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Communicating STEM Learning and Ethical Reasoning: An Evaluation of Curriculum Content in K-12 Programs

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ABSTRACT: The national initiative to prepare more STEM trained faculty and to engage more students in STEM disciplines should not only focus on technical subjects but also the communication and ethical reasoning skills of K-12 students. This paper advocates for greater presence of these skills in curriculum content and instruction.

KEYWORDS: STEM, ethics, communication skills, teacher preparation, K-12, science, technology, engineering, mathematics

1. INTRODUCTION

The familiar warning that the United States has lost its competitiveness with other countries in math and science education (National Math + Science Initiative, 2013), has given rise to a multitude of programs to train more and better teachers in STEM (Science, Technology, Engineering, and Mathematics) disciplines and to develop curriculum designed to engage K-12 students in STEM courses. In addition to the desire to develop scientific knowledge and a STEM-trained workforce is the necessity that these content areas be shared, advocated, and communicated with others. These disciplines must be able to communicate their contributions to knowledge, their influence on the community and culture as a whole, and for their ethical implications as they influence the direction of our policies and understandings of technical issues (Chandler, 2012).

We are currently working on a multi-stage project that will incorporate a variety of research methods to identify the communication training and ethical education extended to K-12 students in STEM-based curriculum programs. In this first stage, we will establish the case for the inclusion of communication and ethical reasoning skills in STEM program curriculum. An evaluation of existing learning goals in STEM curricular areas will serve to establish some of the essential learning outcomes expected of STEM programs and they will be compared to the communication/ethical skills expected in STEM disciplines. In stage two, focus groups will be used to identify (a) teacher preparation practices, (b) criteria for curriculum adoption, and (c) perceived value of curriculum currently used to encourage communication and ethical reasoning. Stage two will assess the focus group results to determine their inclusion of communication
practices and ethical reasoning content. Of particular interest is whether students learn communication concepts to support their demonstration of learning, whether students are acquainted with the ethical practices inherent in STEM and in science communication, and whether they are equipped to discuss and present perspectives on the ethical implications of STEM topics and issues. Finally, in stage three, the authors will recommend appropriate communication and ethical reasoning content for use and connection to K-12 STEM curricular education. These may include teacher training materials and standards, curriculum content and modules for K-12 students, and/or assessment tools and techniques aimed at both educators and students to assist in benchmarking and developing effective and ethical communication practices and the use of ethical reasoning and advocacy practices in STEM fields and on STEM topics.

2. COMMUNICATING ABOUT SCIENCE

The role of communication skills in the practice of STEM disciplines is critical. Safina (2012) explains that if “we choose not to communicate what we do, who we are, and the power of scientific thinking, then our work, and the value of scientific thinking, will be too easily ignored.” The need for more effective science communication has been documented in a variety of contexts and forms, and there are powerful examples that demonstrate the social, political, and financial impacts for failing to account for an adequate understanding of the role of science in our society. High profile topics like evolution, climate change, genetically modified organisms, and vaccinations against childhood illnesses, have all established the implications for failed communication from within the scientific community to the public at large.

The need to foster communication skills at the early stages of STEM education can be justified by the unsuccessful practices of the scientific community these students aspire to join. Meredith (2010) describes this as a “lack of a culture of explanation.” As scientists and their disciplines have not made the effort to maximize their communication potential, they have not considered the linguistic implications of their explanations, they are not strategic in their argumentation strategies with lay audiences, they misrepresent the presentation of facts as arguments, and they are rarely rewarded for or trained to engage the general public about their scientific efforts (Meredith, 2010; Leshner, 2007).

The disconnect between the public and scientists means that successful communication of values and policy proposals cannot be effectively managed. Or even worse, the voices heard by the public are not those of the experts but by the more rhetorically skilled opposition who can effectively influence public knowledge about the choices to be made during scientific controversy (Benham & Shimp, 2007; Leshner, 2007). By failing to excel as communicators about science, scientists are failing to become the leaders they need to be to participate in decisions about public policies based on scientific research (Baron, 2010).

