STEM Works because of Talent, Training, Time and Tools

Abstract

A significant and growing disparity exists between high school exit demonstrated academic achievements and community college minimal entrance expectations. This gap impacts the number of people entering technical and engineering career pathways. The School District of Hillsborough County in the Tampa Bay region of Florida is the 9th largest school district in the country and at its service area community college, Hillsborough Community College alone, over 40% of the first year courses are classified as developmental. The focus of these courses is driven by course content that provides preparation for but not first year college chemistry, physics or calculus instruction. Bypassing the discussion that this current remediation educational practice does or does not provide the mathematics and science instruction students need, it is clear that an intermediate stage between high school and two year or four year technical and engineering degrees is not an efficient educational pathway for producing the 21st Century technical workforce. Any effort to alter this current practice requires a shift in the instructional content and instructor motivation in K-12 education.

The increased awareness that STEM (Science, Technology, Engineering and Mathematics) represents an innovative approach for education with respect to content for and relevance to the K-12 student population, FLATE, the NSF-ATE regional center of Advanced Technical Education in Florida, has begun a major effort to help Florida's K-14 educators, the K-12 and community college faculty, integrate STEM into the classroom environment. This paper will outline the strategies that FLATE has developed, adopted and/or adapted for this task with attention to the tools needed for success. Specific examples of STEM content integration into the elementary school, K-5, middle school, 6-8, and high school, 9-12, class room will be showcased. Features of FLATE's new "sTEm-at-Work" website will also be highlighted.

The Situation:

Historically, industry in the United States has used outsourcing as a strategy to balance cost and productivity. In the 19th and 20th centuries industrial America used its own immigrant population as part of an “in-sourcing” version of this strategy since that workforce was coming to the country and it could be used as a temporary labor resource as needed. Eventually, with the ultimate aid of WWII, the nation built an effective network of small machine shops, specialized manufacturing companies, and part suppliers to support the country’s major manufacturers and trained this workforce by expanding its industrial revolution based educational structure. Today American industry continues to outsource but now “off shores” these activities.

This new twist on an old habit will not go away. In fact, the new national mantra is that we do not have to alter this new outsourcing reality because the U.S. will use its innovative and inventive essence to maintain its lead in the global market place. However, since our traditional education system barely supported the later 20th Century “made in America” silo labor duties structure, there is no way that it will now produce a significantly larger population of innovative, inventive workers to replace the “classic” production worker in this new vision of American industry. The realization that the implementation of invention and innovation requires science, math, and engineering integrated with technology has moved STEM from a trendy topic to a specific strategy for success. This STEM approach will work but not in the time or education frame provided by the current education system. Thus, the challenge is clear and people with a technical and engineering background need to address the problem head-on.

The Task:

The United States must shift the focus of its current education delivery system by injecting a strong and steady dose of technology and engineering curriculum content that uses science and math as the integrating learning tool. This succinct statement does reflect an enormous task. The current education machine cannot simply be dismantled. In fact, that is not a rational approach. However, this K-14 system (K-12 ,the 2 year Colleges, or the first 2 years of 4 year programs) should not just be appended, supplemented, and/or injected with additional math and science instructional resources and then proceed with business as usual. The new goal is to produce workers that have the required science, math, technology and practical tactile engineering comfort level before entering the workforce. It is this integrated science, technology, engineering and mathematics (STEM) knowledge base that triggers innovation and invention.

Currently over 40% of the students in the “extra” 2 years spent within a community college squander that time in developmental courses which, in effect, means that a substantial number of would be American workers already need two more years in the “regular” education system but that extra time investment is disjointed with no accountable structure and does not include any direct progress toward an Associate degree. Therefore, the task is two fold. First, the STEM approach must use math and science as an integrated tool to introduce, study, and understand technology and engineering. If no action is taken on this front, new STEM initiatives will follow the traditional approach of more stand alone, with at best a few engineering or technology examples, science and math classes/activities that have as their objective the presentation of science and mathematics. A focus on math and science education is not bad or wrong but it is “business as usual” and the only guarantee about “business as usual” is that it produces that same results. Second, the integration of STEM as the new “way of doing business” for these three educational entities, K-12, community college, and lower division university, can not be initially accomplished by tinkering with the actual political and practical structure of each entity.

