Going beyond fun in STEM

Instead of telling students that STEM is fun, tell them it's hard, and they'll feel a sense of pride and accomplishment at their success.

By Todd L. Pittinsky and Nicole Diamante

> It goes against the grain of modern education to teach students to program. What fun is there to making plans, acquiring discipline, organizing thoughts, devoting attention to detail, and learning to be self-critical?
>
> – Alan Perlis (1982), pioneering computer scientist and first recipient of the Turing Award

Science class doesn't get much more fun — and the science teacher never seems more cool — than at that moment when she drops a Mento into a bottle and a huge geyser of Pepsi shoots up to the ceiling. But that geyser is no Old Faithful; it soon fizzles. And so do the trajectories of far too many K-12 students across the U.S. who might have become scientists, engineers, and programmers. We see kids of all genders and ethnicities express a lot of interest in STEM fields in elementary school, but that interest drops off precipitously in high school and college as the work in those subjects gets harder. At first glance, it looks like the problem begins when the fun stops. Perhaps the great focus on fun is part of the problem?

American K-12 educators have been focused for some time on getting more kids interested in math and science by making the subjects more fun. This imperative only gained strength as studies began to show that the U.S. is not producing the number of science and engineering graduates it needs to keep ahead in the global economy. The STEM subjects, many decided, aren't fun enough, prompting the *New York Times*, for example, to ask: "Who Says Math Has to Be Boring?" (2013).

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If there is a lack of fun, it isn't for lack of trying. The National 4-H Council is responding to the lack of high school graduates ready for college-level math and science with a program designed to make these subjects "entertaining" (National 4-H Council, 2014). Arizona has camps and clubs intended to create ever more interesting experiences and make learning more fun (Arizona Science Center, 2012). A Raleigh, N.C.-based organization is "on a mission to make STEM fun" for kids by having them work with robots (STEM for Kids, 2014). David Steel, executive vice president of Samsung Electronics North America, explains that Samsung's "Solve for Tomorrow" contest for high school students aims to "foster future innovators by showing students how fun and powerful STEM can be" (Samsung, 2014). The U.S. Army Corps of Engineers held a youth program with an exercise called "Engineering is Fun!" An engineer told the kids that "[e]ngineering is all about having fun, solving real-world problems, creating things that work well and look good, and remembering to laugh out loud every day!" (Castagna, 2014). This is just a sampling of the many efforts nationwide to make STEM more fun and therefore more attractive to young people.

Fun isn't enough

What's left after the Mento geyser? A bottle of flat Pepsi and too many students who still arrive at college academically unprepared for STEM majors or — perhaps more important — emotionally unprepared to stick it out when the subjects inevitably get tough.

There is plenty of evidence that American K-12 students are not, on average, well-prepared in math and science. It does not seem to be an issue of spending; the U.S. government funnels $3 billion every year into STEM education initiatives — far more per pupil than other countries spend. Yet average scores for American 15-year-olds in 2012 on the Organization for Economic Cooperation and Development's Program for International Student Assessment math test were below the average of the 34 participating countries (OECD, 2013). In fact, U.S. scores were lower than the scores for 22 of the other 34 OECD nations and lower than scores for several non-OECD countries and regions, such as Shanghai, Singapore, and Hong Kong.

Despite all the fun in the classroom and in extracurricular programs, we're treading water. The

disappointing U.S. average mathematics score from 2012 — the latest year for which results are available — was not measurably different from PISA results in 2003, 2006, and 2009.

A pathway to success

It is not just a matter of winning or losing an international math contest. Learning STEM subjects is a pathway to good jobs, and those jobs are important to the American economy. Between 2001 and 2011, growth in STEM jobs was three times as fast as growth in non-STEM jobs (Economics and Statistics Administration, 2011). STEM jobs in the U.S. are projected to grow by 17% between 2008 and 2018 (Langdon et al., 2011). President Obama's Council of Advisors on Science and Technology predicts that over the next decade there will be 1 million technical job openings in the United States. Amazon itself had 1,500 technical positions open in 2013 (Chang, 2014). Yet only 17% of 12th graders are both proficient in STEM subjects and interested in STEM careers (Khazan, 2012).

