TIES
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TIES STEM Education Monograph Series

Attributes of STEM Education

The Student
The School
The Classroom

TIES
Janice S. Morrison
Executive Director
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The Student

The hallmark of being a youngster is play, "...the experience of play is grounded in the concept of possibility." (Thorne, 1998) If the cognitive learning theorists are right, then play is the pre-cursor to problem solving. Questioning is central to play. Thus, children asking questions of the adult world is vital to their development. Children are handed verbal cues that keep them safe, "don't touch the stove." Yet, their world is full of stimulation that spurs them to questions, not just acceptance of commands. They "tinker" with notions as much as play dough and legos. "Why" is vital to their understanding. Slowly, over their early childhood they become more and more sophisticated problem-solvers, robust knowledge and understandings are socially constructed through talk, activity and interaction around meaningful problems and tools." (Vygotsky, 1978) Their need to understand the world and address their *whys* creates pathways for them to begin to make sense of the world, "Humans are viewed as goal-directed agents who actively seek information."(How People Learn, Pg. 10) Thus, as an entering elementary student, they have solved many problems for themselves using a design model.

A K-12 STEM educated youngster would then continue their education in consonance with this view of the world. They would be invited to continue to understand process and apply their understanding to novel situations. Knowledge, facts and vocabulary would support their drive to understand and make sense of things.

Suggested Attributes of the STEM educated student:

- Problem-solvers—able to frame problems as puzzles and then able to apply understanding and learning to these novel situations (argument and evidence)
- Innovators—"power to pursue independent and original investigation" (Gilman, 1898) using the design process
- Inventors—recognize the needs of the world and creatively design and implement solutions
- Self-reliant—able to set own agendas, develop and gain self-confidence and work within time specified time frames
- Logical thinkers—using the logic offered by calculus and found in 60% of all professions world-wide; able to make the kinds of connections to affect an understanding of natural phenomena

- Technologically literate—understand the nature of the technology, master the skills needed and apply it appropriately (Knowledge, Ways of Thinking and Acting, and Capabilities as specified by ITEA in Technically Speaking)
- Participants in the STEM lexicon that supports the bridge between STEM education in school and the workplace
- Able to relate their own culture and history to their education

The School

"For too long we have collapsed teaching in STEM to the presentation of information and cultivation of technique" and therefore student understanding has fallen short. (Rosenblatt, 2005). We have treated the material as sacred and paid little attention to the pedagogy that is key to quality instruction. Children learn through experience, talk and discourse. A student learns through shaping an argument and providing compelling evidence for it. On top of this narrowed view of STEM education, we have continued to perpetuate the great silos of biology, chemistry and physics, not as the natural phenomena present itself but as the Committee of Ten in the late 1800's viewed STEM education. "The Committee of Ten reduced the American education system to the pursuit of "knowledge" and the exercise of the mind in the cause of judgment." (Morrison, 2005) Therefore the challenge or charge for the STEM Academy is to, "construct a learning environment in which students have significant opportunities to take charge of their own learning; construct learning environments that are fundamentally oriented toward democratic ideals—independent of the age of the learning—rather than the preparation of "obedient" bodies (Foucault, 1975)." (WM Roth, 1998). Furthermore, as the National Science Education Standards relate, "There should be less emphasis on activities that demonstrate and verify science content" and more emphasis on those "that investigate and analyze science questions" (NRC, 113).

The synthesis of these ideas leads to acknowledging teaching of STEM in the first place but, with design leading the way. Teaching science and mathematics through design, "formally engages students in this basic human approach to meeting life's challenges and in the process addresses several longstanding issues in science education... (and math education)." (Haury, 2002) The design process offers a means of problem solving that is time-tested in engineering, technology and the arts. It compels students to understand the issues, distill the problems and understand processes that lead to solutions, "The major education goal in design is that students can develop two important kinds of knowledge necessary for making increasingly intelligent choices and decisions: (a) deep familiarity within a specific domain (content knowledge); and (b) strategies for bringing structure to complex and ill-defined problem settings invention and engineering." (W.M. Roth, 1998) There is widespread consensus that engaging students in design is vital in science and mathematics education (AAAS, Project 2061, 1993) with studies demonstrating that design can significantly advance academic, creative abilities and cognitive function. (Hetland, 2000; Seeley, 1994; Willet, 1992). The design process offers a sophisticated means of instruction for the school and classroom.

