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Perspectives on Science Literacy: A comparative study of United States and Kenya

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Abstract

Results from a science literacy survey administered to the American and Kenyan educators are presented. Sixty-three educators from the U.S. and Kenya responded to a survey about their perspectives on science literacy. The research questions were designed to examine the factors that affect students' performance in science, the skills required for students to be successful in science, and the challenges of teaching science and recommendations for improving scientific literacy in both countries. Results indicate that educators from both countries have similar concerns about science teaching and learning but they also face some unique problems. The participants were all in agreement regarding proficiency in English language and literacy skills as key contributors to the acquisition of science literacy. The educators integrated these skills through reading, writing of science materials, research, and the discourse of science. The main challenges identified included students' attitude towards science and lack of interest. In addition, the Kenya educators also identified lack of proficiency in English language, lack of good science foundations, and lack of resources and materials as additional challenges. The results of this study imply that both science and literacy educators should work together to increase students' proficiency in science.

Keywords

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Perspectives on Science Literacy: A Comparative Study of United States and Kenya

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ABSTRACT

Results from a science literacy survey administered to the American and Kenyan educators are presented. Sixty-three educators from the U.S. and Kenya responded to a survey about their perspectives on science literacy. The research questions were designed to examine the factors that affect students' performance in science, the skills required for students to be successful in science, and the challenges of teaching science and recommendations for improving scientific literacy in both countries. Results indicate that educators from both countries have similar concerns about science teaching and learning but they also face some unique problems. The participants were all in agreement regarding proficiency in English language and literacy skills as key contributors to the acquisition of science literacy. The educators integrated these skills through reading, writing of science materials, research, and the discourse of science. The main challenges identified included students' attitude towards science and lack of interest. In addition, the Kenya educators also identified lack of proficiency in English language, lack of good science foundations, and lack of resources and materials as additional challenges. The results of this study imply that both science and literacy educators should work together to increase students' proficiency in science.

Keywords: Science literacy, Qualitative research, Teacher perceptions, International Collaborations, United States and Kenya

INTRODUCTION

Science literacy is an important issue that has received widespread global recognition in recent years. In science education, achieving science literacy for all students is an overarching goal of science educators, scientists, and policy makers. Collaborating this idea, Roberts (1983) and Maarschalk (1988), were of the opinion that science education must take on the challenge of developing science literacy amid students who are future citizens. Global calls for educational reform have emphasized the need for a science literate population (Bybee, 2008). Science literacy has been a contributing factor in many science education reforms (AAAS, 1989 & 1993); national science education standards (NRC, 1996); national educational policies (Boujaoude, 2002; Fensham, 1997; Holman, 1997; and Millar and Osborne, 1998). These reports document standards and benchmarks regarding content, pedagogy and assessment that are needed in order for all students to achieve science literacy. In 2007, the National Science Foundation (NSF) in conjunction with the Howard Hughes Medical Institute (HHMI), the National Institutes of Health (NIH), and the American Association for the Advancement of Science (AAAS) launched a national initiative called Vision and Change. This led to the release in 2011 of a final report, titled "Vision and Change in Undergraduate Biology Education: A Call to Action", which provides a blueprint that would help transform biology classrooms (NSF, 2011). This surging focus in science education reform efforts is indicative of a growing sense among science educators to seek for better teaching practices.

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Science educators play an important role in educating students to develop science literacy skills. They are required to provide effective ways for students to develop: 1) knowledge and investigative nature of science, 2) the oral and written vocabulary needed to comprehend and communicate science and, 3) the relationship between science, technology and society. A recent study focusing on a twenty-year survey of science literacy among college undergraduates in the U.S., determined that there was no detectable improvement in undergraduate science literacy between 1988-2008 (Impey *et al.* 2011). In this study, approximately 10,000 students taking astronomy as part of a general education requirement answered a set of questions that overlapped a science literacy instrument administered to the general public by the NSF. For several decades the NSF has conducted measurements of science literacy in the United States and similar agencies abroad. The latest U.S. NSF standard science literacy data report, indicates that Americans accurately answered a merely 5.8 out of 9 items on average in 2012, a ratio that has been approximately unvarying for some time (National Science Board, 2014). To this end, it is evident that science educators in the U.S. need to improve the quality of science education in order to meet current educational and societal challenges as well as those in the near future.