And that thin pipeline of future scientists, engi-

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neers, and programmers really springs a leak in college. It turns out that about 40% of students who go to college intending to major in math, science, or engineering either switch to a non-STEM major before they graduate or don't graduate at all. If you include those with premed intentions, who on average are the best prepared and have the highest SAT scores, the attrition actually increases — to about 60%. This is twice as high as the attrition rate for all other majors put together. And by the way, the attrition rate for STEM subjects is far worse for minorities and women, who make up just a fraction of first- and second-year college students in STEM fields (Lautenberger et al., 2014).

What's going wrong? One big factor is that students who may have thought math and science were going to be more fun than ever in college enroll in the calculus, physics, and chemistry courses but decide they're too hard and too little fun (Drew, 2011). Students who were sold on fun may conclude they were sold a bill of goods. Compounding the problem, STEM majors who are having a hard time soon notice the grading norms in STEM fields and conclude they are working harder for worse grades — and switch.

Alternatives to fun

Making math and science more fun, particularly in early grades, has benefits but clearly is not sufficient for accomplishing what educators hope. What, then, to do? Instead of continuing down the fun STEM path, K-12 educators may need to focus less exclusively on intrinsic motivators such as fun and expand to more extrinsic motivators.

Intrinsic motivation is the urge to take part in an activity just for the experience of doing so (White, 1959). Intrinsic motivation stands in contrast to extrinsic motivation — the urge to take part in an activity in order to gain something else such as material well-being, status, connections, or companionship of others (deCharms, 1968). Many educators — particularly the large community promoting STEM — consider intrinsic motivation to be ethically and practically superior to extrinsic motivation and consider fun to be the primary intrinsic motivation for learning. They are mistaken on both counts.

Taking the second point first, there are more forms of intrinsic motivation for K-12 students than "having fun." Curiosity and mastery can be powerful intrinsic motivators and what they require is grit — the willingness to press on even when it isn't fun. As an education research construct, grit is undergoing ever more precise definition and experimentation. But it always has existed and always has mattered. Finding ways to encourage kids to stick with something even when it's hard and not much fun would do a lot to reduce the STEM dropout rate in college. K-12 is the time to instill that capability. While kids might struggle for longer periods than educators are comfortable with, there is so much joy and satisfaction once a young child reaches the aha moment. This is, in fact, one of the joys many report of teaching in STEM fields.

Not only is there no reason to treat fun as the only important intrinsic motivation for learning math and science, there is no research basis for so heavily favoring intrinsic motivation over extrinsic motivation. On the contrary, the notion that fun is somehow critical to developing a STEM workforce is seen to be nonsensical when we look at the countries with the most impressive STEM education achievements and the most math- and science-literate citizenry. Countries such as South Korea, Japan, Switzerland, and the Netherlands do not emphasize fun in STEM education, yet they consistently and impressively outperform the U.S. on STEM field international tests.

Pride, respect, a good job

Extrinsic motivations can, of course, be distorted or extreme, as can intrinsic motivations. But there is nothing wrong, indeed there is much good, in children being motivated by the idea that they will someday have a good job, make their families proud, or be successful and admired. Another powerful and

valid extrinsic motivation is a student's wish to earn the respect and attention of his or her teacher (Ryan & Deci, 2000). In 2014, a 40-year meta-analysis was conducted and published in the influential journal *Psychological Bulletin* (Cerasoli, Ford, & Nicklin, 2014). Based on findings from school, work, and physical performance domains (e.g. sports), the meta-analysis found evidence in support of both intrinsic and extrinsic motivation and, perhaps most provocatively, found that the two forms interact in complex ways. This suggests that focusing strictly on one form of motivation — in this case, intrinsic — in order to promote STEM will have less effect than a more balanced approach.

Beyond fun

One can hardly help noting that the national emphasis on STEM is extrinsically motivated in the first place. STEM careers are usually well-paying, and the U.S. needs more scientists and engineers to maintain its economic, political, and military preeminence. At the 2014 National Academy Foundation NEXT conference, U.S. Secretary of Education Arne Duncan expressed the extrinsic motivation plainly: "We have a skills gap in this country — and we have to close it. We will either keep or attract high-skill, high-wage jobs here in the United States, or they will migrate to countries that take this work more seriously" (2014).

It is naïve and disingenuous to have this extrinsic motivation pushing STEM as a national priority, but then count on young people to carry it out in the expectation that it will be great fun. Young people are quite capable of understanding and being motivated by extrinsic motivators such as career and respect. Emphasizing such motivations will not only be more effective, it will also show more respect for the students than a steady diet of Mento geysers and fun-bots. K

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