The shortfall in the communication skills of the scientific community is not only damaging to the community in the present, but also threatens its effectiveness for the future. The stream of data indicating shortages in STEM discipline trained students and future faculty point to the need to develop many of the same basic skills that contemporary scientists lack. Ramsey and Baethe (2013) argue that the lack of basic writing, critical thinking, math, and ethical commitment to learning skills in students mean they will not persist and join into ranks of STEM professionals and teachers. Brown (2013) reports that only as many as 40% of college students who intended to major in a STEM discipline actually completed their program of study. One of the most common explanations for this record is the lack of academic preparation for these
academic areas and higher learning generally. Efforts to grow STEM subject students are not likely to succeed without further skills development that should include communication practices and ethical reasoning.

Promoting effective communication practices among STEM students may contribute to improving their odds of remaining in STEM disciplines. Adopting a range of activities or teaching methods helps to insure that the students being actively recruited to experience STEM subjects remain. Watermeyer (2013) explores the basic elements of the science show or science fair as a means to engage students in scientific subjects as well as to “foster the interest and imagination of young learners,” to help “challenge popular pre/misconceptions of science and scientists,” and to help connect “expert and non-expert or learner groups.”

Other research has concluded that active, hands-on efforts to enhance student learning by building communication skills with presentations, discussion, and writing assignments will advance the science education of these students (Tank & Coffino, 2014). When students are actively engaged in STEM discipline activities and their academic preparation expanded to include more than the science and technological components; such as communication, ethics, and reasoning skills; a number of potential benefits may arise.

Current learning goals at state, and national levels have identified an expectation for communication skills not only as a general learning outcome but often one tied to scientific subjects and STEM related coursework. Two examples help support this conclusion. With these skills emphasized in the curriculum, not only will students be better prepared but students might also be better assessed on their level of learning about STEM content.

The State of Iowa includes communication skills in a number of areas including their Iowa Core requirement as Universal Constructs for performance and in the area of Iowa Core Curriculum K-12 Science. At the general level, the State expects development of complex communication skills. These are defined as “based on the successful sharing of information through multiple means, including visual, digital, verbal, and nonverbal interactions. The message is purposeful, clear and concise leading to an accurate exchange of information and ideas” (Iowa Core Universal, 2009).

The State of Iowa also includes communication skills that are more specifically tied to communicating scientific information. The communication section begins with these requirements:

Students in school science programs develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments. (Iowa Core Science, 2009)

There are similar core communication requirements identified in the Literacy (Language Arts) and Math Core requirements for Iowa as well. These particular state level requirements show that communication skills are part of the learning outcomes expected by education leadership. They should be assessed and the degree to which they are currently being taught and tested is unknown. One purpose for the next phase of this study is to actually evaluate curriculum content and teaching practices in STEM areas with regards to communication and ethics instruction. Communication skills should be taught and reinforced not only in the general curriculum, but also hand-in-hand with specific technical subject areas.

This interest and focus in communication skills has also been reflected in other STEM education efforts. The Next Generation Science Standards are a new development of standards
for K-12 education to adopt. Twenty-six states have collaborated on a set of new standards that include areas such as communication and embed them into the learning and assessment process throughout all science-related subjects. These are still in the process of discussion and adoption by states but show potential to help carry these learning goals across state lines and to reinforce them on a national scale (Achieve, 2014).

The benefits for intentional communication skills development in STEM disciplines can be summarized by their contribution to student learning at the earliest level, further skill preparation for higher education, persistence in the study of STEM disciplines, and the development of the skills necessary to be a more successful communicator of science in professional life.

