BrainWorld

USING INTERDISCIPLINARITY
TO IMPROVE OUR MINDS AND OUR SCHOOLS
MERGING ACADEMIC DISCIPLINES
TO FIND THE ANSWERS

BRAIN-STEM

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"The illiterates of the future are not those who cannot read or write, but those who cannot learn, un-learn, and re-learn." — Alvin Toffler, Futurist

Students beginning kindergarten this fall will likely retire around the year 2075. An unpredictable world awaits them. How do we prepare our children for the future, with such an uncertain economy and rapidly evolving technology? According to Microsoft CTO Cameron Evans, current educational approaches were designed to prepare students for careers that don’t exist anymore, and may never exist again. It is estimated that this new generation of school-aged children may hold between five to eight different careers throughout their lives. The most recent projections by the U.S. Department of Labor indicate that 15 of the 20 fastest-growing professional occupations require a significant understanding of mathematics and science, two subjects where American students lag behind Europeans. Consider the following:

- The 2006 Program for International Student Assessment (PISA) reported that the average mathematics score for 15-year-old U.S. students was lower than the scores in 18 out of 24 comparison nations.
- The number of countries scoring *higher* than the U.S. on the PISA science assessment increased from 6 countries to 12 over the past 6 years.
- A survey conducted at the University of California, Berkeley, concluded that 80 percent of K-5 teachers in the San Francisco Bay area spent 60 minutes or less *per week* teaching science. Over 16 percent reported spending no time at all on science.

American school systems tend to put-off studying the sciences in-depth until high school. Only recently has this practice come under long-overdue scrutiny. Over 65 percent of scientists reported that their interest in science began before their middle school years, according to the *International Journal of Science Education*. In order to have curious, scientifically literate students who can bring innovation to a technologically based economy, it is essential that they have a strong foundation of science, technology, engineering, and mathematics, with classes in these subjects beginning in the elementary grades. Perhaps the solution lies in a connected curriculum.

All too often we hear “Math isn’t my strong point,” or “The humanities are more for me, I’m not a science guy,” but the reality is that not only are all school subjects equally relevant to life experiences, favoring one subject over the others deprives your brain of developing to its fullest. Intelligence is widely distributed throughout the brain, not in one concentrated area. The foundation of all learning lies in one quadrillion connections between the brain’s neurons. From preschool, all the way through the university-level classrooms, a connected curriculum underscores the context of the topic under study, rather than delivering isolated content for students to memorize. Interdisciplinarity is not only brain-considerate, but yields the deepest learning returns, because human brain cells actively look to make an unlimited number of connections, or more technically, synapses.

Being fed new information, our brain’s already active connections are “rewarded” with neurotrophins, which fortify circuits and increase the brain’s capacity for learning.

Synapses are created and strengthened as the numbers of meaningful connections are made, as we apply this new information to previously acquired knowledge and experiences. These connections become less vulnerable to deterioration if they are activated repeatedly, delaying the onset of dementia. The hands-on nature of STEM-related activities fosters student engagement, higher-order thinking, and deepens their understanding of how science, technology, engineering, and mathematics (STEM) influence the real world around them.

Over the next two years, American schools will be implementing four major educational reforms: the Common Core State Standards (CCSS) for English/Language Arts, the CCSS for Mathematics, the Next Generation Science Standards (NGSS), and the 21st Century Skills. Implementing such massive changes in four consecutive years would be difficult enough. Introducing three content-related reforms *simultaneously* is unprecedented.

To break this down, educational consultants propose to think of the curricular focus as two different conceptual "umbrellas." Rather than restrict math class to math, think of math as just part of the STEM umbrella, where science, technology, engineering, and mathematics merge as the instructional centerpiece, softening the lines of disciplinary demarcation among these four academic disciplines. Under a second model, we re-frame the STEM conversation by expanding it into ST^2REAM, which includes a "T," an "R," and an "A." The second "T" represents thematic instruction (e.g., project-based learning). The "R" denotes reading/language arts (where reading, writing, dialogue, and discourse serve as the tools accelerating STEM learning), while the "A" is for art, since the sciences and engineering cannot be taught without understanding illustrations, as well as two- and three-dimensional modeling.

