TIES STEM Education Monograph Series

Attributes of STEM Education

The Student
The Academy
The Classroom

TIES
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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 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 Academy

"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 Academy:

- 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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