging a scientific theory. Regardless of whether one agrees with any of the perspectives of the scholars does not change the fact that science is not what the public thinks. Scientists have been accused of phenomenotechnique, or being responsible for creating the science like they created the laboratory equipment used to observe objects of their science (Latour & Woolgar, 1986). The reality is that science is agonistic, filled with craftwork, and
heavily reliant on politics (Latour & Woolgar, 1986). When compared to politicians, it makes sense for scientists to be skilled in logic and argumentation to perform their daily duties as well as defend themselves if needed.

Despite the various activities that comprise science, they all relate to most fundamental aspect of scientific activity known as inquiry. Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work (NSES, 2013). It is the acquisition of knowledge and fully grasping areas of science through the ability to comprehend what it is that permits scientists to learn about the world around them. There are many ways in which activities may be structured to fulfill this standard. Based on the observation three material that was observed, the author concludes that educators who designed the activities certainly had scientific inquiry in mind.

Students had to plan their research in order to determine which sources would be consulted. Once determined, the students then used appropriate tools, techniques, and technology to gather, analyze, and interpret data. Furthermore, the decision of which texts and other reference sources were credible had to be made for them to accept data as factual. Performing their review and analysis of what was known from their previous activities was necessary to constructing arguments and providing explanations based on the evidence obtained from their research. Also, the formulation of argument required them to utilize planning as well as think critically and logically, which allowed them to discover the relationships that exist between the evidence retrieved and the claims to be presented. By constructing their own arguments and having to capture them for case presentation using iMovie, the students engaged in activities that were all related to scientific inquiry and scientific activity that satisfied the guidelines found in the Standards (NGSS, 2013).
With respect to other aspects of the activities related to science as inquiry, the students used appropriate tools and techniques to gather, analyze, and interpret data (NRC, 1996) that was obtained from conducting research using the internet. Furthermore, the students were tasked with constructing arguments and providing explanations based on evidence obtained from their research. The formulation of argument required them to utilize planning as well as think critically and logically, which allowed them to discover the relationships that exist between the evidence retrieved and their claims to be presented.

Correspondence to CCSS (2009) anchors was identified in the activities related to what was observed. CCR Reading Anchor 3 requires the analysis of how and why individuals, events, or ideas develop and interact (CCSS, 2009). Furthermore, the students had not only to plan but precisely follow multiple steps to conduct their research in accordance with RST.6-8.3 (CCSS, 2009). According to CC writing anchor 7, the student should carry out short as well as more sustained research projects based on focused questions, demonstrating an understanding of the subject under investigation (CCSS, 2009). This anchor was satisfied through the planning and carrying out of the scientific inquiry investigating the debates to formulate their best arguments.

Students gathered relevant information from a variety of sources, which included texts and the internet to evaluate for credibility the information thereby meeting the CC writing anchor 8 requirements (CSS, 2009). The task involved assessing the usefulness of sources and paraphrasing conclusions of others. The heterogeneous groups fulfilled the CCR Speaking and Listening Anchor 1 requirements in which students had to prepare their arguments for the case and collaborated with different classmates and engaged in discourse building upon one another (CCSS, 2009).
Central science concepts, hands-on science opportunities, and use of technology in the form of internet research and iMovie were incorporated into the activities. The investigations that students conducted were a combination of teacher designed with the liberty to choose themselves an issue or aspect around which to form their arguments that they may not have otherwise explored on their own (NRC, 2012). Also, that they explored historical scientific debates implied that they were not simply being taught any content of science, but that they were given the chance to learn the context within which the historical, scientific knowledge, as content, in question was evolved.

The students’ research concerning the debates also implied that, in addition to scientific content, the personological aspects (i.e., characteristics pertaining to the individual) (Martella, 2014) of the figures involved were considered. These nonscientific contextual aspects from the HPS perspective provided insight into the theoretical framework contributing to the way each figure viewed the scientific circumstances related to the problem (Kuhn, 1972). In addition to studying debates from a historical perspective, part of their assignment was to construct their most convincing arguments based on their research. As an activity, the formulation of an argument is essential to a sound education in science and reflects the activities in which scientists engage routinely (Yerrick, 2000).