Scientists, engineers, mathematicians, and other STEM professionals spend a substantial portion of their typical day applying skills and concepts that fall *outside* the traditional boundaries of their discipline. The National Research Center concluded that reading and writing comprises over half of the work of scientists and engineers (NRC, 2011). Speaking, listening, reading, writing, computing, sketching, and collaborating with others makes up the average day of most STEM professionals, where we use interdisciplinary competencies on an as-needed basis throughout the day. By completing the chart below, we are reminded of the natural interdisciplinarity of these careers.

Research indicates that approximately 13 percent of all students are auditory learners, suggesting that most schools are likely *not* meeting the learning needs of 87 percent of our students with lectures. In the STEM learning model, solving a real world problem serves as the vehicle for connected learning rather than a textbook designed for one discipline.

Willard Daggett identified the levels of academic content applications that prepare students for the future world as:

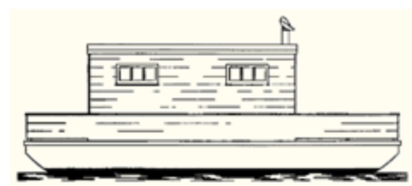
1. Knowledge in one discipline.
2. Application within one discipline.
3. Application *across* disciplines.
4. Application to real-world *predictable* situations.
5. Application to real-world *un*predictable situations.

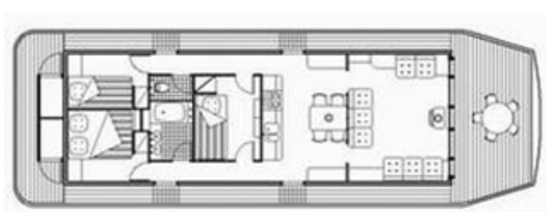
Daily, teachers hear, “When will I ever use this?” Under our STEM model (or umbrella), students actively apply the content, which makes *why* it is important to know such content obvious to them. These “aha” moments not only help students understand the advantage of an interconnected curriculum (reflecting a connected real world), but they also provide them with multiple access routes for understanding. Taking ownership for developing one’s personal knowledge becomes a treasure that students retain for a lifetime.

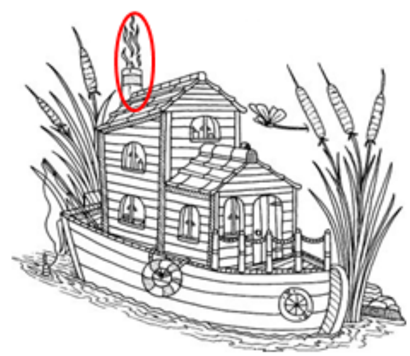
Parents and teachers should learn to recognize “where the STEM is” in what they already teach in class, do at home, or experience during the day. Nearly every aspect of our lives has a STEM element to it. Whether children are riding a car, train, bike, or bus, countless STEM elements are playing a crucial role in making it possible, which should be identified and discussed. Each building we enter came by way of combining multiple STEM/ST^{2}REAM fields, including art and design. Whether we are consumed by emails or productive desk work, or just “surfing the net,” computer technology and STEM made that experience possible. Well-trained creative STEM workers were behind it all. In the computer-dependent, technology-driven Western world, there is hardly a moment in our entire day that is truly “STEM-free.”

Here is an enjoyable STEM learning activity for families. Take a traditional storybook that presents a problem. Ask students to “engineer” a different (preferably better) solution to the problem in the story. For example, you have received an urgent e-mail message from the Three Little Pigs. They have been traumatized long enough by the Big Bad Wolf! Your family/class has been commissioned by the Three Little Pigs to engineer two safeguards to thwart the Big Bad Wolf. How many design and engineering models can you propose as solutions to the Three Little Pigs’ problem? Depending on age, students can provide a diagram and a written description of their STEM-based solution.