What about the curriculum and materials? Science, technology, engineering and math (STEM) is a meta-discipline, the "creation of a discipline based on the integration of other disciplinary knowledge into a new 'whole'." This interdisciplinary bridging among discrete disciplines is now treated as an entity, STEM. It offers a chance for students to make sense of the world rather than learn isolated bits and pieces of phenomena. Yet, STEM is really greater than interdisciplinary. It is actually *trans-disciplinary* in that it offers a "multi-faceted whole" with greater complexities and new spheres of understanding that ensure the integration of disciplines. (Kaufman, et al. 2003, Abts, 2006)

Suggested Attributes of the STEM School:

- STEM literacy as a priority for all students with all learning styles and backgrounds
- STEM literacy as culturally relevant to all students and teachers
- Design process driving the STEM instruction throughout the school
    - Designing is cognitive modeling in which a person gains insight into a problem, determines alternative pathways, and assesses the likelihood of success between solution sets
    - Designing is an intentional activity which can bring about change
    - Designing is intuitive and deductive, it is more than knowing how to use resources, or how to practice skill sets "through designing humans structure continuous experiences into a series of overlapping episodes... by focusing on designing and interpretive activity... construct meaning and knowledge." (Roth, 1998, p.18; Abts MSP Pending 2006)
- Tinkering with notions and materials central in all school areas, curricular and co-curricular
- Curriculum materials in support of the instruction not to supplant it
- All curriculum materials STEM in nature (trans-disciplinary)
    - Emphasis on technology and engineering in science and mathematics courses
    - Use of NSF generated mathematics and science materials with design embedded

    - Broad range of STEM courses available to students throughout their high school career (ex.: animation with AAVID in the ninth grade, GIS throughout, etc.)
- Innovation and invention highly prized in all student engagement
- A culture of questioning, creativity and possibility pervading the school
- Rigor is defined using benchmarking of design process with student outcomes
- Testing of students formative and most often performance based
- Teachers having a "thorough understanding of the subject domain and the epistemology that guides the discipline (How People Learn, p. 188)
- All professional development for teachers yearlong would use classroom materials, integrate STEM across the curriculum and be constructivist in nature (Horizon Research NSF, 2006)
- Compliant in state testing and standards as the floor not the ceiling
- Administrative decisions data driven within the mission of the STEM Academy

The Classroom

Suggested attributes of the STEM classroom Grades 6-12:
- Active and student-centered
- Equipped to support spontaneous questioning as well as planned investigation
- Center for innovation and invention
- Classroom, laboratory and engineering lab are physically one
- Equipped with small hand tools, malleable materials and ventilation to specification
- Outfitted with computers (laptops) with STEM software: GIS, AAVID, CAD, etc.
- Supportive of teaching in multiple modalities
- Furniture is easily reconfigured
- Electricity is accessible from the ceiling and the floor
- Serves students with a variety of learning styles and disabilities

Lingering Issues...

Although we are replete with reports delineating the issues in workforce and school, there is very little that specifies STEM education (attributes of graduates, schools, and classrooms). Few hold a vision for this kind of secondary school reform. Few understand the bridge between workforce and school. Finally, very few understand the needed professional development for pre-service and in-service teachers who will be STEM teachers shortly. Many decision-makers further the misconceptions about this kind of work when they speak to this issue.

Major misconceptions about STEM education…

- Technology and engineering are to be layered as additional coursework
- Technology means additional computers for schools and students
- Technology means word processing
- Hands-on means active learning with protocols
- STEM omits laboratory work and the scientific method
- All STEM educated students will be forced to choose technical fields because they do not have a liberal arts foundation
- Mathematics education is apart from science education
- STEM addresses only workforce issues
- Technology education and engineering are disparate and troublesome
- Tech ed teachers cannot teach science or mathematics
- Engineers cannot teach science and math

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COMMENTARY

From STEM to ST2REAM

Reassembling our disaggregated curriculum

By Kenneth Wesson

Back to Story

Countless millennia before the acronym STEM—for science, technology, engineering, and mathematics—entered our modern lexicon, early man was already engaged in STEM endeavors. Our ancestors spent significant portions of their days experimenting, tinkering, and thinking their way through myriad problems and challenges. During those prehistoric periods, the dreamers, the designers, and the builders identified the urgent problems, and subsequently crafted tools, crude instruments, and strategies to resolve them, working collaboratively for both survival and human progress.

