feature article

steam education:
separating fact from fiction

Many educators and researchers are now calling for STEA(arts)M education to be the approach of choice through which teachers may facilitate growth in habits of mind and practice that are characteristic of a globally literate citizen.

by
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Improving science, technology, engineering, and mathematics education (STEM) is an international imperative as countries work to improve life and prospects for their people. Countries recognize that to improve economic prosperity and national security, their citizens should be prepared to work in a global society that is characterized by digital, technological, and scientific literacy and requires divergent, flexible creative thinking (Honey, Pearson & Schweingruber, 2014). In today's market, almost 100% of jobs require critical thinking and active listening, 70% require mathematical knowledge, and 60% require oral comprehension and expression (Carnevale, Smith & Strohl, 2014). Indeed, the habits of mind and hand that are characteristic of all STEM disciplines are now required for employment in both STEM and non-STEM fields (Honey, Pearson & Schweingruber, 2014). Countries that are successful in producing STEM-literate citizens who are able to transfer knowledge and understandings among school and life, innovate, create, and effectively communicate will lead our increasingly technological and quantitative global society. Heretofore, the United States (U.S.) has not been able to meaningfully move the needle toward improved global literacy (National Science Board (NSB), 2016). Despite increasing global awareness of and funding efforts toward improving STEM educational outcomes, a clear bias continues to exist among those who persist in STEM and those who do not (Bean, Gnadt, Maupin, White & Anderson, 2016; National Research Council (NRC), 2011; Neuhauser & Cook, 2016; Xie, Fang & Shauman, 2015).

Many reasons may exist for the above-referenced failures. Perhaps persistent disagreements about how STEM education is defined may be hindering progress (Bybee, 2013). Related to this definitional indecision is the persistence of educational research from a disciplinary perspective rather than embracing an interdisciplinary or transdisciplinary approach to teaching and learning (Honey, Pearson & Schweingruber, 2014). Maybe lack of clarity as to what effective STEM education actually looks like in the K-16 classroom could also be contributing to the problem (Becker & Kyungsuk, 2011). Evidence clearly points also to a serious disconnect between training and practice of K-16 educators (Gess, 2017; Gess and Hargrove, 2017; Hall & Miro, 2016). It is quite likely that all of the above problems are contributing to the persisting lackluster results seen in the U.S. Educational literature points to an additional idea: persistent siloed disciplinary presentations may be contributing to the reason that the exclusive club of STEM professionals remains as such (Honey, Pearson & Schweingruber, 2014; Hwang & Taylor, 2016). Intentionally moving curricular presentations into more transdisciplinary applications where a problem or purpose that transcends content is used as an authentic context for learning will bring knowledge and understandings constructed in the classroom more in line with what is actually being required of students and adults in real life (Bybee, 2010b).

In addition to using an ill-designed problem, educators should consider capitalizing on the design process as the backbone on which 21st century literacy may be built (Sanders, 2009; Wells, 2008). Orchestrating learning experiences where students have to engage in cycles of design and redesign that require constructing of grade-appropriate mathematical and science understandings may be powerful opportunities for deep learning to occur in the classroom and extend far beyond (Bybee, 2013). The design process is inherent in both engineering and artistic endeavors. It stands to reason, therefore, that either engineering or art may be used as a context in which meaningful learning may occur. In fact, many educators and researchers are now calling for STEA(arts)M education to be the approach of choice through which teachers may facilitate growth in habits of mind and practice that are characteristic of a globally literate citizen. Based on the fact that both art and engineering are based in similar processes of design, this educational choice may indeed be the key to unlocking more equitable access to global literacy.

Defining STEM and STEAM Education

Experts advocate for educators to utilize integrative approaches that exploit the design process to presenting STEM content across subjects in order to promote literacy for all students (Bybee, 2010a; Dugger, 2010; Sanders, 2009; Wells, 2008, 2013). Integrative STEM education refers to technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with the concepts and practices of technology and engineering education. Integrative STEM education may be enhanced through future integration with other school subjects, such as language arts, social studies, art, etc. (Sanders and Wells, 2006). The intent of this definition was to focus educators on pedagogical approaches that "purposefully situate the teaching and learning of STEM concepts and practices in technological/engineering design-based pedagogy" (Sanders, 2012, p. 3). Similarly, the goals of integrative STEAM education, from an instructional standpoint, are to intentionally present the content and practices of math and science in the context of technology, engineering, and artistic (T/E/A) design, and further enhance learning through meaningful integration with other school subjects such as language arts and social studies (Gess, 2015).

Hallmarks of Authentic STE[A]M Education

As educators try to navigate the nuances of effective STEM and STEAM education in the classroom, there are four main points to note about the above definitions: (1) Approaches should be integrative and not integrated; (2) Approaches should be intentional on the part of the teacher; (3) The design process should be used to engage students in constructing authentic understandings through iterative cycles of learning in transdisciplinary classrooms (Dugger, 2010; Wells, 2013, 2016); and (4) An artistic artifact may be constructed as a problem solution that is equal to one in engineering or technology.

Integrative. When speaking about STEM and STEAM education, the -ive ending really matters. By using the -ive ending instead of -ed, we clearly and concisely convey the message that STEM education should be dynamic and student-responsive. Learning should be situated squarely in the present needs of the learner, not in the plans of the teacher that may have occurred months or years prior (Wells, 2013).

