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# Another "M" for STEM? Moral Considerations for Advancing STEM Literacy

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## ABSTRACT

Although workforce readiness is often cited as the primary rationale for STEM education, a broader view of scientific literacy, one that envisions students as members of an informed citizenry able to reason thoughtfully and ethically through increasingly complex STEM issues, seems warranted. To that end, this position paper advances the argument that STEM, particularly with the incorporation of engineering in the *Next Generation Science Standards* (U.S.), must serve as a context for moral development by expanding student argumentation and discourse to include the moral and ethical consequences of STEM decision making. In addition, STEM is positioned as an ideal domain for inclusivity, capable of advancing a more just and equitable society through broader engagement and participation. To illustrate how these visions might be realized in the classroom, the author transforms a typical STEM lesson into a "moral" STEM lesson through the incorporation of two curricular frameworks, Socioscientific Issues (SSI) and Universal Design for Learning (UDL). The purpose of this exercise is to demonstrate the manner in which STEM content and practices can be preserved and enhanced while widening curricular objectives to include the development of an informed, reflective, and inclusive STEM-literate citizenry.

Keywords: STEM, scientific literacy, moral development, Socioscientific Issues (SSI), Universal Design for Learning (UDL)

> *As our own species is in the process of proving, one cannot have superior science and inferior morals. The combination is unstable and self-destroying.*
>
> — Arthur C. Clarke

Much has been written about the need for a STEM-ready workforce poised to address questions and challenges related to the natural and designed world. Responses to this call are reflected in key U.S. educational documents and policies, including the *Next Generation Science Standards* (*NGSS*; NGSS Lead States, 2013) and President Obama's "Educate to Innovate" initiative (The White House Office of the Press Secretary, 2009) aimed at increasing STEM participation and performance. Arguably, even if one is not persuaded by workforce readiness as a central goal of science education, the swell of interest in STEM both in K-12 and higher education nonetheless presents myriad opportunities for promoting students' scientific literacy, defined here as the informed citizen's ability to apply understanding of scientific concepts and processes to real-world decision making (Roberts & Bybee, 2014).

There is, perhaps, another opportunity that warrants our attention particularly given the incorporation of engineering standards within the *NGSS*. If engineering is concerned with "designing objects, processes, and systems to meet human needs and wants" (National Research Council [NRC], 2012, p.202) it seems logical that questions such as, "Which needs and wants *should* be addressed?" and "What are the tradeoffs of meeting those needs?" are more likely than ever to arise in our science classrooms. Whether locating power plants, investigating GMO's, or evaluating the uses of drones, STEM inquiries often reflect the kinds of controversial socioscientific issues (Zeidler, 2014a) that confront citizens on a daily basis, each potentially triggering ethical dilemmas related to privacy, government regulation, equity, allocation of resources, and the like. And while we could easily dismiss these aspects as not within the purview of science, Clarke's cautionary words above remind us of the perils of scientific and technological undertakings in the absence of adequate consideration of the moral consequences of our actions (or inactions). Thus, the time seems right, given STEM's momentum, to examine the role of morality in STEM education; specifically, this article will address the manner in which teachers might facilitate students' moral development through STEM, as well as the prior (and more fundamental) question of whether STEM teachers *should* concern themselves with such endeavors.

## A Moral Mire

The *Framework for K-12 STEM Education* (NRC, 2012), upon which the *NGSS* were based, supports classroom discourse about moral and ethical considerations in the following statement:

> Considerations of the historical, social, cultural, and ethical aspects of science and its applications, as well as of engineering and the technologies it develops, need a place in the natural science curriculum and classroom…For example, because decisions about the use of a particular technology raise issues of costs, risks, and benefits, the associated societal and environmental impacts require a broader discussion…It is also important that curricula provide opportunities for discussions that help students recognize that some science- or engineering-related questions, such as ethical decisions or legal codes for what should or should not be done in a given situation, have moral and cultural underpinnings that vary across cultures. (NRC, 2012, p. 248)