The cognitive involvement in argumentation skills is essential to the overall development of students’ critical thinking skills, as Kuhn (2010) notes. In fact, based on a study of the notebook of Faraday and electromagnetic field theory, it was concluded that cognitive tasks are as much a component of activities such as scientific discovery (Duschl, 1994) as are all others. Students’ abilities to identify flaws in reasoning and logic in their classmates’ presentations are some of the benefits derived from engaging in activities related to argumentation skills (Yerrick,
Moreover, the argumentation skills obtained from science is transferable to social domains and remains at a similar level of mastery (Kuhn, 2010).

Application of what occurs in the classroom relating to the child’s interests and experiences as well as his or her life outside the classroom is vital to the effectiveness of instruction programs (Deboer, 1991). That the students were asked to work in groups satisfies the need and desire for social interaction. Additionally, the group engagement fosters the development and mastery of essential skills necessary for the real world beyond the classroom through meeting the speaking and listening standards related to comprehension, collaboration, and presentation of knowledge and ideas (CCSS, 2009). Gallas (1998) claims that through collaboration, the educator can learn about how children think, which is revealed in the questions and ideas that the students make when given the opportunity. In this way, the curriculum emerges (Gallas, 1998) and both students and teachers benefit.

The Herbartian instructional method that is usually associated with efforts to systematize instruction led to the dichotomy that developed between coordination and correlation of courses (Deboer, 1991). Whereas coordination of individual classes became the mainstay in earlier thought, it was only more recently during the New Progressivism that interdisciplinary study of science in the greater context of other areas (Deboer, 1991) was emphasized and based on core overarching principles.

Interdisciplinary, according to the Oxford Dictionary (2017), refers to the relationship of something to multiple fields of study. Such approaches were also found to be among those implemented by the science educators teaching responsible for the activities in which the fifth-grade students participated. According to the information provided, the students were tasked not only with constructing arguments as found in the CCSS (2009), but they also learned to write,
present, and analyze speeches and short stories through the use of iMovie. This class of students recorded and presented the argument for a case to classmates combining several legitimate areas of knowledge. In fact, in some capacity the activities comprising the observation three transcripts related to science (the theories), technology (iMovie), advocacy (presenting their case), history (contextual perspective), and philosophy (argumentation and logic).

Some aspects are related to science education without which cohesiveness and comprehension may not be easily achieved. Much has been learned from the trends in science education that have historically neglected many core aspects of basic curriculum and instruction that were and still are vital (Deboer, 1991) to succeeding in science education. With the goal of science education being for students to be equipped with at least an age-appropriate level of knowledge, can comprehend, and possess a level of proficiency in performing science-related procedures (NRC, 1996),

Although the number varies depending on the iteration of standards to which one refers, various domains together comprise science (NRC, 1996; NGSS, 2013) each with its own particularly suited set of information. Nevertheless, regardless the domain-specific information in the form of scientific content knowledge, although important, it is alone insufficient to bring about the sort of learning experience or conceptual change (Posner, Strike, Hewson & Gertzog, 1982) that may be required of students who are in the process of learning. In addition to the content of science as a product, the activities and skills through which the information was and may be obtained (i.e., process) have a significant part in learning science as well. Furthermore, concepts such as implication, or cause and effect (NGSS, 2013), that elucidate the relationship between the content knowledge and the skills related to activities from which it may be derived are necessary.
From previous attempts early in history in which too much information overwhelmed the science curricula, it is known that students were unable to realistically learn what was asked of them (Deboer, 1991). In order to avoid a similar outcome due to the tendency toward rote memorization that may be found to occur to compensate for deficits of time and for sufficient comprehension (Deboer, 1991), such underlying ideas and notions that join the process and product must be accounted for in any curriculum. Together the process, product, and ideas that relate one to the other are the foundation upon which a sound basis for instruction methods geared to educating students in the sciences. It was according to these three foundational aspects that the Next Generation Science Standards (NGSS) were established, which have been incorporated into guidelines appropriate for each grade level as cross-cutting concepts, science and engineering practice, and disciplinary core ideas (NGSS, 2013).

In the fifth-grade performance expectations of NGSS (2013), students are expected to demonstrate grade-appropriate proficiency in developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, engaging in argument from evidence, and obtaining, evaluating, and communicating information. The ability to perform these activities reflects an understanding of the core ideas. The observation 3 activities consisted of the performance of many activities indicated or implied by the standards and supported in the literature.