The STEM Approach to the Task:

The two pronged task identified above, to provide real STEM education without altering educational infrastructure, defines a big challenge and therefore bad news however the good news is the beauty of difficult challenges. Such challenges really appeal to engineers. Since this particular challenge is within the education domain, it should be particularly attractive to engineers that know, love, and live within that domain. The engineering educator’s community approach to STEM education can be multi-tiered and is linked to the available talent, training, time, and tools.

At the university tier, there are engineering college administrators within institutes or universities that are identified by their engineering education essence. Rose-Hulman, Clarkson, and George Institute of Technology are examples that quickly come to mind. These engineering deans can apply direct influence on how science and math are taught in the lower division of their institutions as well as on the technical programs in the two year colleges that feed into their programs or support the engineering and technical industry within their service area. These efforts is not restricted by talent or training but is compromised by time and tools. (1)

At the academic tier, effort is directed toward teachers in K-12 and community colleges (the K-14 environments). This tier is the general collection of engineering educators within a college or university structure where their College of Engineering or perhaps Department of Engineering is important and productive but only one component and certainly not the focus of the institution’s educational mission. For these engineers, the talent, training, time and tools list can be reduced to just a matter of tools. In this case, a tool means curriculum material that represents math driven, engineering or technology related, and grade level appropriate course work. Any time element constraint is dampened by the faculty member’s passion for the task.

A third tier is based on the current NSF supported GK-12 initiative. Although this program does provide an avenue for faculty involvement with STEM activities, its primary focus is on engineering graduate students becoming involved. If the faculty member has several GK-12 scholars, the actual faculty contact with the target teachers may be minimal.(2)

Collectively, engineering faculty and graduate students have three paths toward implanting (grafting) STEM into the K-14 environment. One path is for the faculty member to use the GK-12 mechanism as a model for entering a K-12 classroom and presenting a lesson based on or derived from the research practiced by that faculty and graduate students. These lessons typically employ a project learning approach that does support an enriched learning experience but can often just represent a “drive by” event if the lesson is not followed up with additional interactions with the teacher and the class. Another path involves the faculty member becoming a mentor for a small group of teachers. Perhaps this group is the local organized science or mathematics teachers’ group for a school district that is a feeder for the engineering college. In this situation, faculty members will help teachers see how math and science intertwine with technology and engineering.(3) This will most likely include teacher professional development related to the actual math or science principle central to the targeted technology or engineering science concept.

The third pathway is a more intense involvement with a particular school that includes continuous interaction with the school, its faculty, and its curriculum (4,5). In addition to increased demand on the engineering faculty time, this path requires a considerable amount of talent injected into or resident within the school's administration and staff. Significant resources will also have to be secured to implement a coordinated science and math training program for all of the school's teachers so that a unified STEM message can be created for all grades in all grade levels.

In all three pathways introduced above, the curriculum content developed and made available to the teachers for presentation to their students should reflect a distinct STEM characteristic. In addition it should be attenuated for appropriate grade level delivery. Finally, this content must meet identified science or mathematics standards that the teacher must report to. (6)