1. Design a new house for the Three Little Pigs with an aluminum rooftop (a *materials engineering* solution).
2. Replace the chimney with a central-heating system (a solution from *building services engineering*).
3. Wolves are afraid of snakes, so place a snake pit around the house (*agricultural engineering*).
4. Build a solar-powered environmentally-friendly fan that blows air *away from* the new house. When the wolf blows air *towards* the house, the fan will blow the air back towards the wolf (*applied engineering*).
5. Build a house with a 35-degree angle rooftop making it too steep to climb (*architectural engineering*).
6. Wolves are afraid of water, so install a motion-sensitive automatic water sprinkling system (*mechanical engineering*).
7. Recognizing the Big Bad Wolf's fear, build a houseboat ten yards from the shore (*structural engineering* and *environmental engineering*) with a retractable bridge, of course.







Student illustrations, oral and written presentations of STEM solutions (science-centered language development), to storybook fables and fairy tales, all afford students a measure of creativity that can be combined with skills from science, art, mathematics, language arts, design, and engineering. They can also make a claim to be proven or disproven with evidence-based solutions. By applying art and design, students can produce a model of their problem-solving inventions that changes the final outcome of the story.

One of the most extraordinary human traits is our ability to create — design, engineer, and manufacture — an indescribably diverse inventory of problem-solving tools, from respirators to battle axes to PET scans. Human beings were engaged in STEM enterprises well before we ever referred to them as “STEM.” Everywhere on the planet, people devoted significant portions of each day tinkering, experimenting, and thinking their way through a myriad of challenges, working creatively and collaboratively for survival. Early dreamers, designers, and builders crafted tools, instruments, and strategies for problem-solving.

By engaging in language, complex social structures, tool-making, and problem-solving, Homo habilis experienced exponential brain growth, enlarging both the cerebral cortex and a modified cranium to encase and protect it. Within a brief evolutionary period, our *Homo sapiens* brain doubled in size to 1350 cm-squared, where its distinguishing features were a new brain (1) that was extremely large relative to body mass, (2) that possessed the cognitive abilities to create tools, to reason and to plan, and (3) with the ability not only to adapt to a wide range of environments, but to create its own, rather than merely adjusting to the limits of one’s natural surroundings.

Although we have long entered the “Innovation Age,” creative thinking still takes a backseat to “standardized” thinking in our schools. Professor Yong Zhao and the Global Entrepreneurship Monitor recently reported an inverse relationship between high international test scores and entrepreneurship/creativity. However, creativity remains three times stronger than IQ as a predictor of individual lifetime success and accomplishment.

Almost 500 years after his death, Leonardo Da Vinci still tops most lists of the greatest scientific minds in world history. A “Renaissance Man” of insatiable curiosity and determined innovation, Da Vinci became an accomplished inventor, scientist, mathematician, painter, sculptor, architect, cartographer, engineer, anatomist, botanist, geologist, and writer. Da Vinci left us the following Seven Da Vincian Principles to guide the pursuit of scientific discovery:

1. Curiosità: An insatiably curious approach to life and an unrelenting quest for continuous learning.
2. Dimostrazione: A commitment to test knowledge through experience, persistence, and a willingness to learn from mistakes.
3. Sensazione: The continual refinement of the senses, especially sight, as the means to enliven experience.
4. Sfumato (literally “Going up in Smoke”): A willingness to embrace ambiguity, paradox, and uncertainty.

5. Arte/Scienza (Art and Science): The development of the balance between science and art, logic and imagination ("whole-brain" learning and thinking).
6. Corporalità: The cultivation of grace, ambidexterity, fitness, and poise.
7. Connessione: A recognition of and appreciation for the interconnectedness of all things and phenomena.

"Creativity requires the courage to let go of certainties," as psychologist Erich Fromm once said. Our test-centered schools may be unwittingly *constraining* student imagination by insisting that all thinking must conform to a preordained "correct" answer, rather than allowing for multiple solutions, multiple avenues to reach them, and more than one suitable answer to the same problem. The world may be in constant motion, and the future increasingly uncertain as 2075 approaches, but human ingenuity will always be an unbridled force, prepared to match whatever the future has to offer.

Kenneth Wesson is a former faculty member and administrator in higher education. He works with educators and administrators throughout the U.S. and overseas. He delivers keynote addresses to educational organizations and institutions on STEM, ST^{2}REAM, and the neuroscience of learning.