These ideas were reflected within the *NGSS* in several places, including the Engineering Design performance expectations as follows:

> HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. (p. 102)

Additional supporting language can be found in the *NGSS* Science and Engineering Practices section entitled, "Engaging in Argument from Evidence" which states:

> Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). (p. 101)

It is clear that moral and ethical considerations must be integrated into STEM deliberations, yet the process by which this is to occur seems a bit murky. While the *NGSS* make multiple references to "analysis of costs and benefits" (p. 97) for STEM decision making, such reasoning seems better suited for "tidy" economic considerations than for "messy" humanistic concerns; after all, what exactly is the cost or benefit of a human life, a species of wildlife, or one degree of temperature due to global climate change? How should we weigh one group's desire for technological advancements against another group's interest in maintaining traditional culture? While it is one thing to suggest that students need to develop an analytical heuristic for decision making, it is quite another to expect them to reconcile such irreconcilable currencies, at least not without a teacher who can thoughtfully and sensitively guide them through complex problems that have no clear answer. How *do* STEM teachers address problems whose resolutions can't be determined on a ledger?

Now some might say, "That's not our business," contending that ethical decision making is dangerous territory for STEM educators, a shaky stratum better reserved for philosophers and ethicists. Yet we need not look any further than our classrooms to see that we are actually standing on solid ground. Societies are not value free, and if schools are microcosms of society, then they too are value-laden. It probably comes as no surprise that teachers and administrators make value judgments each day about what content should or shouldn't be included in the curriculum (Flinders, Noddings, & Thornton, 1986), what behaviors are rewarded or punished, and how to best facilitate students' navigation through daily ethical dilemmas (e.g., Should I tattle on a friend who is cheating? Should I return a test that was incorrectly scored in my favor?), thereby shaping students' moral lives. Some scholars have pushed the envelope even further, particularly in the context of socioscientific decision making. Zeidler, Berkowitz, and Bennett (2013) envision science teachers as moral agents who have an affirmative duty to introduce the normative aspects of STEM practice; in other words, to facilitate students' thinking and discourse not only about what STEM *can* do but what STEM *ought* and *ought not* to do. Ignoring these aspects, it is argued, renders STEM a "deficit framework" (Zeidler, 2014b, p. 1) which lacks the humanistic, sociocultural perspective that acknowledges the inseparable nature of head and heart. Hodson (2010) demands that STEM curriculum compel students to venture beyond words toward sociopolitical action in order for it to adequately serve as a conduit for moral development. It is critical to note that these scholars are not advocating for educators to tell students *what* to think or do in particular situations, but rather, to facilitate the development of a collective social conscience whereby students consistently reflect upon the potential consequences of their actions or inactions, maintain flexible and open minds, and strive to do what is right in all situations, regardless of personal costs. It appears that STEM education, particularly with contemporary emphasis on engineering ideally aimed toward the betterment of society, could be fertile ground for the formation of character if curriculum and pedagogy explicitly target the norms that contribute to it, such as open-mindedness, perspective taking ability, personal and social responsibility, compassion, and conscience, to name a few.

Another way to frame the issue of moral development and STEM is to begin to conceptualize STEM as a vehicle for inclusivity, an incubator of innovation and inquisitiveness for *all* students, each of whom has a stake in STEM, perhaps as a future vocation, most certainly as a future global citizen. It is conceivable that integrating engineering processes within science classes may well tap skills and talents that would otherwise have been overlooked, thereby facilitating a strengths-based (Armstrong, 2012) rather than deficit model for student achievement. The authors of "All Standards, All Students" (*NGSS*, Appendix D) envision STEM as uniquely positioned to appeal to increasingly diverse classrooms by providing students who have been traditionally marginalized with the opportunity to apply engineering solutions to local problems, thus making science and all STEM disciplines relevant and personally meaningful. Fulfilling the promise of universal engagement could give rise to more equitable decision making in matters of public socioscientific significance and contribute to the development of an informed *global* citizenry ready to thoughtfully apply STEM understandings in their everyday lives. While this is unquestionably a just and laudable goal, it is one that likely necessitates a paradigmatic shift in how educators view inclusiveness, from one that sees quality STEM education for all students as a *legal* right to one that embraces it as a *moral* right (McGinnis, 2003). To press this point even further, it is argued here that a moral STEM epistemology deems educational excellence for all students as not just *a* right, but rather, *as right.* Pedagogies and curricular frameworks that can facilitate mastery of STEM content and habits of mind while fostering such moral characteristics as empathy, appreciation of multiple perspectives, caring, reflection, inclusivity, accessibility, responsibility, conscience, character, and moral reasoning are a first step in promoting this vision of a moral STEM education.