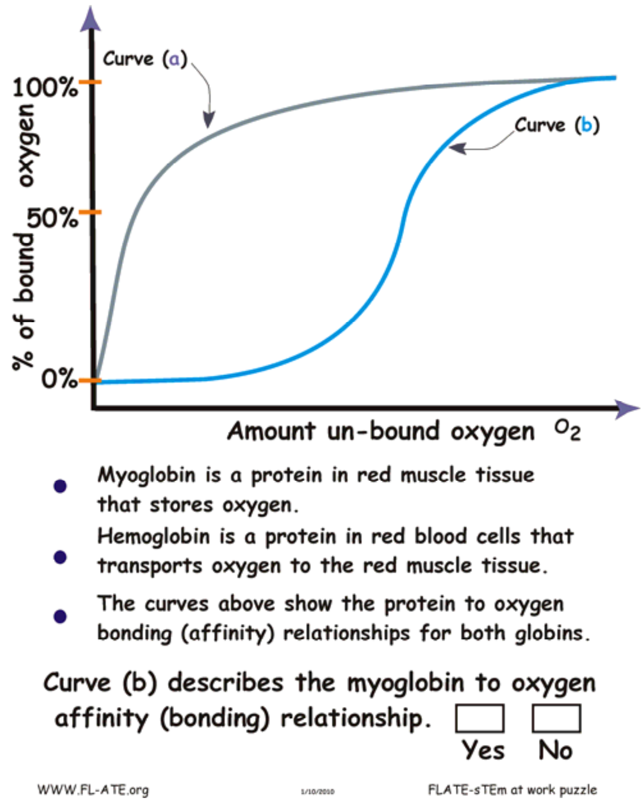
The sTEm Resource for the Task

As an organized effort to develop and collect a specific format of STEM curriculum content, FLATE, a NSF supported Regional Center for Advanced Technological Education in Florida, has initiated a "sTEm at Work" website that will post FLATE created STEM curriculum content as well as host STEM curriculum content developed by any STEM interested engineering faculty and graduate students. Not withstanding the blatant overtone to transfer the focus from science and mathematics onto Technology and Engineering as suggested in the letters in its URL, www.sTEm-at-Work.org, there are two tangible aims for this STEM content.

The first aim is to provide succinct classroom and/or homework vignettes to support K-14 specified grade level science and math instruction while clearly demonstrating how math and science are the means to understand the technology or engineering element in that curriculum piece. This STEM content will be grouped on the website to support specific science concepts that require a math framework for its technology and engineering application. The second aim is to provide content for engineering faculty to use as an interface tool with the K-14 environment faculty. Such an interface will keep teachers focused on STEM and at the same time incorporate the teachers into an engineering and technology awareness and career recruiting strategy.

The figure below and to the right provides one vignette example. It is intended for a high school chemistry and/or biology classroom as a biomedical or biotechnology challenge or puzzle to make students use a bit of science and math to confirm or deny the declarative statement associated with the data provided. The intent is to put students in a situation where they have to think about what the facts are and how that information is combined with exploratory information provided in a graphic format. The goal is to have students become comfortable with the task of providing a simple answer (yes or no) without guessing or doing a lot of calculations. It is an opportunity for the student to develop the “back of the envelope” type of math and science thinking skills that feed the innovative and inventive thought process.

These vignettes can also be used to trigger student small group discussion that must culminate with a unanimous declaration of the answer by the group. In this situation, the students could be told that the graphic is part of a report that is being created by a biomedical technician that must be labeled correctly. As an additional component of the discussion exercise, each group will have to report why they agree/disagree with the statement and what logic was used to convince the dissenting members of the group to agree to the final group answer. The final figure below and to the left provides the teacher curriculum support for this example. Again, the idea is to keep the information brief and to the point.