Columbus' historic trans-Atlantic journey in 1492 was driven as much by innovation as it was by exploration. Fifteenth-century art, design, engineering, and innovative technologies made his expedition achievable. Once the highly maneuverable caravel sailing ships were invented, the travel time between continents was cut in half. Caravels were smaller, faster, and easier to navigate than other large vessels of that time. The mariner's compass and astrolabes made long-range voyages fast and feasible. Cartography, map-printing accuracy, and European printing techniques had taken a quantum leap forward courtesy of Johannes Gutenberg. Advances in mathematical procedures for estimating the earth's circumference gave greater precision to calculating global distances.

The European discovery of the New World constituted a prime example of the real-world synergies among science, technology, engineering, art, and mathematics. However, Columbus' impressive voyage has been academically quarantined to social studies, rather than viewed through a transdisciplinary lens where STEM content overlaps.

Problem-solving in the "real world" requires integrated solutions, in which science, language, mathematics, engineering, visualization, scientific reasoning, and technology are regularly intermingled in various combinations, sequences, proportions, and durations. Similarly, the components of STEM can merge into a "ST2REAM" model of connected learning, where science, technology, thematic instruction, reading/language arts, engineering, art (visual/spatial thinking), and mathematics converge to reveal not only what "human knowledge" is, but how we know it is so. Critical and creative thinking come by way of one's ability to mentally manipulate information and to do so from a broad range of divergent perspectives.

We can "hook" students on the value of learning best by "hooking" the curriculum back together through content integration in meaningful learning contexts. In the process of "acquiring" knowledge, what occurs inside the brain is more accurately described as the integration of new information into existing relevant neural networks. Thus, "learning" is hardly a process of acquisition, but instead is the integration of new elements into a complex web of ever-expanding intertwined knowledge that has personal meaning. The subsidiary benefit of these massive connections includes the capacity for complex and flexible thinking, strategic reasoning, and recognition of the possibility of multiple solutions and fused answers, rather than a single one.

Understanding our external world would be extremely complicated without knowing how to produce and interpret models, illustrations, and visual information. If students lack the capability to visualize a concept, it becomes correspondingly difficult for them to describe it verbally, understand it in print, recognize it in another context, or reproduce it during subsequent assessments. When our students say, "Oh, now I see!" their declarations underscore the learning power derived from constructing the relevant visual image.

The hippocampus is a subcortical structure responsible for establishing memories and plays a crucial role in daydreaming, imagination, and creativity. Thirty percent of our days are devoted to these states, when our brains shift from concentration to "wander and wonder," paving the way for innovations and inventions.

Contrary to popular belief, the evolution of memory was not governed by a need to recall the world of the past. Instead, memory evolved to assist us in predicting and navigating the future based on intelligent forecasts substantiated by our prior knowledge. We developed the capacity to solve likely problems visualized as lurking in the immediate or distant future. Synthesizing useful information is the goal of long-term learning, not memorizing disjointed information from a broad academic menu of "specialties."

Approximately 4 billion bits of information are processed by our brains every second, regardless of the school schedule or the time of day.

Our brains naturally organize incoming stimuli based on any recognized connections to stored information, rather than by academic designation. Memories are reinforced and expanded upon when related pathways are activated within a relevant context. The brain grants itself a chemical reward for making these connections, which is why "aha" experiences are emotionally lifting and addicting.

"Our brains naturally organize incoming stimuli based on any recognized connections to stored information, rather than by academic designation."

To capitalize on the finite number of hours in each school day, educators can extend the current STEM model to incorporate visualization and language. Developing visual literacy is an essential ingredient in design and engineering. STEAM adds art to the equation, while reading, writing, listening, and speaking are embedded in the ST2REAM model, in which each of the composing disciplines is intentionally deployed to explain and comprehend its counterparts. Scientific articles use more high-frequency, high-utility, and polysemous words than any other subject area, making science the richest source for teaching academic vocabulary. Science can indeed serve as the centerpiece for language development. These two curricular arrangements encourage us to boldly cross the conventional curricular borders and give students new bridges that contribute overtly to making each discipline comprehensible.

Our instructional focus should be on the points at which the ST2REAM disciplines naturally intersect in the course of producing knowledge in realistic situations. Students seldom ask, "Is this going to be on the test?" when they appreciate the transdisciplinary relevance, irrespective of our insistence that they perceive concepts through the lens of traditional subject-area silos. The ST2REAM disciplines all converge, allowing the learner to construct knowledge from context, because it makes sense rather than because it might be assessed.

"Learning is deepest when it engages the most parts of the brain," according to neurobiologist James Zull. When we increase the number of neural pathways linking markedly different regions of the brain, we can make substantive changes to brain circuitry, physiology, and architecture. Instead of attempting to enhance student learning through the conventional delivery systems—subject-area isolation and memorization—ST2REAM helps achieve our learning goals via situated learning, where the content resembles the wafer-thin layers composing a hologram. When stacked together, those layers are barely 12 millimeters thick. The beauty lies in an image that appears to be 3 feet deep but is derived from a half-inch-thick hologram.