**Ontological & Epistemological Commitments**

With respect to conceptual change that occurs with students who learn, it may be considered from differing perspectives. On the one hand, one may refer to the process that occurs through emphasizing the nature of what is real to the students, or how the change is manifested in their view of reality. Conversely, when the focus concerns the truth of what
knowledge is learned and one’s justification for claiming to know it, conceptual change may be seen differently. In the former case, this shift in view of what is real or exists to the student may be referred to as changing one’s ontological commitment (OC) whereas in that of the latter, the shift in view in terms of what is known involves a shift in epistemological commitment (EC) (Fraser & Tobin, 2012).

Although observation three did not involve activities in subjects like energy transfer or genetics, the use of, and drawing from, multiple sources did concern what they learned and involved their EC regarding what they claim to know as true. A determination of factual data by the students through a sort of triangulation of sources (Martella, 2014) from texts, the internet, and movies occurred while conducting research. Such a determination required them to establish and deal with their EC based the level of confidence they had in the information being credible. Furthermore, when argumentation was involved, each student formulating their argument required considering the EC of their position for which they had to provide evidence as proof of knowledge truth.

While the content-knowledge comprising the Historical Debates observation three activities concerned heliocentrism, planetary orbit, and asepsis, which are all connected to a variety of different ideas that have real-world applications and relevance. Furthermore, it was on the basis of Historical Debates as a common denominator that allowed the educator to integrate the three interrelated areas of science content successfully. Related concepts of argumentation were involved not only with respect to the substance of the debates themselves but in the students’ formulation of their arguments to present their cases. In addition, the little reenactments of observation three were accurate with respect to content and the opportunity to portray the scientists instead of simply learning about them from text psychologized the learning
process through relating the activities to something experienced in their lives (Dewey, 1932). The students had a chance engage in recognizably scientific behaviors through conducting their research and constructing arguments, which is what scientists do every day (Yerrick, 2000). Moreover, by exploring the lives of the famous scientists and the controversial content of the debates through acting, the experience took on even more significance.

The activities were developmentally appropriate for the students to complete. Because they were asked to conduct research prior to the development and presentation of their arguments and case based on what they learned, any previously held naïve conceptions contradicting the information they obtained would be exposed in the case iMovie presentations, which would allow the educator to take the appropriate measures if needed to bring about conceptual change (Posner et al., 1982). The students actively engaging in argumentation construction implies that, at a basic level, they would be considering potential avenues for inconsistency and refutation of their classmates’ argument or their own. Moreover, the formation of mixed groups entailed collaboration essential to any scientific learning community. Given the activities and assignments provided by the teacher, it may be deduced that the educator has provided an opportunity for the students to engage and behave as though they were indeed scientists.

**Activity or Unit Designed**

One of the best aspects of the activities was that the teacher did not rely on the traditional methods and strategies discussed in the literature that revolve around power plays. For instance, Lemke (1990) argues that through the use of the Triadic Dialogue in the classroom, which teachers tend to prefer heavily over others (Gallas, 1995), he or she establishes the nearly absolute control or power over classroom conversation and social dynamics among the students. In the activities involved in this recording, while certainly not impossible, such issues related to
dialogues and power struggles were not observed. If things such as talking out of turn were to occur at all in these activities, then the author would believe that the group would be that activity during which they would happen.

The aim of the activities related to observation three was clearly defined in the introduction to the recordings. Students were instructed on all aspects of the project and could work in groups. Working in groups reinforces the behavior that is found in a real learning scientific community (NRC, 2013). Although it was not explicitly stated that there were customizable components to accommodate either those with disabilities or different learning styles or the gifted and twice-exceptional students, from choosing classmates with whom to work in the groups to the sources for factual data and argumentation the students appeared to have some latitude.

The activities appeared to be intentionally designed in this manner to be sufficiently structured for most the students without being excessively restrictive to those who are gifted and twice-exceptional, or proscriptive for those with different learning styles. In addition to the activities being student-centered, freedom in how students planned to conduct research, accomplished the tasks, formulated their arguments, and collaborated with their groups was structured sufficiently to give guidance (NRC, 2011, p. 61) while providing enough personalization to accommodate a range of student abilities and preferences.

