International Journal of the Whole Child
2021, VOL. 6, NO. 2

STEAM

STEM Content vs. A Sense of Wonder and Joy of Learning: It Shouldn't Have to be a Choice

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Abstract

The purpose of this reflective article is to examine how structured STEM programs often fail to promote key traits that are crucial to the scientific process including creativity, wonder, curiosity, and imagination. Typical STEM programs are content-driven, outcome-oriented, and scripted in a curriculum-centered, teacher-directed manner. Because of their rigidity, these programs often preclude more open-ended explorations that foster creative explorations in STEM. The article gives examples of scientists and inventors who dared to imagine and explored the world with a sense of wonder in non-scripted, active ways. The article discusses programs like Genius Hour and provides suggestions for promoting creativity in STEM programs.

Key Words: STEM, STEAM, Creativity, Wonder, Curiosity, Imagination

Introduction

During 39 years of a career in education at both the elementary and university levels, I have discovered a significant dichotomy in science-teaching philosophy. On the one hand, science teachers have been diligently following a standardized curriculum, arguably arbitrarily set by federal, state, or local officials in order to help students cope with "an ever-changing, increasingly complex world . . ." (U.S. Department of Education: Science, Technology, Engineering, and Math, including Computer Science, n.d., para. 1).

The compulsory standardized program was developed in 1996 by the National Research Council, simply known as the "National Science Education Standards," but eventually was expanded to include technology, engineering, and math (STEM) in 2005. In recent years, officials have added the Arts and Computer Science to the program, now recognized, unofficially, as STEM/CS. According to the United States Department of Education, the program is designed to prepare students to "bring knowledge and skills to solve problems, make sense of information, and know how to gather and evaluate evidence to make decisions" (U.S. Department of Education: Science, Technology, Engineering, and Math, including Computer Science, n.d., para. 1).

Although the compulsory curriculum has been designed to help students to become more efficient in the academic areas covered by STEM/CS, some educators are concerned that the standardized curriculum does not take into consideration such non-quantitative areas such as curiosity, creativity, imagination, and a sense of wonder, and how those areas are vital for the cultivation of new ideas, as well as the implementation and development of those ideas. Even adding the arts (STEAM) does not foster these characteristics in any meaningful way, as STEAM programs often are scripted, and teacher directed.

Science, technology, engineering, math, and computer science depend on the ability to imagine, be creative, and think outside the box to come up with hypotheses, methods of inquiry, and possible paths to solutions.

In a sense, the two approaches to the teaching of STEM/CS are at opposite ends of the thought spectrum: one representing a more structured approach with desired outcomes that can be identified and measured, while the other approach represents a more open-ended method that values curiosity and imagination. Some educators are concerned that one approach is more focused on the content of material being taught, while others place more emphasis on the importance of developing a sense of wonder, allowing the student to dream, imagine, and be curious – not only to come up with new ideas, but also to be creative in how to solve problems and find solutions. Sir Ken Robinson (2015) emphasizes that "a lifelong sense of curiosity is one of the greatest gifts that schools can give their students" (p. 136). Can we provide this gift for our students?

As a faculty member in the College of Education at a state university, my goals for teaching science methods courses were three-fold: 1) To recapture the JOY of learning; 2) To develop a sense of wonder; and 3) coming in a far distant third place was the content. Yes, to some, placing the science content that far below the other two goals may seem to be irresponsible. Let me explain.

Scientists and Inventors who Dared to Imagine

I have had several "heroes" in education who have greatly influenced me in my teaching career. Among those are Lt. Col. Francis Parker (1837-1902); Research Professor and author, Dr. Peter Gray; Sir Ken Robinson; and Alfie Kohn. Perhaps most influential in my career was Jerome Bruner (1915-2016). Jerome Bruner was a prolific researcher in the area of Cognitive Psychology and published many books relating to psychology and education. During WWII, he served on the Psychological Warfare Division of the Supreme Headquarters Allied Expeditionary Force Committee under the command of General Dwight D. Eisenhower. Furthermore, Jerome Bruner was one of the brightest scientific and educational minds who were chosen to participate at the Woods Hole Conference in 1959 (Smith, 2002). The Woods Hole Conference was formed in response to the Soviet Union's launch of Sputnik (1957), a small, artificial satellite, which orbited the Earth for three weeks before its batteries died, and then falling back to Earth. Among the 35 people who participated at the Woods Hole Conference were Robert Gagne, B.F. Skinner, Jerome Bruner, and many other educators, scientists, corporate officers, medical doctors, and mathematicians. The Woods Hole Conference led to the beginning of educational changes and social science reforms and was the inspiration for Bruner's 1960 book, *The Process of Education* (Evans, 2011). Bruner's ideas, born out the Woods Hole Conference, were the catalyst for major reform of the American educational system.

Among one of Jerome Bruner's statements that has been widely quoted from his book was one that intrigued me, as a science educator: "Any subject can be taught in some intellectually honest form to any child at any stage of development" (Bruner, 1960, p. 12). That statement was the topic of many personal conversations with colleagues, usually resulting in no consensus of opinion, but it certainly piqued my interest. Further readings led me to another statement: "Content knowledge is the natural consequence of process."