The power of our incomparable human brain comes by way of maximizing its ability to make deep and long-lasting transdisciplinary connections, which permit us to dissect, reassemble, and make sense of the ever-changing world around us. The density of those connections is central to memory and comprehension, giving depth and stability to our knowledge.

The metadiscipline ST2REAM makes learning with rigor possible. Instead of merely mandating that more-rigorous math and science standards be delivered in the customary manner to advance the STEM agenda in America faster and more permanently, we must take advantage of the unifying ST2REAM model for learning. Redesigning our daily curricula with "coherence" as the primary driver will surely increase the number of academic success stories in which the constituent subject areas are learned well, applied often, and modified in the "real world" when circumstances demand. If you have any lingering doubts, just ask Columbus.

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FOCUS ON: ARTS EDUCATION

STEAM: Experts Make Case for Adding Arts to STEM

Goals are creativity and engagement

By Erik W. Robelen

Back to Story

The acronym STEM—shorthand for science, technology, engineering, and mathematics—has quickly taken hold in education policy circles, but some experts in the arts community and beyond suggest it may be missing another initial to make the combination more powerful. The idea? Move from STEM to STEAM, with an A for the arts.

Although it seems a stretch to imagine STEM will be replaced in education parlance, momentum appears to be mounting to explore ways that the intersection of the arts with the STEM fields can enhance student engagement and learning, and even help unlock creative thinking and innovation.

In fact, federal agencies, including the U.S. Department of Education and the National Science Foundation, are helping to fuel work in those areas.

The NSF has provided research grants and underwritten a number of conferences and workshops around the nation this year, including a forum hosted by the prestigious Rhode Island School of Design, titled "Bridging STEM to STEAM: Developing New Frameworks for Art-Science-Design Pedagogy."

Picking up on the Rhode Island institution's push for STEAM, in late September, a lawmaker from that state, U.S. Rep. James Langevin, a Democrat, introduced a House resolution to highlight how "the innovative practices of art and design play an essential role in improving STEM education and advancing STEM research."

On-the-ground examples of bringing the arts and STEM learning together abound, from Philadelphia and Boston to San Diego.

For instance, the Philadelphia Arts in Education Partnership, with support from a $1.1 million Education Department grant, is working with city schools to help elementary students better understand abstract concepts in science and mathematics, such as fractions and geometric shapes, through art-making projects.

High school students in several U.S. cities, meanwhile, compete for an annual **ArtScience** Prize. First launched in Boston in 2008, the contest fuses concepts in the arts and design with the sciences. The theme of last school year's curriculum and contest was the Future of Water. This year, it's Virtual Worlds, and next, the emerging field of synthetic biology.

One advocate of the STEM to STEAM push is Harvey Seifter, the director of the **Art of Science Learning**, a project financed by an NSF grant that organized three conferences last spring in Washington, Chicago, and San Diego that brought together scientists, artists, and researchers, as well as educators, business leaders, and policymakers to explore how the arts can be engaged to strengthen STEM learning and skills and produce a more creative American workforce.

"For me, it is about connecting—or reconnecting—the arts and sciences in ways that learning can happen at the intersection of the two," said Mr. Seifter, an expert in arts-based learning who also consults with Fortune 500 companies on business creativity. "We believe there is a powerful opportunity here to use the arts and arts-based learning to spark transformational change in science education."


In an art class at the Dayton Regional STEM School in Kettering, Ohio, teachers incorporate art and biology to enhance student engagement and learning.
—Andrew Spear for Education Week

One core idea Mr. Seifter and other STEAM advocates emphasize is that the arts hold great potential to foster creativity and new ways of thinking that can help unleash STEM innovation.

"There is creativity in STEM itself, super genius in it, ... but in arts education, it really is the raison d'etre to be out of the box, to accept the chaos," said John Maeda, the president of the Rhode Island School of Design, in Providence.

Artists and designers, he said, are "risk takers, they can think around corners."

Mr. Maeda invokes STEAM as a pathway to enhance U.S. economic competitiveness, citing as an example the late Apple co-founder, Steve Jobs, a leading force behind the iPod, iPhone, and other electronic devices.

"What STEAM means, it should feel like Steve Jobs, what he did for America," Mr. Maeda said. "It is an innovation strategy for America."