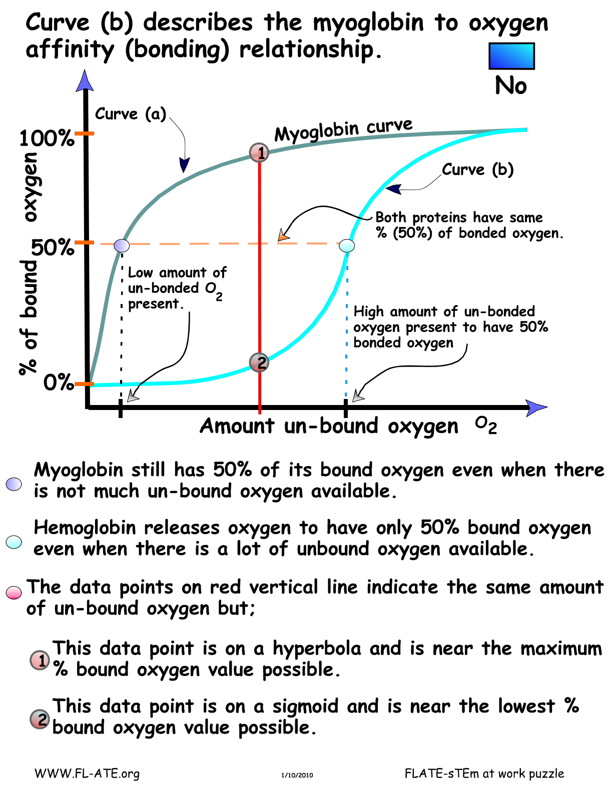


These two figures represent a single packet of STEM material. The first is the challenge for the students so they can see why science and math are needed in a technical career. The second is actually more important than the puzzle itself. The role of the second is to assure that the teacher has a clear understanding of the specifics of the puzzle. STEM will work as a strategy only when the science and math teachers buy in and use STEM focused examples blended into their lesson plans. That will happen when the teachers are really comfortable with the examples. For K-12 teachers that comfort level should not be assumed just because the teacher has experience teaching science and math in K-12 classrooms. Talent, training, time, and tools are all factors when dealing with K-12 math and science teachers with each factor influencing how or if a teacher will use any STEM tool provided. Thus, the puzzle support figure is actually a professional development tool.

The sTEm puzzle support figure has an intended presentation limitation. In this biotech example, as will be the most common situation, the teacher will not need much help with the general science concept. The puzzle support figure presumes this to be the case but assumes that teachers need some assistance connecting the math to that science concept and then integrating both into the engineering and/or technical application example. For this example, information about the stated role of hemoglobin and myoglobin in the oxygen transport and storage process, respectively, is known or obtainable via a Google search on either. However, integration of the “book learned” facts with the interpretation of a mathematical construct, the data presentation, is not a skill that is available directly from a text or the web.

In this particular challenge, deducing the validity of the puzzle statement either by interpreting the significance of two different values on the abscissa with a selected value on the ordinate or a specific value on the abscissa with two different ordinate values will not be an analysis approach found in many text examples. This is particularly the case in this example since the low value on the hyperbola's abscissa indicates the high oxygen affinity of myoglobin, the storage protein. However, the same abscissa value on the sigmoid indicates the lower oxygen affinity of hemoglobin, the transport protein. On first exposure, the idea that information can mean more affinity in one case but also less affinity for the other may seem counterintuitive if not incorrect to many teachers. However, it is the blending of the affinity concept with the hyperbola and sigmoid function properties that removes any perceived contradiction.

The myoglobin curve establishes the fact that myoglobin will hold its bound oxygen, has a high affinity for oxygen, even when the amount of available oxygen in the tissue is relatively low. The hemoglobin sigmoid curve indicates that hemoglobin will take up or release its bonded oxygen with slight changes in relatively high available oxygen concentration. This supports the idea that the hemoglobin binds oxygen when there is a lot of oxygen available and releases it after moving that bound oxygen to tissue that does not have a high oxygen partial pressure. Both curve's discussions draw on Le Chatelier's Principle.



Once this concept integrating message has been understood by the teacher and students that message will support or strengthen the teacher's lesson plan. If it is a chemistry class, this vignette can trigger discussions about the role hemoglobin's amino terminuses play to facilitate the binding of 2,3-bisphospphoglycerate as the major effecter for oxygen binding. If it is a biology class, the discussion could shift to the movement of the metabolic product, carbon dioxide, back to the lungs via the assistance of carbonic anhydrase. Ultimately the depth of instruction and for that matter the grade triggered by the vignette really depends on the blending of your and the teacher's collective talent, training, and time.

References:

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