In many countries, science education remains in a deplorable state; this is particularly true in developing countries. Reports have shown that the level of science literacy among African students is low (Adolphus, Telima, and Arokoyu 2012, Ojimba 2013, Oyoo 2010). Ojimba (2013) documented the problems facing science and technological literacy in Africa and offered some recommendations. Ojimba's findings were corroborated by Oyoo (2010). In a study of high school science teachers in Kenya, Oyoo enumerated the challenges of teaching science, which included lack of qualified science teachers and lack of proficiency in the English language among others. In this regard, it is notable that in order to improve science literacy in Africa, there is need to address important challenges faced by teachers in their classrooms. Overall, research around science education in the U.S. and Kenya, as well as across the world, suggests the need to promote science literacy both in high school and introductory undergraduate science courses.

Scientific Literacy

Scientific literacy is a broad term that has been subject to numerous definitions by several researchers and associations worldwide (AAAS 1990, CMEC 1997, Norris and Phillips 2003, NRC 1996 and OECD 2000). Holbrook and Rannikmae (2009) have recently documented the wide range of meanings of the term science literacy. According to Dani (2009), science literacy consists of the knowledge and understanding of science concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. Science provides a setting in which students are intellectually obligated to make sense of data, draw inferences, construct arguments based on evidence, infer word meanings, and construct meaning for text—the same dispositions required as good readers and writers. Norris and Phillips (2003) added the language and literacy dimension to the definition of science literacy, arguing: "literacy in its fundamental sense is central to science literacy." Developing science literacy depends on knowledge of both literacy and science disciplines. They argue that the reasoning required to read, comprehend, interpret, analyze, and criticize can be applied to the study of science, as well. Within the science disciplines, communication occurs primarily through the use of technical and academic language. This language can be a barrier to an individual ability to comprehend, evaluate, and communicate scientific information. In many developing countries, the challenges associated with teaching and learning in the sciences is exacerbated by the fact that both teachers and students use English as a second language. In these settings, mastery of the language of instruction, i.e. the English language, is critical to understanding science—students must use

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English for discussion, planning, reading, and writing, as well as deliberations and argumentation (Webb 2010). The implication of this, which is supported by findings from the present study, is that the effective discourse on science literacy development especially in Africa should involve both science and literacy experts.

The goal of this baseline study is to investigate the congruence of educators' perceptions of science literacy and factors that affect student science performance in the United States and Kenya. Science educators from these countries were asked to participate in an online-survey to assess their perceptions of science education and science literacy skills among high school and first-year college students. The survey examined the educator's understanding and perspectives on science literacy, teaching strategies and challenges of teaching science.

METHODOLOGY

The authors of this paper represent those from science and the literacy fields, respectively. They are genuinely interested in studying ways to facilitate science literacy in higher education as well as in the K-12 settings.

This study data collection was conducted through Qualtrics® online survey platform during the summer of 2013 and responses were collected anonymously. All participants were science teachers at the college or high school level. The survey was sent to a list of science educators from the United States and Kenya. Survey questions consisted of multiple choice, rank order, and open-ended questions. The participants were recruited voluntarily via email. The snowballing sampling technique was utilized to recruit potential participants (Glesne, 1999). The authors sent requests for participation via emails to high school and university faculty listserv and participants helped to contact their colleagues.

The survey questions were designed to elicit responses about: 1) the academic skills that the teachers would like their students to possess in order to be successful in science, 2) the factors that affect students' performance in science, 3) the importance of literacy skills for science literacy proficiency, 4) how educators integrate literacy skills in their science classes and 5) the challenges faced in teaching science literacy, among others. In addition, all participants were asked to pick the most appropriate definition of science literacy from four definitions that were provided and asked to explain the reason they selected that particular definition. A total of 63 completed responses were received, 32 of these were from the U.S. and 31 from Kenya. U.S. participants were from the following institutions: public university (28.0%), private college (41.0%) and public high school (31.0%), whereas the Kenya participants were from public college or university (39.0%), private college (3.0%), high schools (national, 6.0%; provincial, 13.0%; and district, 35.0%), and other (technical institute and county school, 6.0%). The grade level that the participants in the U.S. teach ranged from 7th grade to freshman year at college or university (6 participants have taught at some point in their career at the middle school level, 26 at high school, and 23 at college or university).

Table 1. Participants teaching experience in years

Teaching Experience	*U.S. (n=32)*	*Kenya (n=31)*
1-5 years	7 (21.9 %)	8 (25.8 %)
6-10 years	11 (34.4 %)	8 (25.8 %)
11-15 years	4 (12.5 %)	3 (9.7 %)
16-20 years	3 (9.4 %)	2 (6.5 %)
20 or more years	7 (21.9 %)	10 (32.3 %)

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As shown in Table 1, the participants teaching experience varies in all groups, however, on average, the majority of the participants teaching experience were between 1-10 years in the U.S. (56.3%) and Kenya (51.6%).