## A Moral Makeover

To advance the discussion of promoting moral development through STEM education, two frameworks are briefly described below. Although they are quite different in their approaches, they can nonetheless be seen as complementary in the quest for meaningful, accessible yet rigorous contextualized STEM curriculum taught in an inclusive and equitable environment.

Socioscientific Issues (SSI) – SSI (Zeidler, 2014a) is a framework that utilizes controversial, societal issues related to science as the context to prepare students for informed, participatory citizenship as adults. Through social discourse using evidence-based reasoning, students become aware of multiple perspectives as they grapple with the ethical implications of their decisions on matters such as genetic engineering, the use of animals in research, fluoridation of tap water, and nuclear energy, among many others. Extensive empirical evidence suggests that implementation of SSI promotes moral and character development, empathy, argumentation, understanding of the nature of science, and cultural perspectives necessary for responsible global citizenship (Lee et al., 2013; Sadler, Barab, & Scott, 2007; Zeidler, 2014a).

Universal Design for Learning (UDL) – UDL (Rose & Meyer, 2002) is a promising curriculum design framework that emerged from architectural design for people with disabilities and has since been applied to educational contexts to optimize learning for all students, including students with disabilities (Izzo & Bauer, 2015) and English Language Learners (Proctor et al., 2011). Grounded in research from cognitive and learning sciences, instructional design, and technology, it is premised upon the notion that classrooms and curriculum can be made relevant and accessible for all students with minimal need for individualized accommodations if three principles are applied: 1) Multiple means of engagement (affectively stimulating interest and motivation); 2) Multiple means of representation (how information is presented to students); and 3) Multiple means of action and expression (how students show what they know) (CAST, 2011).

In order to see how a typical STEM lesson might be adapted to reflect the SSI and UDL frameworks, a middle school lesson which focuses on the engineering design cycle is presented below, along with modifications and explanations. This particular lesson challenges students to design and build a model that solves a problem associated with colonizing the planet Mars using material constraints. The plans described are loosely based on activities from NASA's "Maker Mars" activity (NASA, 2015) and the NSTA Press® book, *It's Debatable! Using Socioscientific Issues to Develop Scientific Literacy, K-12* (Zeidler & Kahn, 2014). They are meant to provide a snapshot of what would be part of a more comprehensive Earth and Space Systems unit.