**Enactment of Science**

**Accurate Yielding Artifacts Demonstrating Science**

It may be difficult at times to determine whether there exists a correct perspective regarding anything. Everyone has their own theoretical framework with which issues are viewed and through which they are addressed (Gallas, 1995, p. 15). That notwithstanding, the author would agree that discourse is a vital part of the educational process for students. Furthermore,
discourse should allow for thematic exploration and childhood experiences of students to be involved, which have played important roles in the lives of Nobel Laureates (Gallas, 1995).

In observation three activities, the students could incorporate their preferences and experiences into the process of conducting research, constructing an argument for their cases, as well as in how they chose to make the iMovie recording for presentation. The research activities, the process involved in the construction of the argument, use of technology purposefully, and collaboration were all clearly indicative of the students embracing the norms of science, as scientists engage in them routinely. Furthermore, the products of the activities such as the data obtained from the research, the argument produced and the resultant iMovie presentation were authentic scientific artifacts that resulted from engaging in true scientific activities.

**Appropriate Choice and Activity Defensible as Science in the Lives of Students**

The observation three activities consisted of behavior and actions that were meaningful in the lives of the children, which is consistent with the liberatory concept of education (Fraser & Tobin, 2012). That is, instead of being viewed as containers into which knowledge is placed, the active role played in the students embeds meaning into the activity for them reinforcing all aspects of the process and product of learning.

Content-centered approaches to the process of learning in science education tend to create dependence on external sources to guide students. The traditional format of science education for a long time had ignored the essential aspects of effective teaching. Placement of the emphasis of instruction was on the transmission, or imparting, of content knowledge (i.e., the “what”) of science instead of incorporating historical context and background information to offer a comprehensive account of science derived from the HPS through which can be taught the processes by which it is obtained (i.e., the “how”)(Schwab, 1962). In fact, the American
Association for the Advancement of Science (AAAS) has acknowledged the importance of the role that “how” plays and developed a curriculum that includes both core and integrated processes of science such as observation, measurement, and formulating hypotheses (Duschl, 1994). It appears as though together, the what and the how are what builds confidence and freedom so that students may become capable of self-education and go on to develop independence (Hawkins, 2007).

What was involved in the activities for educational purposes was not just science that could be used; they were engaged in things that have a true socially relevant application to their lives. Collaborating, determining how best to locate information using a variety of media and technology. In addition to the other ways in which activities were significant to them, the socially relevant aspect transformed the learning process into one that was personally meaningful.

There were multiple opportunities to engage in discourse about scientific ideas involved in the activities related to observation three. During the research and data gathering, the time spent in groups constructing their arguments, as well as when the students had to record and present their cases to classmates. Although each was different, the chance to collaborate though required for the group portion expressly was implicitly encouraged in all the activities in some capacity by involving choices, options, and other students as part of the process.

For instance, while not impossible to record oneself with the appropriate ancillary equipment, given that students used iMovie to capture their argument on the recording, it would facilitate the process if another classmate assisted by doing the recording and provide feedback that may only be obtained from their perspective. The scientific thinker would arrive at this
decision giving the available options, which is another way that the activity provided the chance to think, act, and behave like a scientist.

By engaging in the class activities, students were encouraged to use their minds and ideas to carry out the assignments. Furthermore, the formulation of an argument not only is essential to science or the specific activity in class, but argumentation is also a scientific skill that goes beyond its use in the completion of the activities. Argumentation is required for sound decision-making in one’s personal life outside of school or work, which is alignment with the aim of scientific literacy (NRC, 1996).

**Curriculum Standards, Desired Outcomes Through HPS and Assessment**

A comprehensive approach to the science education curriculum has the benefit of providing a more accurate picture using history and philosophy of science (HPS) (Matthews, 1994). Through HPS integration, many of the influences that intuition/imagination, childhood experiences, metaphysical/philosophical frameworks, and subjectivity (Gallas, 1995) may be more readily appreciated by the students for playing as significant a role as the physical aspect of the world with which they interact. With both aspects of science, there is a significant amount of information ranging from the core principles to that which is abstract and theoretical.