If an effort to enhance communication competence in STEM students is accomplished there may be one additional benefit, better recruitment and retention students to begin with. Students can help teach and inspire other students with their experiences in their academic programs and serve as leaders and role models to others. By expressing and articulating their learning students may not only enhance their own retention but also assist in the recruiting of others. Current promotion of STEM education and the STEM crisis, to date, has been mostly a top down approach. Business, government, the public, schools, and parents all know that there is a need for more STEM-trained students, but do the students know this themselves? They might serve as powerful advocates for the STEM disciplines. The popular public relations campaign for STEM education has built the case for STEM training, it has not been designed to consider what are the most effective ways to engage and retain student interests in STEM disciplines (Promoting STEM, 2008).

Communication skills are one of a number of additional areas of study that should be included in the building and promotion of STEM disciplines. As contemporary experiences in the sciences have demonstrated, the work of science has many influences on our personal, social, and political lives. The challenges of addressing them also make the case for students to learn to understand the ethical issues, criterion, and impacts of their interest in furthering and applying scientific innovations.

3. STEM EDUCATION & COMMUNICATION ETHICS

Supreme Court Justice Potter Stewart once defined ethics as “knowing the difference between what you have a right to do and what is the right thing to do” (Augustine, 2002, p. 6). While STEM has more recently gained the attention of academics, the scientific community, and the American public, the need for ethics education in grades K-12 has been discussed much longer. Reports such as The Ethics of American Youth, conducted biennially by the Josephson Institute have consistently documented unacceptable levels of cheating, lying and stealing by high school students since data gathering began in 1992. Over time, the need to develop stronger ethics in students has been related to effective citizenship, employer needs/desires, educational outcomes related to critical thinking and higher levels of learning, and to the development of more effective communication skills (Ralston, 2008).

In response, over the years, many K-12 schools nationwide implemented a variety of different types of educational programming and training designed to develop students’ character and to reinforce ethical behavior. Two of the most popular are “Character Counts” (Josephson Institute, 2014) and “The Leader in Me” (Covey, 2014). Some of these popular programs educated students on the virtues associated with good character. Character Counts (2014) is
COMMUNICATING STEM LEARNING & ETHICAL REASONING

based on virtue ethics and focuses on teaching students about “The Six Pillars of Character:” trustworthiness, respect, responsibility, fairness, caring and citizenship. “The Leader in Me” (Covey, 2014) is a model of leadership and character education based on Steven Covey’s popular 7 Habits of Highly Effective People series and its content is integrated across the curriculum in participating schools. These two programs and others (8 Keys of Excellence, etc.) also involve the creation and maintenance of a school culture that values ethical behavior. In order to create and/or maintain such a culture schools have instituted different initiatives and policies designed to reinforce students’ positive ethical behaviors. These efforts include including zero tolerance policies, school codes of ethics, student codes of conduct, and honor codes.

Character education as described above are broad based and are typically linked to school curriculum and the Iowa CORE in multiple areas and across grade levels. While we acknowledge that all of these efforts play a role in the overall ethics education of K-12 students, we are interested in more closely examining ethics education related to STEM, communication ethics, and science communication ethics.

3.1 STEM Education & Ethics Education

Much has been written about the relationship between science and ethics (Resnick, 1998; Keefer, 2012; Gilbert et. al, 2013; Donney, 2013; ALLEA, 2013; Barry, 2012; Goodwin & Priest, 2013). An examination of this literature reveals that ethics in science refers to a number of different issues that can be categorized into the broader areas of research ethics, professional ethics, and personal ethics. For example, Augustine (2002), writing about engineering ethics (though it applies to all of STEM), described a range of ethical concerns stating “[m]acroethics involves ethical issues that affect large segments of society, whereas microethics involves issues that affect a smaller, more immediate group, such as one’s boss or one’s client” (p.5).

More recently, ALLEA (2013) published a statement on the need for ethics education in science. In it they state that: “[e]thics education in science should cover both internal and external research ethics, both canons of good research practice and ethical aspects of the relations between science and society” (p.3). They go on to describe the challenges faced by STEM fields including the fact that research is “increasingly collaborative, competitive and global, using – and developing – new technologies and progressing rapidly” (p. 4) and the need for individuals to be aware of the responsibilities of scientists personally, professionally and in society. While ethics education in science covers a wide number of topics, responsibilities, and audiences it is apparent STEM professionals understand principles of ethical communication and ethical science communication and that they need to develop the skills necessary to engage in ethical communication practices.

