Scientific Literacy: Its Meaning and Application

In the humbling age of the late 1950s there was a murmur of scientific revolution where space flight was to become common and nuclear chemistry would power the next generation of Americans through the second half of the twentieth century. According to Dr. Paul Hurd, an associate professor of education at Stanford University, the transistor introduced the electronic age, a jet made the term supersonic common, and the space age made our universe much smaller (1958). He was one of the first educators to write openly about the meaning of scientific literacy in America's schools as he noted education as the sharing of experiences of the culture and that science must have a significant place in the modern curriculum. Of particular interest to Americans in that time was the fact that many were calling for a complete overhaul of educational programs, even as far up as President Eisenhower. Dr. Hurd saw that this issue would soon be a part of every major educational agenda for many years to come:

> In this period there will be a demand for intensive specialized training for an increasingly larger fraction of the population. Already the creative and the technical manpower shortages are problems of serious proportions. Can science education be modernized fast enough to meet these challenges without destroying the balance of educational experiences? (p. 14)

Topics that were once discussed in that era are, unfortunately, similar to those that research still conveys as relevant to the modern day: bridging the gap between the wealth of scientific achievement and the poverty of scientific literacy. While academic literature has pushed the boundaries of what we define as scientific literacy, more questions and concerns have arisen since Dr. Hurd fathered the concept. At the same time, though, academic literacy has tended to focus on education in a holistic manner leaving much of this research on scientific literacy in a realm outside of the United States.

This collection of research is intended to describe common themes related to the current and historical focus of scientific literacy around the world, specifically in chemical education. Themes include the uses of academic texts for promoting scientific thought, the interplay of science, technology and society (STS), motivating students to learn through writing and the apparent lack of source material related to scientific literacy in the United States. Additionally, this research aims to describe how reading, writing, and using scientific language in discussions will empower students with the ability to successfully communicate their knowledge of scientific content.

Texts

Laura Robbs' theory for the implications of multiple texts in creating knowledge (2002) has been a defining moment of self education in the 21st century due to overwhelming amount of data available via the internet. This makes science textbooks virtually unnecessary when students can fashion their learning in ways suited their needs. However, these artifacts still play a significant role in the teaching of science as it is a source for linear material, graphic representations, and reference to equations, formulas, and laws.

Chemistry textbooks incorporate the languages of many different genres including, but not limited to, various spoken languages, heavily dated contextual jargon, advanced mathematic formulas, and graphical representations of the microscopic and macroscopic worlds. In order to successfully negotiate the knowledge within you must master each of these languages, usually by the tenth grade. Textbooks and other scholarly articles rely on their two dimensional material to guide a student through the understanding of our physical world while attempting to hold the attention of less than mainstream readers. The delivery of information from a textbook can therefore not be the sole institute for chemical knowledge since it cannot always explain its content with questions from students. These types of texts are riddled with compiled data that stem from ancient languages through modern chemical dictionaries with which printed material cannot keep up. Just like the written language has evolved over time, scientist had to invent new types of math to explain what it takes to be chemically literate. These concepts make reading scientific literature extremely difficult for most students.

It is safe to say, however, that there are more resources today via the internet that make a substantial difference in understanding chemistry due to the use of multiple interpretations and technical media. Prior to when the conventional web was at our fingertips chemistry textbooks were the sole invention for teaching students to be chemically literate. Critics of every school district analyzed every detail of these texts for accuracy, precision in delivery and cost. A study from 1991 conducted a quantitative analysis of seven textbooks which were commonly used in high school chemistry courses throughout the United States and produced in the state of Texas. It was the opinion of the researchers that these textbooks were relied on all too often throughout the learning process of students and were not adequately promoting instructional support for students (Chiappetta, Sethna, & Fillman 1991). "Many science teachers rely too much on the assigned textbooks, which probably give students a false impression of the nature of the science," (p. 939). This assumption is likely due to the fact that the information could not be manipulated nor was it put in context. Each textbook was analyzed because it was felt at the time that they did not live up to a high standard of education at that learning material should present scientific knowledge in fresh new ways. They should help to make meaning of the subject and present science as an enterprise that seeks out meaning in natural phenomena. Most of all they should present content in an accurate manner which stresses the methods of development of science through investigation and technology by incorporating historical and human aspects of scientific discoveries.