While breadth implies a focus on the core ideas of science and is central to teaching science at all grade levels, depth refers to knowing and understanding not only the basic ideas within a science discipline but also some of the supporting experimental and theoretical knowledge (NRC, 1996). The activities of observation three focused mainly on the core ideas of science, which included aspects of the standards such as scientific inquiry, collaboration from the group portion, utilization of technology, and the formulation of argument (NGSS, 2013).
Just as there are certain things that students should be able to know and do, there are things that science educators are expected to know and do as well. These particular abilities may be found in the science teaching standards (NRC, 1996). Observation three activities satisfied many of the areas in the science teaching standards. For example, the activities were inquiry-based because student initially conducted research to gather the data from sources before any other activities were completed in compliance with science teaching standards. Furthermore, by the placement into groups, the educator created an environment that guided, enabled, and facilitated learning through establishing a sense of community and an environment in which the students could share the learning experience.

The desired student outcomes from the activity were designed to correlate with the California English Language Arts requirements, which blended the knowledge and skills acquired well within the established existing assessments. The excellent placement of HPS in the activities designed by the educator guided students to use a variety of technologies. In this fashion, HPS led to the integration of technology into the engagement of activities in the overall curriculum. During the research gathering, computers and the Internet were used. Also, the use of iMovie was included so that more than one program or application was used. Furthermore, the technology was both used to complete the main components of the activities and used in multiple activities, which satisfied different framework areas.

The in addition to meeting the California English Language Arts standards, these activities were consistent with the national standards. What was remarkable was that both the CCSS (2009) and Frameworks (NRC, 2011) were satisfied while permitting the students with disabilities and those that were gifted and twice-exceptional by allowing them to customize their approach according to individual requirements in learning styles and in their level of creative and
intellectual abilities. In this fashion, a variety of ideas, skill sets, and backgrounds were able to be incorporated into the completion of tasks in the activities and considered when assessing outcomes.

The assessments were embedded in the products of the activities at each subsequent stage in a nested fashion, which allows teaching and learning to be customized or enhanced as needed. Because the assessments in this observation associated with each task could occur as the process progressed, they may be considered formative (Fraser & Tobin, 2012). Nevertheless, the final task required everything that was completed before that point to be understood, which renders the final assessment occurring during the iMovie both formative (i.e., during) and summative (i.e., at the conclusion of all activities of learning). That is, to say, the success of the final iMovie case presentation was contingent on having thoroughly constructed an argument while working in groups that itself relied on the factual data obtained during the research conducted according to the initial plan that was built. Designing engaging activities that depend on successful completion of previous ones ensures that knowledge and skill are based upon what is already known through assimilation of what is being learned.

Section Three: Implications and Conclusion

If it were possible to remove oneself for a moment from the emic, or insider’s, perspective (Terrell, 2016), of either having been a student or an educator at one point, then it would be readily apparent that both teaching and learning are contrasting views of the very same process. The author argues that changes in the behavior of an individual that occur over time are how one may define learning to be a process (Lachman, 1997). That notwithstanding, whether in response to a feeling of losing control or insecurity, teachers behave differently and change over time (Fraser & Tobin, 2012) as well. Therefore, if changes in the behavior of an individual that
occur over time define learning as a process, and a teacher is an individual, then teaching may also be defined as the same process.

The process is dynamic and consists of dichotomous giving and receiving aspects of an exchange that occurs between a teacher and a student. However, for the exchange to happen, what is given must share at least some property with what is received. Otherwise, although the author acknowledges the differing subjective nature of the perspectives with regard to the same process due to interpretation, there would be no way to rationalize the occurrence of a transferal in educational experiences of something from one to the other.

The point of education is dependence, according to Hawkins (1974), which implies that at the outcome the students may engage in self-directed learning. Also, the author interprets Hawkin’s (1974) perspective to be one where teaching is not as an instruction of product, but as an instruction of a process, viz., “how to teach oneself (p. 56).” Therefore, one may describe the process of education that occurs as “educators teaching students to learn to teach themselves.” Despite being very meta-laden, the proposition captures a universal perspective of all the key components around a centralized process in the following manner: the giver (educator), the recipient (students), the process of giving (teaches), the process of receiving (learns), what results from this process for the recipient (the process of learning), and the effects the results have on the recipient (ability to teach themselves to learn). Ultimately, when the educator teaches, and the students learn, the educational process is self-perpetuating and being utilized to its fullest.