The research questions for this study included: 1) What were the American and Kenyan science educators' perception of the factors that affect students' performance in science?; 2) What skills do students need to be successful in science?; 3) What challenges do science educators from both countries face?; and 4) What suggestions do the educators offer for improving science literacy in both countries?

DATA ANALYSIS

In order to assure that the participants answered the survey questions, a force-response option was activated in Qualtrics®. Descriptive statistics were used to analyze the survey questions and to describe the basic features of the data in the study (e.g., the percentage of participants who responded to each item was tabulated). The open-ended questions were analyzed inductively (Creswell 2014, Miles & Huberman 1994, Patton 2002) through reading and re-reading thoroughly to ascertain the meaning behind the participants' responses. This was followed by performing an initial coding in which a list of emerging themes (i.e., coding scheme) was created. The pattern coding technique was used to group emerging themes into categories (Miles & Huberman, 1994, p. 69) and facilitates the open-ended survey questions analysis. This procedure allowed us to reduce the data into a manageable number of codes and helped in the development of trends and assertions during the data analysis. The initial list created by the original researcher was shared with the other colleagues, and modifications were made as needed. Emerging patterns, disagreements, and doubts were clarified in a researchers meeting and tested for validity and reliability through peer debriefing judgment discussions (Lincoln & Guba, 1985). The open-ended questions were used to triangulate the findings from the quantitative data.

Threats to validity were identified in this study. For example, the sample size is considered small. Despite the fact that the samples were selected from different email lists, they do not in any way represent the overall population of educators in the U.S. and Kenya. The threat of internal validity due to this small sample size was minimized as much as possible because of the voluntary nature of the participants. As far as external validity threats, for example, generalizing the results of this study to other settings might be difficult because of the sample size. However, we believe that the findings from the study provides some perspectives that educators can use as a stepping stone to initiate a much needed discourse on science literacy and science education in general.

RESULTS

Overall, the results show that there were a lot of similarities between American and Kenyan educators as far as issues around science teaching and learning are concerned. But, there were also differences. While both group of educators identified negative attitude toward science and lack of interest in science as the major challenges, the Kenyan educators also identified lack of resources for teaching science, lack of qualified teachers, and students' language background as additional challenges that they faced.

Definitions of Science Literacy

Several definitions about science literacy were presented to the educators to select the best one that describe science literacy (AAAS 1990, CMEC 1997, Norris & Phillips 2003, NRC 1996, and OECD 2000) as shown below:

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1. "Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity (NRC, 1996)." (U.S. 16% & Kenya 6%)
2. "Scientific literacy is based on the same knowledge base that underlies science which involves the reasoning required to comprehend, interpret, analyze, and criticize any text which is the same reasoning at the heart of all science. Literacy in its fundamental sense is central to scientific literacy (Norris & Phillips, 2003)." (U.S. 15% & Kenya 32%)
3. "Scientific literacy is 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 (OECD/PISA, 2000)." (U.S. 35% & Kenya 55%)
4. "The scientifically literate person is one who is aware that science, mathematics, and technology are interdependent human 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, 1990)."
5. "Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision making abilities, to become lifelong learners, and to maintain a sense of wonder about the world around them (CMEC, 1997)." (U.S. 42% & Kenya 23%)

Figure 1 shows the percentage distribution of educators that agree with the different scientific literacy definitions. It seems that 42% of American educators agreed more with the fifth definition (#5) in which science literacy was defined as the ability to "develop inquiry, problem-solving, and decision making abilities… to maintain a sense of wonder about the world around them" (CMEC 1997) whereas 55% of Kenyan educators agreed with the third definition (# 3), which defines science literacy as the ability "to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world" (OECD 2000).