3.2 STEM Education, Communication Ethics & Communication Skills

As noted earlier, the goals of STEM education include increasing the number of students who enter STEM professionals in order to ultimately be more competitive globally as well as to increase STEM literacy for all students. It appears that K-12 programs need to be accomplishing multiple goals in their integration of ethics into K-12 STEM curriculum. For those students interested in STEM providing strong understanding and foundations of research ethics will be critical to academic and professional success. The curriculum should be developed and delivered
in such a way that research ethics, communication ethics, and ethical science communication practices are integrated into both STEM standards and the IOWA CORE competencies.

The types of ethical training needed in the STEM professions include research ethics which have important ethical communication components related to issues such as plagiarism, research design, relationships with colleagues, conveying ideas to the public and advocating for the sciences in an ethical fashion in addition to the larger ethical questions inherent in the work they engage in and the impact of that work on society. STEM professionals will also need to be able to identify the dilemmas that arise from conflicts between their personal and professional ethical values and make choices to behave ethically when they resolve the conflicts.

Ethics education in science focuses on the critical examination of arguments and the assumptions they are based on, as well as on the rational justification of ethical decisions taken. To be able to argue rationally and to examine arguments critically – including in situations where there are conflicts of interest and in newly emerging fields of science – researchers must have developed a competence in ethics and be able to use it to deal with the issues they face. (ALLEA, 2013)

Thus, communication skills should be at the center of STEM ethics education. However, we do not know if this integration occurs in current K-12 STEM education efforts.

In addition, the STEM goals related to increasing STEM literacy for all students also need to be met. Again communication skills are at the heart of these efforts. All students should be trained to be critical listeners and critical thinkers and they should be trained to ask questions and articulate their concerns about scientific communication directed at them from the media, the science community, and other sources. The integration of Iowa CORE competencies related to media literacy should educate all students to discern “how communications technologies and other forms of media are used—the interests they serve, the messages they convey, the consequences of these messages, and their underlying values . . . .” (Makau, 2012, p. 11).

4. CONCLUSION: ANALYZING EXISTING STEM EDUCATION, ETHICS & COMMUNICATION ETHICS

Most of the engineers whom I have seen get into trouble on ethical matters did so not because they were not decent people but because they failed to recognize that they were confronting an ethical issue. As a result, they made horrendously bad decisions—decisions they had to live with for the rest of their lives. (Augustine, 2002, p. 5)

The preceding quotation can be applied to students in all walks of life, but it serves to focus our attention on what learning outcomes should be taking place in STEM education that are infused with training in communication and communication ethics. Rau and Clayson (2012) report that consensus exists on the need to immerse students in STEM education efforts early in order to engage the students successfully and ultimately increase the likelihood that they will pursue STEM education later in life. Further, Ralston (2008) makes a strong case for teaching ethics in the high school in order to successfully educate students in reasoning about moral dilemmas, to increase their communication skills, and to facilitate their participation in the democratic process as citizens later in life. Moreover, programs generally directed at character education and ethics have demonstrated success in K-12 education in the past.

We have made the case that the integration of ethics and communication skills into K-12 STEM education is both viable and necessary in order to successfully meet the learning goals and outcomes associated within the state of Iowa. Makau (2012) noted:
in sum . . . ethical communication across contexts requires attentiveness to at least the following: one’s intention, the means used to fulfill these ends, and the likely consequences of one’s choices. Even within these parameters, however, differentiating more or less ethical communication pathways is often difficult. (p. 3)

The next step in our research agenda will be directed at ascertaining the current curriculum content, pedagogical efforts, and support for integrating communication skills training and ethics in K-12 schools in Iowa.

REFERENCES