All books presented chemistry as a body of knowledge in the form of facts, laws, and principles rather than how scientists developed conclusions with the scientific method. While these texts contain accurate representations of chemical knowledge they also did not fall into the four aspects of scientific literacy: (I) presents the knowledge of science, (II) investigates the nature of science through active engagement, (III) encourages reflection of historical scientists' reasoning, and (IV) ideally relates the interaction of science, technology, and society (STS) in everyday life (Chiappetta, Sethna & Fillman 1991, p 943-944). This study revealed that most chemistry textbooks represent only the first aspect of literacy while very few percentage points were accredited to the final three aspects. With this it can be inferred that typical textbooks do not allow students to literate the content with respect to relevant issues and current societal events.

An ethnographic study of laboratory textbooks in South Africa reveals that chemistry and physics are taught with two streams of alternate literacy. According to their research, literacy is not a single entity which one either has or lacks, but it is the interpretation of data where one may use their own language to communicate knowledge. This model of literacy is used when teaching subjects such as chemistry and physics as examples of student texts were written in the mode of 'cookbook' and 'investigation' respectively (Parkinson & Adendorff, 1997). In the first students follow instructions, make accurate measurements, record and manipulate their results while the investigative manual requires students to predict results before they are performed and keep a record of why they chose to do what they did. Relevant to this interpretation is the reader's availability to laboratory instruction through familiarity and play an active role in the process. These students had the opportunity to work with scientific concepts in a manner which is more pleasing since they engaged in more common ways than chemical research. I feel that this is important to note since many students' views of lab time are more relative to professional development therefore may be the door to literacy by inducing career choices. The lab manuals themselves were more or less the road to that door.

The use of texts should allow students to learn scientific methods in engaging ways that stimulate their ability to transform knowledge from one thinking style to another. They must be able to communicate their practiced skill in both written and spoken form (Sola & Bennett, 1992). Textbooks are in essence a helpful way of delivering concrete information to students of physical science although no one book can encompass knowledge for all users. Similarly, students cannot become literate of scientific knowledge through the same means therefore a large variety of scientific texts should be readily available to any student attempting to convey abstract knowledge. Fortunately the advent of modern technology allows us to share different perspectives of natural phenomena and the laws and principles that govern them.

Science, Technology and Society (STS)

An unprecedented goal of scientific literacy is based on the aim of science education to prepare students to handle the increasingly reflexive, trans-disciplinary and large scaled amount of scientific knowledge (van Eijick, 2010). This is especially important in the case of new developments in science such as the biochemical research conducted and genomic development used to sustain life. Michael van Eijick's research encapsulates the ongoing idea of Paul Hurd's 1958 theory that the age of science and technology is upon us and we must prepare our students to be mindful of their direction. The question that arises is how can we design science education in a way that fosters scientific literacy among the next generation of citizens who are continuously confronted with new emerging disciplines? Many theories are being developed now which will aid in the advancement of education such as the action research that teachers conduct as a part of professional development though van Eijick's research raises the question "of whether and how definitions of scientific literacy [will] appropriate the dynamics of science," (van Eijick, 2430). Through personal research it seems fair to say that while many have developed the right path toward defining scientific literacy as the ability to confidently communicate knowledge of the subject matter in relevant ways, most researchers are discovering new ways to incorporate literacy in science.

In European and United States schools chemistry education has remained unpopular with students due to the fact that their lessons have been ineffective in promoting higher order cognitive skills which would include evaluating socio-scientific issues and communicating with content literacy (Marks & Eilks, 2009). According to this research students feel that chemistry courses are all too often content driven and lack personal relevance to their lives or cultural society. This in turn deters motivation to learn and eliminates any reason to engage in scientific interests. German culture has been highly regarded as the scientific homeland as it has brought the likes of Einstein, Heisenberg, and van Laue to the scientific community yet the country's chemistry teaching has been regarded as ineffective in promoting the thinking skills necessary to communicate socio-scientific issues.

> German chemistry teaching is not sufficiently oriented towards problem-solving and practical applications. Therefore chemistry teaching does not focus enough on the interplay of science, technology, and society with regard to local issues, public policy making and global problems (p. 232).