Intentional. Remembering that an important goal of public education is to produce globally literate students, it stands to reason that basic knowledge is no longer enough. Access to the world wide web places more knowledge than ever at a person's fingertips. This point was emphasized when I taught Anatomy and Physiology to college students several years ago. I had devolved into lecturing again, and I asked a benign question about the structure of the heart. From the back of the room, I heard a student whispering "Hey Siri, …" How resourceful! Of course, Siri could answer this question and point my student to the knowledge they needed. This incident impressed on me what my job was and how, that day, I was failing at it: my plans for that day did not include expressed intent on my part to engage the students in meaningful learning. I was focused on achieving standards, not applying standards to real-world situations. In order to resolve this issue, I should have been intentionally planning with the end in mind—and intentionally leveraging multidisciplinary standards applied in the context of an authentic, transdisciplinary situation.

Anchored in design. The design process is the central element through which students may apply knowledge and construct deeper understandings. It is "a process by which human intellect, creativity and passion are translated into useful artifacts" (Eagan, 2001, p. v). Students, by engaging in iterative cycles of design and meaningful reflection on the creation, may conceive of and realize new things (Cross, 2001, 2006). "There are forms of knowledge special to the awareness and ability of a designer, independent of the different professional domains of design practice" (Cross, 2001, p. 54). Design is the transdisciplinary endeavor that intersects each STEM discipline and enables students' development of the habits of mind and hand that are characteristic of global literacy (Costa & Kallick, 2009; NGSS lead states, 2013). "The purpose of design projects is to develop the students' ability and confidence to work through the complete design process, ending up with a feasible design solution" (Pahl & Beitz, 2013, p. xxvii). Students may not be successful in their first or even second design solution. They may encounter a seemingly insurmountable obstacle when working on their projects. Teachers should be at hand to discuss the problem and brainstorm with the student to propose a possible solution. "By doing this, the students continue to confront the problem" and persist until success is realized (Pahl & Beitz, 2003, p. xxviii). Through the co-teaching of content and practices inherent in all STEAM disciplines, students may be better equipped to "engage in and aspire to solve the major societal and environmental challenges they will face in the decades ahead" (NRC, 2013, p. 437).

Art as an equal, not an afterthought. The engineering design process is largely concerned with designing and engineering solutions to societal wants and needs. An important component of this work is to ensure that whatever solution is created is aesthetically pleasing as well. It is clear that the artistic side of engineering and fine arts are "closely and vitally related. Any attempt to separate them completely is artificial... In the process of their design and production, however, the two purposes [of science and art] are almost inseparably related" (Bonser & Mossman, 1923, p.5). In fact, the artist, too, constructs design solutions to real-world problems. Art does not just have to be used as an aesthetic component to an engineering solution; rather, the art may become the embodiment of experience or solution to the conundrum (Dewey, 2005).

Harnessing the Power of STEAM

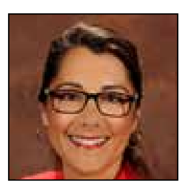
In essence, the integrative STEAM classroom "may be a vehicle through which high-quality, evidence-based, differentiated, standards-grounded instruction may be delivered to all students. In this classroom, clear learning goals are established by teachers and students that are anchored in literacy and not rote knowledge" (Gess & Kuo, 2017, p. 3). The pathway to such an ideal learning environment is through employing the design process to "connect hands-on with minds-on, where hands-on experiences are intentionally utilized to achieve minds-on learning outcomes" (Wells, 2016). In doing so, students may be more likely to persist through education (Plasman & Gottfried, 2016), transfer knowledge among disciplines and contexts, both in and out of school (Fortus, Dershimer, Krajcik, Marx & Mamlok-Naaman, 2004, 2005; Berry, Reed, Ritz, Lin, Hsiung & Frazier, 2004), and increase depth of knowledge and understandings (Kolodner, 2002). Situating STEM learning in the arts may provide the opportunity for meaningful scaffolding that all students, but especially students with disabilities, need in order to construct understandings (Hwang & Taylor, 2016). Additionally, by adding the arts into the STEM classroom, increased motivation, engagement, and achievement may result for wider student audiences (Becker & Park, 2011). Meaningfully integrating the arts into K-12 education can "lower the threshold of learning STEM disciplines because it facilitates student access to STEM knowledge" (Hwang & Taylor, 2016, p. 43).

STEAM Education: Proceed With Caution

The goal of integrative STEAM education is to enable all students to be able to achieve a level of proficiency in core knowledge and skills. Because STEAM education benefits all students, it is important that teachers are prepared to make STEAM education accessible to students with special needs—which means all students in a truly differentiated classroom. That being said, it is important that educators not be fooled into jumping into the first STEAM activity that crosses their inbox, or sign up for the first STEAM training that is being offered by a company trying to capitalize on the global interest around STEM and STEAM education. Be discerning in selecting resources. Seek out those who subscribe to an integrative approach and who focus on design as the tie that binds. Finally, be careful as to the kind of delivery that trainers want to provide. In order to facilitate an effective STEAM educational experience for your students, you should be participating in the same iterative cycles of design and reflection that you are planning for your students (Gess & Hargrove, 2017). "Sit and get" training is not enough! Rather, seek out opportunities to work in a learning community that is steeped in inquiry—supporting ongoing analysis of the practices of teaching so that you can effectively guide your students toward becoming productive citizens (Darling-Hammond & McLaughlin, 2011).

References

The references associated with this article are available in the online version at www.iteea.org/Publications/Journals/TET/TET-Nov2017/121427.aspx#publicationContent.



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