In da Vinci's Footsteps

To be sure, the idea of integrating the arts with learning in other fields, including the stem disciplines, is not new. In fact, some observers have noted an increase of late in activity more broadly to promote arts integration across the curriculum, at a time when the arts struggle to keep a foothold in classrooms amid school budget cuts and the pressure for academic gains in subjects like reading and math. (**"Schools Integrate Dance Into Lessons,"** Nov. 17, 2010.)

But some experts perceive a special connection between the arts and the STEM fields. Mr. Seifter, for instance, points to a 2008 **study** led by Robert Root-Bernstein of Michigan State University, which found that Nobel laureates in the sciences were 22 times more likely than scientists in general to be involved in the performing arts. Others note that Albert Einstein was an accomplished violinist. And then there's the Renaissance figure who some view as the personification of STEAM: Leonardo da Vinci, the Italian painter and sculptor who also made a name for himself as a scientist, engineer, and inventor.

Whether integrating the arts with STEM education enhances student learning is not exactly a settled matter, as even advocates like Mr. Seifter acknowledge.

"There is no question, to me, the critical missing piece is the data," said Mr. Seifter. He adds that even as he's witnessed the power of the intersection, he sees a critical need for a "solid body of empirical knowledge about what the arts bring to the STEM equation."

Indeed, research examining the effect of arts integration on student achievement across disciplines appears to show mixed results.

Leaving the research question aside, however, some experts stop short of embracing a change from STEM to STEAM.

Alan J. Friedman, a former head of the New York Hall of Science, said it's crucial for students not to lose sight of the differences, for example, between art and science.

"One crucial point at which they part ways is the act of deciding, 'Is it good art? Is it good science?' " said Mr. Friedman, a member of the National Assessment Governing Board who holds a doctorate in physics. "Science and art have a lot to learn from each other, a lot of inspiration to share, a lot of commonality. They also have some very essential differences that are at the core of what they are, which is why I have trouble with STEAM."

Susan R. Singer, a biology professor at Carleton College in Northfield, Minn., echoes the point.

"Not to devalue the symmetry, but they are very different ways of knowing the world," said Ms. Singer, who previously served on the National Research Council's Board on Science Education. "I would stop short of STEAM, but celebrate the ways that they work together."

'Fraction Mural'

What the intersection of the arts with STEM learning looks like in practice varies widely.

The Philadelphia Arts in Education Partnership is focused on math and science instruction in the elementary grades, with support coming from its four-year grant from the Education Department's Arts in Education Model Development and Dissemination program. For example, through art-making projects, students at one school manipulated the abstract concepts underlying fractions for a more concrete understanding of how they work. The students even created a "fraction mural" displayed at the school.

"We match arts skills and processes to a specific learning goal in math and science," said Raye Cohen, the education director at the Philadelphia arts group.

She said that work with the visual arts is especially promising. "Visual arts just seems to really be able to home in on the concept, taking it from the abstract to the concrete, so students are really able to understand it," she said.

Ms. Cohen says the project involves an "intense research component" and will look at a variety of effects, including student test scores, suspensions, and unexcused absences, as well as parent engagement in homework and changes in teaching practices.

In California, a $1.1 million grant last year by the state's Postsecondary Education Commission, using federal teacher-quality aid, is supporting the 134,000-student San Diego school district's work linking the arts with science in grades 3-5.

"It's not just teaching science through the arts, but teaching science and the arts together, and what comes from that is more than either of them standing alone," said Karen Childress-Evans, the district's director of visual and performing arts.

The Wolf Trap Foundation for the Performing Arts, based in Vienna, Va., has recently developed early-childhood initiatives that blend STEM learning with the arts. The work—supported in one instance by a 2010 federal Education Department grant, in another by the philanthropic arm of aerospace giant Northrop Grumman—involves performing artists in theater, music, dance, and puppetry working alongside classroom teachers in preschool and kindergarten settings.

The ArtScience Prize, meanwhile, is built around the ideas of Harvard University professor David A. Edwards, the author of *ArtScience: Creativity in the Post-Google Generation*. High school students work in small teams on projects over a year's time in an after-school or in-school setting. The program has quickly expanded beyond Boston to include Minneapolis and Oklahoma City, as well as international locations.

The winning team in Oklahoma City earlier this year developed a biodegradable water bottle, while the top-rated Boston team is creating public art installations that communicate how people around the world struggle to gain access to fresh water.