Marks promotes the position of "education through science" rather than "science through education" as the former invokes discovery through inquiry. The later concentrates on the education process which normally does not rely on contextual content. Marks and Eilks solution to the dilemma of poor educational choices in chemistry is to incorporate issues of society and the implications of science and technology as the groundwork of lessons so that the gap between school, science, its applications and critical evaluation may be narrowed. Relevant science concepts should be put into play with student learning in a manner which is oriented to their personal needs and interests.

Reform in the German culture from the 1980s to today have encompassed the idea that science education should promote a broad view of science that fosters an appreciation of its uses to better society and demands that "the learner makes connections within the science disciplines, between science and technology, and between science and technology and the larger social problems and aspirations" (2009, p. 233). STS is intrinsic to the teaching of scientific concepts as it incorporates authentic and socially relevant topics as essential in education. Marks' 2010 research suggest that methods utilized in there types of lessons include those that involves mimicking and role-playing political decision making and critical analysis. One particular scheme that the researchers give in this article uses oral and written communication of opinions as a means of showing critical thinking skills, content literacy, and social awareness. An example is giving in this latest study which assesses student knowledge through pseudo-journalistic lessons where they are asked to create news spots geared toward a specific audience. Through this lesson individuals present their opinion on topics based on both knowledge of the scientific content as well as their ability to research a topic and formulate critique based on their analysis. This case study showed that not only did students engage in active learning of scientific content, but it also induced the evolution of thought process by critically analyzing different points of view since many students responded to the same news tickers in various ways. Marks team of researcher on both studies help to validate that scientific literacy is developed through active engagement of reading, writing, and communicating knowledge.

Current Literacy Studies

Reflecting on the research process, it seems that most of the current studies are coming from outside of the United States. European studies conveyed that education is regarded as highly valuable and should incorporate real life examples. In addition to Marks' research in Germany (2009-2010), Parkinson's case study of textbooks was developed in South Africa and van Eijick's case of genomics came from the Netherlands (2010).

A Dutch article from the Chemical Education International journal stresses that chemical literacy is achieved when it can be used to solve real life problems through reading and writing (Beers & Witte, 2003). Citigroep (CITO) is the world's largest and most respected testing agency and was commissioned by the Dutch to develop national school examinations. These tests are specifically formulated to represent how scientific concepts could be used in careers and other real life situations while requiring individuals to answer by reading, analyzing, and writing in their own words. In fact, many programs across the globe follow this same strategy

The Programme for International Student Assessment (PISA), the brainchild of the world-wide Organization for Economic Co-operation and Development (France) defines chemical literacy as "the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (Beers & Witte, 2003, p. 2). In the Netherlands these chemistry exams are used to test two main skills: using and dealing with written information and using chemical knowledge to determine a position on scientific debate. Questions analyzed through this assessment are as follows: Do students understand the context of the given information? Can they put it to use? Are they able to recognize valid arguments to the pros and cons of scientific development? For example, this type of test gives a situation dealing with water storage while camping, working in the food service industry, analyzing a newspaper article on sewer disposal techniques. These questions involved mental mapping by the students as they had to negotiate information for successive analytical questions. In addition to multiple choice questions students also had to write complete thoughts through short essays.

An experimental study in Taiwan advocates the use of technology to support scientific literacy by having biology students use online publications to both critique and develop writing skills (Liang & Tsai, 2010). Part of the goal required that students play a large role in both the authoring and reviewing processes since the demand in scientific literature stems beyond a written essay on any given topic but also involves ideas of analytical research, experimental design, and quantitative statistics in order to convey valid data and interpretation. The demands for accomplishing such tasks are seeded in consistent review and feedback. The theory is that students will learn better scientific writing skills when they are engaged in the cyclical process of critiquing while constructing their own writing. To Liang and Tsai scientific literacy is developed through the writing process and mastered with successive research.

In conclusion this research revealed that the importance of scientific literacy is an important issue in many places around the world due to the cultural and social implications of where scientific discoveries are taking us. It is evident that many countries see the value in science education and having students become literate in the language and context of the subject since new concepts will eventually become part of important the social culture in the future. While it seems that the argument for encouraging scientific literacy began in the United States most new studies do not seem to come from outside of the country. Holistically, though, many countries seem to share similar opinions on how scientific literacy is both defined and achieved.

Review of Literature on Science Literacy

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