Satisfying the Essential Practices for K-12 Classrooms

One of the most important outcomes of education in general, as well as science education in particular, is the ability to engage in independent self-activity (Deboer, 1991). Through the unpacking and implementation of the content of the standards appropriately, this outcome is
achievable. The implications for the students of successfully implementing the unpacked standards related to observation three is the creation of an exceptional set of educational science activities. By participating in such activities, students had the chance to develop new and existing skills that contribute to acquiring knowledge, both of which are recommended in the guidelines (NGSS, 2013).

It is important that educators acknowledge that the educational process is not simply about forcing knowledge onto a child (Dewey, 1934). There is a dynamic balance between reorganizing both what is already known to best receive what is being learned, as well as properly formatting what is being taught to fit nicely into what is already known. The activities were psychologized (Dewey, 1934), and the students’ investments in them made them significant. Through the relation to, and expression by, their personal experiences, the students found meaning that was reflected in the way they chose to accomplish tasks. Therefore, the structured-yet-nonrestrictive format was conducive to knowledge acquisition through the processes of assimilation and accommodation (Deboer, 1991).

Students explained their cases to classmates, which required them to communicate their arguments in the form of iMovie presentations. Once they had asked their teacher and themselves the right question to help define their research problem, they were able to solve problems related to planning or conducting research to obtain the information sought in the inquiry. Also, the children evaluated what was found before they organized the data meaningfully to form evidence (Machi & McEvoy, 2016). They analyzed the evidence retrieved from the investigation and interpreted what they had found. The participation in these activities that legitimately may be considered science according to the definition previously mentioned and resulted in the students doing what scientists actually do. Except for mathematics, computational
thinking, and designing a model, the activities satisfied all the other Essential Practices for K-12, as found in the Frameworks (NRC, 2011).

Science as Evidence for Public Policy

Like those in which the students in observation three engaged, activities of science involve the identification, measurement, review, assessment, and evaluation of a variety of problems (NAS, 2012). Although traditionally thought of as being problems of the physical environment, not all problems amenable to scientific resolution are material in nature. In fact, many scientific problems that need to be addressed are intangible, which include problems that may potentially impact the public. Just as proof to substantiate the existence of a problem that could affect the public is required, the evidence is needed for there to be a basis for belief in the existence of a potential solution to address that public problem, which often comes in the form of public policy.

The use of evidence in the formulation of policy when it concerns the public has been promulgated by organizations such as the National Academy of Sciences (NAS). The NAS is responsible for advising the Federal Government in matters of public welfare with regard to science and technology (NAS, 2017). In a report by the NAS (2012), it was stated that knowledge obtained through science should be used to substantiate policy decisions, which is referred to by the term Use of Scientific Evidence in Public Policy.

Policies may concern individual topics as well as refer to entire areas or domains of specific interest to the public. As the domain of education within which the subject of science education concerns the public, policies that encompass science education have been created through an iterative process over many years in consideration of the most recently available knowledge derived from scientific evidence available at the time. Over the last three decades,
much progress has been made with respect to science education policy due to the latest research. Between the Frameworks for K-12 (NRC, 2011) and the Next Generation Science Standards (2013), the goal of achieving a scientifically literate society is more realistic than ever.

**Definition of Scientific Literacy**

In an ideal world, teaching just would be thought of the provision of meaning to children through the use of objects and words derived from an activity that they enjoyed. (Deboer, 1991). While that may not be the reality of for teaching and educators in general, teaching should be able to bring about a scientifically literate society realistically.

As a goal, scientific literacy corresponds with the aims for educating the public in science throughout their primary and secondary educational experiences (NRC, 1996). Unlike the general understanding of the word literacy, which simply means the ability to read and write (“Literacy | Definition of the word Literacy by Merriam-Webster, 2017”), scientific literacy comprises additional aspects. Scientific literacy may be thought of as possessing the knowledge and comprehension of both the processes and products of science that are needed to be personally useful by assisting with one’s decisions relating to matters of economic, cultural, and civic concern (NRC, 1996). In other words, being able to read and write science words does not imply the possession of knowledge and skill required for it to be personally useful.