| 5E Phase | Original STEM Lesson | Modified "Moral" STEM Lesson | Framework Informing Modification |
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| Engage | • Students are asked to discuss the challenges of living on Mars.<br>• Prior knowledge about the physical characteristics of Mars (e.g., air, temperature, terrain, etc...) is elicited and discussed. | • Students watch a video segment of NASA's Mars Curiosity rover and read an excerpt from *The Mars Trilogy* about interplanetary travel and colonization.<br>• Students participate in an agree/disagree "spectrum line" activity in which they are asked to discuss, "Should humans pursue colonization on Mars?"<br>• Prior knowledge about the physical characteristics of Mars is elicited.<br>• Ethical dilemmas regarding property, safety, resource conservation, and stewardship are articulated. | UDL (Multiple means of engagement by use of different media)<br><br>UDL (Multiple means of action and expression by providing options for sharing knowledge)<br><br>SSI (Ethical dilemma is being used to engage students, elicit prior knowledge, and promote argumentation and perspective taking) |
| Explore | • Students are provided with a handout that describes the physical characteristics of Mars.<br>• Class identifies problems that Mars colonists would encounter.<br>• Teams choose problems and try to solve them by designing and building a solution using provided materials. | • Students visit interactive websites to investigate the physical characteristics of Mars, which they record on a graphic organizer.<br>• Teams collaboratively identify and rank problems that need to be solved.<br>• Teams design and build a solution to their top-ranked problem using provided materials. | UDL (Multiple means of representation such as interactive websites provide options for how information is perceived)<br><br>UDL (Multiple means of action and expression by supporting executive functions through graphic organizers)<br><br>SSI (students engage in discourse and debate regarding priorities for colonization) |
| Explain | • Students orally present their solutions as well as their design process to the class. | • Students present their solutions using a format of their own choosing (e.g., a video, skit, formal presentation).<br>• Assessment rubric is provided. | UDL (Multiple means of action and expression by providing options for sharing knowledge and providing assessment rubric for self-monitoring and executive function) |
| Extend | • Students explore websites about Mars and modify their solutions. | • Option 1:<br>Groups collaboratively develop a "Proposal for a Mars Colony" by exploring Mars websites and using web 2.0 tool such as e-books, digital mind maps, weblogs, and animations to communicate the problems, their solutions, their tests and modifications, plans for future research, and how limited resources available to their | SSI (Ethical dilemmas of resource allocation, food scarcity, water scarcity etc... are addressed; Option 2 extends activity to include social action that addresses issue)<br><br>UDL (Multiple means of engagement by allowing choice of activity) |

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| | | colony will be allocated.<br>• Option 2: Students are challenged to extend and revise their Mars solution to solve a parallel problem on Earth (e.g., water scarcity, food scarcity, waste disposal, etc…); Students engage in social action to address problem either through direct (e.g., recycling, gardening) or indirect (e.g., letter writing, public education) means. | UDL (Multiple means of action and expression by having flexible tools for communication of ideas and both physical and virtual means of interacting with problem) |
| Evaluate | • Students reflect on the design cycle and built solution.<br>• Teacher utilizes scoring rubric to assess student work and reflections regarding the design cycle and built solution. | • Students revisit question about Mars colonization, engaging in argument from evidence both in class and on an online discussion board.<br>• Students reflect on design cycle, built solutions, and perspectives on the controversial issue.<br>• Teacher and students process student thinking about the issue (e.g., Did your position change on this issue? Why or why not?)<br>• Teacher utilizes scoring rubric to assess student work and reflections regarding the design cycle and built solution, and use of evidence for arguments regarding the issue. | SSI (Ethical dilemma is being used to assess learning, promote evidence-based argumentation and perspective taking)<br><br>SSI (Reflection is utilized both in regard to design cycle, built solution, *and* students' perspectives on the issue)<br>UDL (Multiple means of action and expression by providing students with multiple means of conveying understanding) |

It is important to note that these modifications do not affect the lesson's learning objectives insofar as the engineering cycle; rather, they reframe the content within a societal context, emphasize discourse and evidence-based reasoning, seamlessly integrate STEM with language arts and social studies, and provide flexibility in both teacher and student communication media. It bears noting that developing a classroom climate conducive to such emphases requires some effort and reflection. STEM educators might look toward a compendium such as Nucci and Narvaez's (2008), *Handbook of Moral and Character Education* to find inspiration from a range of perspectives and pedagogical approaches including social interdependence, developmental discipline, and ethic of care, among many others.

In the hands of thoughtful educators, STEM has the potential to serve as a beacon that guides all students toward becoming responsible and reflective decision makers. If we can succeed in helping students to develop their moral compasses through STEM, we can ensure that even in times of whirlwind change, they will never be lost.

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