"We're empowering young people to come up with their own ideas while exploring and playing in the arts and science," said Carrie Fitzsimmons, the executive director of ArtScience Labs, the Cambridge, Mass.-based organization that manages the ArtScience Prize. "It's all fun, experiential learning, but we're teaching them to be critical thinkers and problem-solvers."

In Ohio, the **Dayton Regional STEM School** takes the integration of subjects, including the arts, seriously.

Jenny Montgomery, an art teacher at the school, said her colleagues in other disciplines often approach her about working together. Last month, for instance, she team-taught with a biology teacher as part of a project in which students made watercolor paintings of cells.

"We were studying cell structure," she said, "and we were looking at paintings [the students created], these beautiful artistic renderings, and students could pick out the structures that they had been studying."

Ms. Montgomery said her work with science teachers has helped her make connections between the disciplines.

"One thing we looked at ... was how artists and scientists have common methodologies in observing the world around them," she said.

At the same time, Ms. Montgomery said, even in a STEM school, it's important for art not simply to be valued for its application to other disciplines.

"I also uphold the value of making art for art's sake," she said, "that students have an opportunity just to engage in art for the sheer joy of it."

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The Seattle Times
Winner of a 2012 Pulitzer Prize

Editorials / Opinion

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Op-ed: Don't pit science and math education against the liberal arts

Guest columnists Sandi Everlove and Michael Zimmeran say the competition between the liberal arts and a STEM education is a false conflict.

By Sandi Everlove and Michael Zimmerman

Special to The Times

ONE of the skills that students who study the liberal arts learn is how to distinguish a real controversy from a manufactured controversy.

Recently, administrators from academic institutions across the state of Washington gathered to promote the value and importance of the liberal arts.

Some fear the emphasis placed on STEM fields -- science, technology, engineering and mathematics -- because businesses are urging the state to fund these areas of study. Businesses need graduates trained in science and technology to fill their jobs. This effort has prompted some to argue a false conflict: That we must choose between liberal arts and STEM disciplines.

The reality of the situation is dramatically different. STEM disciplines should not be seen as being apart from the liberal arts. They are a part of the liberal arts. Second, narrowly educating students, regardless of field, dramatically limits options.

Studying the broad range of disciplines encompassed in a liberal-arts education -- literature, history, politics, languages, art, philosophy -- feeds academic success in general and success in STEM disciplines in particular. Scientists and engineers need the critical thinking skills and creativity to design new solutions that come from liberal arts course work. And they need the perspective gained from studying the humanities and arts if they are to be able to think deeply about the social implications of their work.

It is equally important for writers, philosophers and linguists to understand mathematics and the scientific method, to be able to differentiate between pattern and anecdote, and distinguish science from nonscience and nonsense.

The controversy isn't between STEM and the liberal arts.

America does have a STEM problem. We're neither educating enough students who go into those fields nor educating a citizenry that is even rudimentarily literate in the sciences. The science and mathematics test scores generated by our students are significantly lower than those of our international competitors, sending deep repercussions throughout our economy.

But fixing the STEM education problem in a meaningful way can't be done simply by improving science and math instruction, or by inducing more students to study STEM fields. As biologists we both understand the nature of complex systems and recognize that when attention is paid to only one facet of such a system the impact is likely to be far less impressive than expected.

American higher education will be most effective when students, regardless of major, receive a broad education rich with the rigorous study of many subjects. Such an education helps people communicate effectively, solve complex problems, think critically and creatively and work with others as part of a team.

Some educated citizens will be scientists and some will be musicians, some will be engineers while others will be linguists, but all will help us understand what it means to be human.

When an imaginary controversy is promoted between STEM disciplines and the liberal arts, all it does is divert our attention from focusing on the larger problems associated with the lack of public funding for higher education. Such false controversies make poor public policy.

Sandi Everlove, left, is chief learning officer of Washington STEM, a nonprofit dedicated advancing science, technology, engineering, and mathematics. Michael Zimmerman is vice president for academic affairs at The Evergreen State College.

University of Cincinnati – Masters of Education Program

MASTER OF EDUCATION ONLINE

Incorporating STEM in All Classrooms

How STEM Relates to all Educators

Just as an English teacher's job doesn't end once a book is finished, a math teacher's job isn't over just because the student solves the problem. Education should be so much more than that. It's about helping students connect the dots and find meaningful ways to interpret and understand the course's materials. This often results in critical thinking and applied learning that is more likely to stick with the learner than other more basic tactics, like memorization and assigned readings. Deepening the connection between learner and lesson is a principle responsibility of every educator. Fortunately, current trends in education are steering teachers toward a more exploratory way of helping students learn in every subject through initiatives to support STEM education in schools.