The precise definition of scientific literacy depends on the context and has been interpreted in many ways by various educators. It has been interpreted dichotomously to be comprised of narrow and range-contacts, as the possession of sufficient knowledge to be considered familiar with scientific methods and practices, or as knowing enough to stay abreast of the latest current events in the media involving science and technology (Deboer, 1991). Nonetheless, the most common use by educators, according to a study by Pella (1967), is in
conveying the interface between science and society. Due to the renewed focus placed on social relevance as a theme in the 1970s and 1980s, from the most common interpretation of scientific literacy just mentioned the logical entailment of incorporating technology into a term that reflected it as the interface was a natural progression into the theme of Science-Technology-Society (STS).

To be considered a productive, contributing member of a scientifically literate society, one should be capable of deriving pleasure associated with the excitement and the enrichment that is related to comprehension of the world in which one exists. Furthermore, the routine use of appropriate skills and knowledge gained from an effective science education to assist in personal decision-making is also a result of such scientific literacy. Through the usage of relevant scientific knowledge to contribute to one’s community through participation in public exchanges is among the many ways a sound scientific background may be valuable outside of the classroom. Citizens adequately equipped with some degree of intelligence about aspects of, and topics related to, science and technology also have the potential to significantly enhance both their individual standing within society as well as society’s economic well-being. Moreover, the comfort, capability, and confidence to engage intelligently in public discourse and debate about matters of scientific and technological import will serve them well throughout their lives. Ultimately, scientific literacy is about maximizing the greatest return of benefits that may be derived from the investments in the form of appropriate science education standards that have been established.

Despite the existence of differences in between the iterations of science education policy, from Benchmarks for Scientific Literacy and Science for All Americans, through NSES into and the Frameworks and NGSS, they all have contributed toward common goals for everyone. With
scientific literacy as a goal and successful implementation of standards to assist in educating the public, achieving it for society and its constituent members may be more realistic. Moreover, once realized, with the achievement of scientific literacy will come the joy of knowledge fulfilled through comprehension in order to provide a sense of accomplishment that may only come with proficiency.

The National Standards as Guidelines

The notions of necessity and sufficiency as well as their relation to one another are critical for the educator to understand to effect change. What is necessary is that without which an outcome may not be achieved whereas that which is sufficient to bring about that same result may not be required to do so. For instance, in speaking of scientific literacy differing from general literacy that was mentioned earlier in this paper, it would be appropriate to state that being able to read and write is necessary for achieving scientific literacy, but is not sufficient to do so.

The relationship between necessity and sufficient is analogous to that of the standards and the overall purpose they are supposed to serve. That is, while the standards may be thought of as being necessary to “unpack” (Wiggins & McTighe, 2012) to be useful in achieving the desired outcome, alone the standards themselves are by no means sufficient to achieve it. There are other components also required from the educator together with which specific goals may be reached.

The author likens the concept of unpacking as the repurposing of the standards by teachers. It is the educator's responsibility to appropriate the content of the standards for the specific goals of the child through the development and implementation of curriculum components. Thus, while the standards are necessary to be satisfied in design, alone, they are by
no means sufficient to meet goals for the child specifically. In other words, the standards are not the target for which science education should strive; the creation of an individualized educational experience that has meaning to the child should be. That is, unpacking the standards may, therefore, be interpreted as what logically warrants the developed curriculum and is the link required in order to justify the existence of a connection between the standards and the goal for the child.

The NGSS (NRC, 2013) comprises fifth-grade performance expectations that include PS1, PS2, PS3, LS1, LS2, ESS1, ESS2, and ESS3, which are Disciplinary Core Ideas from the NRC Framework. In all, students identified, planned, collected information, evaluated and critiqued, reasoned and synthesized information to be able to support their arguments. Through the completion of the activities, the students did each of the following that correlates with CCSS (2009):

W.5.7 Conducted short research projects that use several sources to build knowledge through investigation of different aspects of a topic.

RI. Quoted accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.

RI.5.7 Drew on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.

RI.5.9 Integrated information from several texts on the same topic in order to write or speak about the subject knowledgeably.

W.5.8 Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources.
W.5.9 Drew evidence from literary or informational texts to support analysis, reflection, and research.

RI.5.8 Explain how an author uses reasons and evidence to support particular points in a text, identifying which reasons and evidence support which point(s).

W.5.1 Wrote opinion pieces on topics or texts, supporting a point of view with reasons and information.

SL.5.5 Included multimedia components (e.g., iMovie, Computer, the Internet) and visual displays in presentations when appropriate to enhance the development of main ideas or themes.
References


