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The Challenges of STEM Education

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STEM's Identity Crisis

In the 1990s the National Science Foundation moved to identify critical subject areas which most directly impacted the economic development in our nation. Science, math, engineering, and technology were recognized and combined to form the acronym - SMET; unfortunately, SMET sounded too much like smut, so the NSF wisely decided to find a better acronym, and STEM was born. So since inception it would seem, STEM has struggled with its identity. As a result, the first and most pressing challenge of STEM Education is recognizing what STEM is and what it is not.

STEM's identity crisis is evidenced by its many variations: There is STEM, STEMC – because computer science and coding are really important for our future technological development; there is STEAM – add an 'A' for the arts because no great products were ever created without artistic sensibilities, just ask Apple; STREAM – add the 'R' for reading because no one can be successful without knowing how to read. It would seem that everything in the curriculum is important and wants to be included, but the problem is when everything is important, essentially nothing is.

This identity problem is further evidenced by the misunderstanding that so many have in thinking STEM is about emphasizing certain subjects at the exclusion of others. I do not believe that was ever the intent. The purpose of STEM was to take advantage of the effectiveness that these critical subjects can have when they are integrated in real world applications by modeling the way they are used in industry.

Districts and states are really struggling with "what STEM is" to the detriment of the movement. Well said one wise person, "*If* the *trumpet give an uncertain sound*, *who shall prepare themselves for the battle?"* If the purpose of STEM is not understood, implementation will unavoidably suffer. The reason for this struggle is that clearly, districts have no idea what the technology and engineering pieces are supposed to look like. Science they know, math they know, but engineering and technology because they are applied, are elusive subjects for academically minded people without an industrial background. The biggest difficulty then with enacting STEM Education programs, is that many professional teachers do not know how engineering skills are used in industry, so they cannot relate them to their students or deploy them properly as part of an effective STEM strategy.

For example, many believe that if they give their students iPads to use in a science or math class they have covered the technology piece of the STEM equation. So some background instruction is in order: Technologies are the products of engineers. The work of scientists is to make discoveries in their questioning of WHY. The work of engineers is HOW to take scientific discoveries and design them into products (technologies) for economic and societal benefits. Technology and engineering are not just additional subjects to be added to the academic mix, they must be integrated members of the strategy - *they are in fact, the context.* Technologies are the product of engineering design activity. It goes without saying that if a STEM strategy is not making the requirement that students design, iterate, and create technologies as part of their program of study, they are simply not engaging in STEM.

Poor leadership in education perpetuates these misunderstandings and the status quo. *"Educational institutions unfortunately have little incentive to produce more and better STEM graduates, especially graduates with the kinds of skills needed by industry. It's not a failure of imagination or knowledge; it's a failure of will on the part of institutions."* (Atkinson, Mayo, 2012). Without direct ties to industry there is little incentive in education to change these attitudes despite our President identifying the STEM initiative as a critical National Security Issue – *"if we do not improve the quality and quantity of science, engineering and math students as well as the general technological literacy of our workers, our country will lose significant quality of life and world leadership standing."* (Moravec, 2010).

The STEM movement requires systemic change and a fundamental upheaval in the way we view our purpose and our methods in educating. *"For over a century, science, technology, engineering, and mathematics education have established and steadfastly defended their sovereign territory [and] it will take a lot more than a four letter word to bring them together."* (Sanders, 2009)

The Essential Importance of Integration

The Next Generation Science Standards (NGSS) speaks highly of the importance of content integration in STEM learning. The NGSS refers to content that spills over into multiple subjects as “crosscutting concepts.” The fact that a major portion of the standards address the need to recognize crosscutting concepts is both affirming and condemning. It is affirming in that it recognizes how powerful it is when our students make connections with other concepts, applications, and disciplines. It is condemning in that by raising the notion of crosscutting concepts to such a level of importance in the standards, it is an admission that it previously was not being done. NGSS gives further encouragement for the ideas of subject area integration: “*Students should not be presented with instruction leading to one performance expectation in isolation, rather bundles of performances provide greater coherence…also allow(s) students to see the connected nature of science and the practices.”* (NGSS, Volume 1, 2013)

Additionally, *“…advocates of a more connected approach argue that teaching STEM subjects in a more integrated way, especially in the context of real-world issues, can make these fields more relevant to students and ultimately increase their motivation and achievement. Integration should be made explicit. Students do not spontaneously integrate concepts across different representations and materials on their own. The people who design integrated STEM experiences should provide intentional and explicit support to help students build knowledge and skills within and across disciplines; currently, such supports are often missing or implicit. In addition, programs that prepare educators to deliver integrated STEM instruction need to help these educators make the connections among the disciplines explicit to their students.”* (National Academies Press, 2014)

In education we try to provide for lower achieving students by finding methods which are especially effective to these populations of students. Often this is done at the expense of the other students. A compelling finding from teaching using an integrated model is that not only low performing students improve learning gains; it is being shown that all students in fact benefit. According to the National Science Foundation, *“…raising academic achievement levels for all students is a top priority for education reform at all levels across the United States. Interdisciplinary education can increase learning gains among low achieving minority students while increasing engagement and problem solving skills for all* *levels of students. Interdisciplinary education has the potential to increase STEM literacy levels among all students."* (Mehalik, Doppelt & Schunn, 2005).

Are Science Teachers Qualified to Teach Engineering?