A substantial part of early education deals with making students more aware of how they impact their immediate environments and how those environments in turn influence their successes. This goes for both their academic pursuits and things they encounter just in daily living. As a whole, education serves to prepare individuals for productive, fulfilling lives. This is why STEM education is so critical to the curriculum, because it embraces the very subjects that regularly influence and impact students in their everyday lives. Which is also why it's not just an important focus for teachers dealing with the specific subjects of science, technology, engineering and mathematics, but for every teacher who is interested in expanding their instruction to broaden student perspective in all subjects. By invigorating your curriculum and instruction according to STEM objectives, you can transform your classroom to become an improved learning environment for your students.

STEM education focuses on promoting creativity and exploration in the learning process. This means that educators shift from textbook teaching to more project-based learning, which can be scary for educators who aren't used to relinquishing control of their curriculum. Remember that just because the classroom isn't on a strict schedule, it doesn't mean the students aren't achieving their learning objectives. Overall, the benefits of this type of education are so rewarding that teachers would be foolish to neglect how simple variations in instruction could change a stagnant classroom into a dynamic learning environment. Knowledge retention is just one major benefit. Critical thinking is another. During project-based learning, students are encouraged to find their own answers and draw their own conclusions.

Assisting students in these types of classroom exercises requires more than just establishing a firm knowledge in your subject area. It asks instructors to expand that insight to include more learning strategies and new research processes. This is where a STEM degree in Curriculum & Instruction can be a real aid in the curriculum development process. Becoming a STEM teacher gives educators the opportunity to diversify lesson plans in their own departments and even in their entire schools, potentially moving into leadership roles as their expertise in multiple learning styles becomes evident to both their peer teachers and administration.

To explore this further, let's take a look at what exactly defines a STEM educator. At their roots, STEM educators strive to compel students toward careers and academic pursuits involving four broad subject areas: science, technology, engineering and mathematics. But limiting STEM education to those academic subjects that fit within these broad categories ignores how it relates to all educators. STEM integration is the key to this puzzle. What's more, this improved quality of education better situates middle school and secondary school students to compete with their peers from other countries, who are currently outperforming the United States in STEM subjects.

For all educators who are concerned with how their students can position themselves for success and truly benefit their communities, STEM subjects are an essential component to both of these agendas. Teaching STEM subjects is just one of many ways educators can become proponents of this initiative. By seeking an advanced education in curriculum & instruction with a focus on STEM education, any teacher can enjoy the advantages of progressing their education careers. Making this change in instruction allows educators to acknowledge the society that students are living in right now and prepare them to be functioning and, in many cases, important cogs in that system. Working toward an education system that embraces modern society, revolutionizes old tenets of education and recognizes ways to excite learners are all critical to the STEM education movement, and thus becomes an important goal for any and all teachers currently working within that system.

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WHAT WORKS IN EDUCATION

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STUDENT ENGAGEMENT

Engaging Students in the STEM Classroom Through "Making"

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Students at Analy High School painting the walls of their new maker space. Photo credit: Casey Shea

A few days ago, I visited a math teacher who was busily preparing his classroom for the start of the school year. This classroom, however, was a bit unusual. Casey Shea, who teaches at Analy High School**(1)** in Sebastopol, California, was transforming an old wood shop into a "makerspace." With his students' help, much of the furniture was built from scratch, and the space will soon be filled with students working on projects that might range from solar-powered battery chargers to geodesic domes and a pedal-powered blender.

Casey is one of a growing number of teachers who are incorporating "making" into their teaching methods, and turning their classrooms into makerspaces.

What is *making*?

The past few years have seen increased interest in making and makers. A maker is someone who makes something – from food to robots, wooden furniture to microcontroller-driven art installations. Makers are typically driven by their curiosity for learning and creating new things, as well as by an interest in sharing their work and processes with others.

Maker Faires are now occurring in cities throughout the world. These gatherings allow makers to exhibit their work, and to gain inspiration, new ideas, and new friends. Online communities where people share their projects and how-to guides are flourishing. There is a sense of play in the maker community. If you wander around a Maker Faire, many of the things you will see are incredibly complex, but also have an element of whimsy to them. More and more families and children are attending these Faires and wondering how they can get started in making.

How does making relate to STEM education?

For the six years prior to joining the Maker Education Initiative, I was an engineering professor teaching engineering to undergraduate students and PK-12 educators. One of the things that struck me in discussions with other engineering professors around the country was how many students had little experience in actually building things. Making is about realizing that you can be a creator instead of just a consumer. At its best, making allows kids to follow their own interests and passions and create something that is uniquely theirs, while applying the knowledge that they are gathering in all aspects of their life.