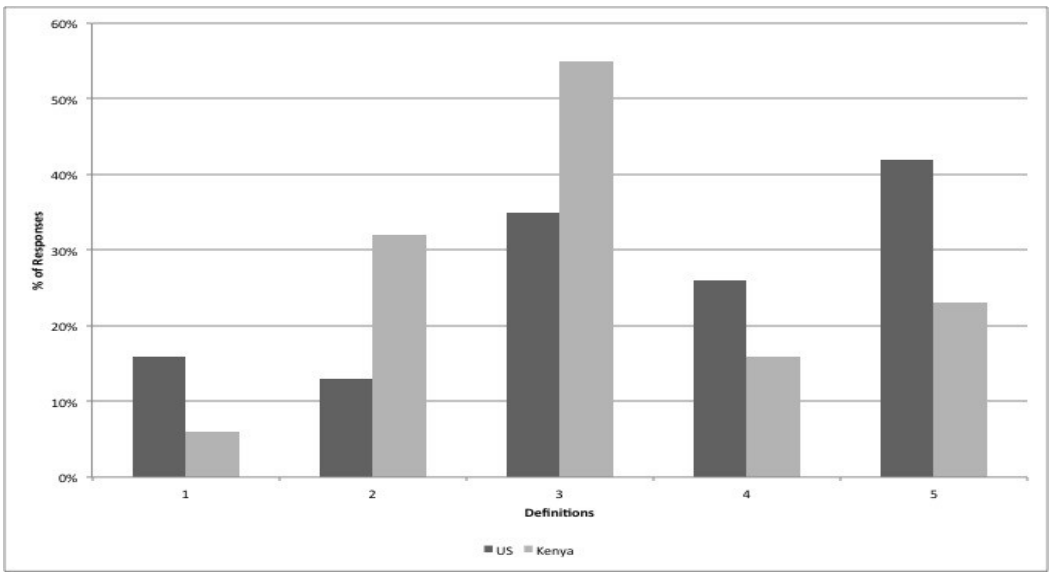

Figure 1. Figure 1. Percentage of educators that agreed with the different Scientific Literacy definitions (Legend: 1=NRC 1996, 2=Norris & Phillips 2003, 3=OECD 2000, 4=AAAS 1990, and 5=CMEC 1997.

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Importance of Literacy Skills in Science Literacy Development

One hundred percent of the American and 97.0% of Kenyan educators were of the opinion that literacy skills such as: ability to read, write, speak, and comprehend are very important or important for students to be proficient in science. The following excerpts support the claims from both groups about the importance of literacy in science literacy development. One Kenyan participant wrote:

> I teach Chemistry and a student has to be able to read to understand the instructions. Has to know how to write to give the report. Has to speak out to the other, more so when the experiments/research involves groups. Has to comprehend to acquire the subject matter. Has to relate to make the experiment/research continuous and problem solving in day-to-day life.

An American participant reiterated this perspective:

> It is very important for students to be able to read, write, speak, and comprehend what they have read, written, or spoken. This is true for both their time as an undergraduate student in both their major work and general education work as well as when they graduate and continue on into graduate school, professional school, or the work force... Literacy skills are incorporated into each of those assets and each of those assets are enhanced by improved literacy skills.

These two excerpts above do support the thinking that a strong background in literacy is critical for proficiency in science. If students cannot read, write, think and engage in the discourse of science, they can hardly develop scientific literacy skills. There were also other issues:

> Many students who are interested in science cannot read at grade level or are ESOL (English as a second language) students so they struggle at understanding the material given to them. I use visuals quite often and several hands on activities. This allows students to gain understanding... (U.S. participant).

While all the above excerpts generally support the need for a good language background in the development of science literacy, this last comment brings up an important challenge to proficiency in science literacy, which is the issue of second language learners. Recall that the Kenyan educators had identified the lack of proficiency in English language as a problem in developing proficiency in science literacy. It is interesting that in the survey, it was actually an American educator who mentioned ESOL students. This shows that educators from both continents recognize this issue as a challenge. Evidence from the study suggests that science teachers from both America and Kenya are making efforts to integrate literacy in their science courses. About 65% of American and 80% of Kenyan educators mentioned that they integrated scientific literacy skills in their teaching. For example, American and Kenyan educators integrated scientific literacy in their teaching by: readings (books and articles), writing (lab reports and essays), evaluating data and results on papers, and oral presentations. Finally, both group of educators overwhelmingly believed that their main role in increasing student literacy skills is as a facilitator and/or mentor. There has been a long-standing debate about the role of science teachers in literacy teaching. Experts believe that the enormous task of teaching reading and writing should not be left to English language arts (ELA) teachers alone. Teachers need to scaffold students' reading, writing and comprehension skills across all subjects. Yet, science and other content teachers claimed that it was not their job to teach literacy, but the push has been for all content area teachers to integrate literacy in their courses. Such a collaborative approach to scaffolding students' literacy development would no doubt facilitate students' growth in both the content areas and in English language arts

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(ELA). Therefore, findings from this study show that content area teachers recognize the need to help facilitate literacy learning in their subject areas, which is a welcome development. The teachers were also asked to identify the factors that affect students' performance in science.