While the NGSS recognizes the prominence that engineering must have in the curriculum to satisfy the President's charge, its solution is to have science teachers teach engineering in addition to their science curriculum: "*Science and engineering are integrated into science education by raising engineering design to the same level as scientific inquiry in science classroom instruction at all levels and by emphasizing the core ideas of engineering design and technology applications."* (NGSS, Volume 2, 2013)

As far as this model goes to support STEM, the fact remains that science teachers are very poorly equipped to teach engineering: "*Few science teachers have had even one engineering course. The faculty members who prepare future teachers…have limited experience with engineering education. Thus the current generation of teachers has not been prepared to incorporate engineering into science teaching"…* and, "*Even if science teachers did have appropriate preparation in engineering education…the science curriculum is already filled. There is insufficient time to do justice to current science topics, much less add a new layer of new requirements."* (Bull and Slykhuis, 2013).

Another concern with the "have science teachers teach engineering" model is the imperative that whoever conducts engineering instruction have a background in the requirements of industry – how is engineering used in the workplace? "*Studies are converging on a view of engineering education that not only requires student to develop a grasp of traditional engineering fundamentals, such as mechanics, dynamics, mathematics, and technology, but also to develop the skills associated with learning to imbed this knowledge in real-world situations."*(NGSS, Volume 2, 2013, p. 16)

Since a traditional science educator would have gone through the typical teacher preparation program in college, it is unlikely that many have had any industrial work related experience. How is a science teacher in this situation going to be able to effectively model and explain the work of an engineer when they do not understand it and have never done it themselves?

Overcoming Barriers with Essential Industry Ties

Engineers understand the worlds of math and science because they had to go through those worlds to get to engineering. The same cannot be said of scientists and mathematicians – there is no engineering requirement in their programs of study. This speaks to the essential need of our academic teachers having experience and understanding in the means and methods of industry. *"They need to have more access to experiences within real organizations where technology is being developed and used. Clearly, industry appears willing to be part of this process, if permitted. A large number of U.S. technology companies from a variety of industry sectors have active programs to help improve STEM education…but if STEM education is to be… effective, partnerships with industry need to be more systemic and deeper [and we need to] shift accountability measures for high schools from a content-based to a skills-based paradigm."* (Atkinson, Mayo, 2012).

Another barrier which prevents effective STEM implementation in the US is not a problem with our global rival China: *"Chinese officials recognize that STEM is more important than other subjects because the overall societal contribution from a STEM graduate exceeds that of a social sciences or humanities major. Such a view is rejected in elite policy circles in Washington (which coincidently, are populated largely by individuals with law degrees)."* (Atkinson, Mayo, 2012). Understanding and overcoming this bias is essential for us to make headway on the STEM front.

As previously mentioned, a significant barrier to the integration of engineering and technology in math and science classes can be with the math and science instructors themselves - if they cannot communicate to their students how the skills they are teaching are utilized in the world of work. This is where industries can help with teacher externing, inservices, and industrial fellowships. A vocational business exchange program (VIBE) matches teachers with industry and grants a number of hours paid placement with a local industry. In another example, STEM teachers are provided with industrial work experiences during their summer break. This model provides a win, win, win, solution as businesses and industry does its part to enhance education and provide for a strong pipeline of future talent; Teachers benefit by better understanding how academic skills are used in the workplace and they realize enhanced credibility with their students as they relate the experience to classroom practice; but the real beneficiary are the students who can then make better connections between the classrooms skills and future jobs.

In Conclusion

It is very likely that the STEM crisis in our educational system did not happen despite our best efforts at educating students, but was more likely caused by the way we educate students.

Our silo thinking philosophy of academic instruction, which leaves many students behind, is not founded in research in how students learn best or in the requirement of real-world application. Continuing to use an academic model with discrete educational “silos” as the solution to a problem that was most likely caused by this mindset is not acceptable. Clearly, if the challenge to effectively teach engineering education along with an integrated math and science content is beyond the scope of what teachers are qualified to perform, what should be done?

The T and E of STEM are the applied portions. Just as in college, many science courses cannot be adequately covered without the lab course which is taken concurrently with the academic course; so to, for STEM to work it must include opportunities for hands on engineering design work creating technologies. One way to do this would be require a T and E lab course concurrent with math and science offerings. By having a dedicated engineering course of study along with their academic courses, students learn to ply their academic and technological skills in the context of how they will be used in the world of work.

Similarly, career academies with an engineering or technology focus gather student cohorts and establish a school within a school small learning community. History has shown that if you desire to build and accelerate growth and capacity in an area, one of the best ways to do it is to gather it as a community. STEM career academies accomplish this by attracting students with similar career interests and structuring their academic program around the interest. STEM academy students share common academic teachers along with an engineering or technology teacher. This teaching team coordinates curriculum and instruction to align with the students shared career interests to focus the instruction where it will be of the most usefulness and interest to the academy students. Some examples of how STEM career academy teams can do this are with thematic units that are cross curricular. Students studying Greek and Roman civilizations in history class can find intersections with the literature of those times in language arts class as well as the civil engineering, warfare, and weapons technologies in their CTE class.

There are very successful models across the nation that integrate academic instruction with an engineering CTE program to create effective STEM instruction. Such programs replicate engineering design activity through the use of project based learning (PBL) which naturally integrate STEM subjects*: "…the STEM PBL challenges provide students with authentic real-world problems captured and re-enacted in a multi-media format designed to emulate the real-world context in which the problems were encountered and solved."* (Massa, DeLaura, Dischino, Donnelly, Hanes, 2012).

Anytime a teacher makes a requirement for students to learn, collaborate, or produce a project using the appropriate technology, they leverage the learning gains by not only providing learning content in a compelling way, but in the context of how it is used in the world. As we do this, we provide our students with the skill set for tomorrow's workplace. To be sure, the secret of an effective STEM program is understanding STEM Education is really a euphemism for WORKFORCE DEVELOPMENT. Teaching our students necessary workplace skills, integrated, applied, and contextual, just as they are used in the real world, is the greatest possible outcome of the STEM Movement.

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