At a time when many people are asking how we can get more students interested in STEM fields, we are hearing from teachers who have found making to be a great way to get students excited and engaged in their classrooms. We are seeing making occurring in subject classes such as math or science – in classes specifically listed as maker classes – and in a variety of less formal settings such as clubs and study halls. Many of these projects incorporate a variety of STEM topics. Students working on designing and building furniture for their classroom use algebra and geometry to figure out the dimensions. E-textiles and soft circuitry, in which circuits are sewn using conductive thread or fabric, have shown to be an engaging way to teach electronics and programming, especially for young women. The possibilities for ways to incorporate making into the school day are endless, and it is exciting to see what teachers have been developing and sharing.

Sponsored by Autodesk, this series covers innovations and best practices for the STEM classroom.

One of my colleagues at the Maker Education Initiative, Steve Davee, spent 8 years teaching math and science at the Opal School**(2)**. Steve is a maker at heart, and is always looking for ways to get his students involved. Not long after Hurricane Katrina, Steve was having a conversation with his fifth grade math class about emergency shelters. Steve realized that his students were truly interested in finding ways to help people impacted by such disasters, and that such a project could incorporate many of the academic standards that he would have to cover in that class, such as volume, fractions, measurements and averages.

His students started creating designs for these shelters in their notebooks and building scale models. The students then wanted to create a full scale model, but didn't have access to enough materials for an adult shelter, so they decided to build an emergency shelter for preschoolers. After measuring preschoolers, the students went on to collaboratively build a full-scale preschooler emergency shelter, which was quite popular with students and teachers of all sizes! A fourth grader at the school

Project-Based Learning from Start to Finish

saw this project, and decided that it would be great if the shelter could drive itself to emergencies. In his free time, at school and at home, this student built a prototype of a shelter on a robotic base that could drive itself. When I talked to Steve about this project he stressed that one of the key elements was that it came out of his students truly caring about providing a solution to a problem that they felt was important.

Making is about empowering students to see that they can bring their ideas to life, and create new things. I strongly believe that we are all makers at heart, and that every new project incorporates new learning opportunities. So, I'll end with a question: what will *you* make this school year?

Where to find making activities for your classroom

Many makers are willing to share their projects and help others. This has led to a wealth of online resources and project instructions. Some good places to look for project inspiration and instructions include:

- Make: Projects**(3)** is a curated site with a strong emphasis on maker projects, and the Kids and Family section**(4)** of the Make: blog has projects specifically aimed at young makers.
- Instructables**(5)** has 80,000+ illustrated projects ranging from food to electronics.
- The MENTOR Makerspace program has produced a guide for creating a makerspace in high schools**(6)**.
- Makerbot has curriculum for using 3D printing**(7)** in a variety of subject areas.
- Adafruit has tutorials that cover topics such as electronics and Arduino microcontrollers**(8)**.
- The High Tech Low Tech group at MIT's Media Lab has created a workshop facilitator's guide for soft circuits**(9)**.

What other ways can I get involved in making?

- Go to a Maker Faire or a Mini-Maker Faire! Maker Faires are gathering where makers share their work. It's a fantastic place to get inspiration for projects to do with your students. Here is a listing of currently planned Faires**(10)**.
- Look to see if your city has a hackerspace or makerspace. This is often a good place to find the makers in your city. (Here is a list of makerspaces**(11)**, and list of hackerspaces**(12)**)

There are many other great resource sites available, and I encourage you to list your favorite resources and links in the comments!

*This blog is part of a series sponsored by Autodesk***(13)**.

Source: www.edutopia.org/blog/stem-engagement-maker-movement-annmarie-thomas

Links

1 www.analy.org/
2 opalschoolblog.typepad.com/
3 makeprojects.com/
4 blog.makezine.com/kids/
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6 makerspace.com/2012/05/01/makerspace-playbook/
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When we think of STEM education, we think high school students taking chemistry and algebra courses, not third graders and multiplication. But with a little forethought and a bit of tweaking to your lessons, a STEM-based curriculum can be suitable for elementary students. Why Start STEM Education so Young?Â How do you implement STEM education into your classroom? Do you have any strategies that you use? Please share with us in the comment section below, we would love to hear your thoughts. Janelle Cox is an education writer who uses her experience and knowledge to provide creative and original writing in the field of education. Janelle holds a Master's of Science in Education from the State University of New York College at Buffalo.