Factors that Affect Students Performance in Science

Participants were asked to identify the factors that affect students' performance in science. As shown in Table 2, the three main factors that affect students' performance in science according to educators from both countries were: "Students attitudes and beliefs about science (U.S. 72.0% & Kenya 94.0%)," "lack of interest (U.S. 72.0% & Kenya 71.0%)," and "lack of a good foundation in science (U.S. 53.0% & Kenya 81.0%)." It is important to highlight that 42.0% of the Kenyan educators also selected lack of proficiency in English language as a key factor that affects students' performance in science, unlike their American counterparts (25.0%). When asked to explain any other challenges, the American participants stated; lack of good math skills (18.7%), lack of independent work (12.5%), and complexity and unfamiliarity of the subject to a lesser extent. On the other hand, Kenyan participants identified inadequate teaching facilities and resources (37.0%), poor teaching methodologies, untrained or unqualified teachers and/or lab technicians, large class sizes, and lack of science journals at much lower percentages.

Table 2. Factors that affect students' performance in science according to American and African educators

Factors that Affect Students' Performance in Science[*]	*U.S. (n=32)*	*Kenya (n=31)*
Students attitudes and beliefs about science	23 (71.8 %)	29 (93.5 %)
Lack of interest	23 (71.8 %)	22 (71.0 %)
Lack of a good foundation in science	17 (53.1 %)	25 (80.6 %)
Societal and cultural factors	15 (4.7 %)	14 (45.2 %)
Lack of general literacy skills in English	11 (34.4 %)	11 (35.5 %)
Lack of proficiency in English language	8 (25.0 %)	16 (51.6 %)

*Note: participants could select more than one factor on this question.

Related to the above question was one that asked the participants to indicate the skills they would like to see their students acquire at the end of their science courses. The participants indicated; problem solving, critical thinking, analytical, team, and process skills. The survey results also showed that the participants believed that language and literacy skills are very important for students to be proficient in science. American participants indicated that they integrate literacy skills into their teaching by using the services of librarians, having students read published articles from sources such as Science Daily and Popular Science, and engaging students in research-based writing exercises, assignments and discussing them in a group format. Kenyan participants indicated that they integrate literacy skills by assigning laboratory reports, writing assignments, reading scientific journals, presentations, engaging students in peer review, guiding students in reading and writing, asking students to state scientific laws, using examples in class, and question and answer.

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Science Teaching Challenges

The results from this study show that the challenges of science teaching and learning are many and varied. American participants identified lack of good math skills, lack of independent work by students, and the complexity and unfamiliarity of the subject to a lesser extent. One participant identified "lack of appropriate background in science and math skills," while another indicated "student skill level in scientific and mathematical reasoning."

In contrast, Kenyan participants identified inadequate teaching facilities and resources, poor teaching methods, untrained or unqualified teachers and/or lab technicians, large class sizes, and lack of science journals as the major challenges. Overall, challenges exist and the onus is to find ways to navigate these challenges so that they do not adversely affect the learning of science.

CONCLUSION AND IMPLICATIONS

Science literacy skills have become an imperative for students in a global economy. From the advanced countries of the West to the developing countries in Africa, it appears that teachers at the high school and college levels have identical concerns as far as science teaching and learning is concerned. All participants in this study agreed that science education should enable students acquire problem-solving and critical thinking skills. They also acknowledged the need for proficiency in English language and literacy skills as critical to acquiring science literacy. Students need a strong background in reading, writing, comprehension, thinking and reasoning skills to do well in science. Both American and Kenyan educators integrated literacy skills into their science courses through reading and writing of science materials, research, and through the discourse of science. In both U.S. and Kenya, the most prevalent problems that were identified by educators were: attitude to science, and lack of interest by students. However, Kenyan educators also identified lack of proficiency in English language, lack of good science foundation, lack of resources and materials, as major problems. This may be understandable because of the status of English as a second language.

This study implies that issues in science literacy development are a worldwide phenomenon. It's well recognized that different countries face slightly different challenges due to differences in demographics, availability of resource and trained science teachers and the level of science education and learning. This study highlights the need to catalyze international collaborations around science education and learning. Such collaborations should involve interdisciplinary groups of science and literacy educators. With this purpose in mind and using the results of this study, the authors were actively seeking funds to make such collaboration a reality and early brainstorming and planning stages were taking place. In addition, developing countries should invest more in science education, provide resources for the teaching of science and invest in the training of qualified science teachers. The issue of lack of interest in science and general negative attitude toward science affects students from both countries. We believe that building students' interest in science must start as early as possible. It will be important to pay attention to science literacy at the elementary school level, where students acquire the foundational skills needed to navigate the learning of science. Efforts should be made to entice students at this level to inculcate a love of science by introducing them to science concepts through read aloud of science texts, hands-on activities, group collaboration that supports the discourse of science, field trips and student-friendly pedagogies.

There is a need to harness synergies that will promote science literacy development worldwide. A strong language and science background will no doubt help to reduce the problems associated with science teaching and learning in later grades.

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