I used that powerful statement for each class that I taught for eight years. During that time, I searched and searched to find the reference for Bruner's wise statement - to absolutely no avail. So, sometime in 2006, I called Dr. Bruner at his office at New York University to ask him where I could find that reference. To be honest, I did not even know if he was still living (if so, he would have been 90 years old). To my great surprise, he answered his phone, and we had a very nice, yet brief, conversation. I asked about the statement, and to my even greater surprise, he responded with, "You are not able to find the reference to that statement because I never said that. But it is a good one, and I wish I had said that." He went on to explain, "What I did say was, 'Knowledge is not found in the content, but in the activity of the person operating within the content domain'" (J. Bruner, personal communication, 2006).

The conversation with Jerome Bruner changed my thinking completely. And it clearly places me on the side of those educators who are more concerned with enabling students to develop their imaginations, creativity, curiosity, and to me, the most important quality of all: to instill a sense of wonder in our students. If they are free to exercise those qualities, they will become so immersed in following their own interests, the content *just happens*. I firmly believe you cannot stop it from happening.

There are countless examples of scientists and inventors who have become famous for their contributions to society as a direct result of their passionate and creative curiosity and imagination. Most of them did not reach their levels of success and notoriety by memorization and recall. According to Bruner's statement, "Knowledge is not found in the content, but in the activity of the person operating within the content domain" (J. Bruner, personal communication, 2006). Activity within a content domain requires curiosity, imagination, and creative thinking. These important qualities are not usually found, encouraged, or valued in the standardized curricula in most schools.

Perhaps one of the most well-known examples of a successful scientist who gained notoriety by just “messing around” was physicist, Richard Feynman. As a Cornell professor eating in the school cafeteria, a friend tossed a plate in the air. As the plate spun around in the air, Feynman noticed that the school logo in the center of the plate was spinning at a different rate than the outer edges of the plate. That piqued his curiosity, so just as he did as a child, when he would simply tinker around in his home-made lab laboratory, creating simple gadgets, motors, and photocells, Feynman began to study the rotation of the plate. He had no apparent reason for doing so, other than the fact that he enjoyed it. He eventually worked out a mathematical formula that explained, through quantum electrodynamics, the wobble and rotation of the plate. The result of his “messing around” with that plate earned him the Nobel Prize for Physics in 1965 (Feynman, 1985; Wasserman, 1992).

In his book, *Surely, You’re Joking, Mr. Feynman!* (1985), Feynman said, “I don’t know what’s the matter with people; they don’t learn by understanding; they learn some other way -- by rote, or something. Their knowledge is so fragile!” (p. 44). In regard to some of his university students, Feynman figured out that they “memorized everything, but they didn’t know what anything meant . . . Everything was entirely memorized, yet nothing had been translated into meaningful words” (Feynman, 1985, p. 242-243).

In Richard Feynman’s case, he acquired meaning by *playing* with objects and ideas, figuring out how things work and finding solutions for problems. He called it “piddling around.” Perhaps the standardized STEM/CS curriculum should include a section on piddling around.

Leonardo da Vinci (1452-1519) is known for his imaginative inventions that were hundreds of years ahead of their time. He was a painter, engineer, architect, theorist, and, of course, the inventor of such futuristic creations such as an armored fighting vehicle, an adding machine, a flying machine similar to a helicopter, solar power, and the hydraulic pump, among many other inventions. Leonardo was not necessarily known as a genius, as we would define it today. Yet he was extremely imaginative and highly creative. He was curious about many things such as a goose’s foot, what a woodpecker’s tongue looks like, how birds fly, astronomy, geology, mechanics, and the human anatomy. As Stone (2017) notes, imagination gives people the freedom to create and invent, which is a foundation for their future roles in society.

Leonardo da Vinci was self-taught. What little schooling he had was focused on mathematics, yet he found few benefits of formal schooling, instead spending his time experimenting. He considered himself a free-thinker, and once said, “I suspect that people will say that ‘I have no book learning’ . . . but they do not know that my subjects require experience rather than the words of others” (Isaacson, 2017, p. 4). For da Vinci, personal experience and experimenting brought knowledge and understanding.

There is also the example of a scientist who, by “messing around” with things and ideas, came up with an invention that not only earned him an obscene amount of money, but also helped him to be inducted into the Alabama Engineering Hall of Fame in 2011 (Raatma, 2020; Schwartz, 2018). Lonnie Johnson was born in Alabama in 1949. As a young boy, he loved to fix things. “As far back as I can remember,” Lonnie recalled, “I was interested in devices and how they worked . . .” (Raatma, 2020, p. 8). Lonnie mounted a lawn mower engine on a go cart and drove it around his neighborhood. At one point, Lonnie attempted to make rocket fuel on the stove top, but it caught fire. Instead of being angry, his parents “bought him a hot plate and told him to do his experiments outside” (Raatma, 2020, p. 9). The valuable lesson here is that Lonnie had parents who supported him and encouraged his creativity and imagination as he experimented with various inventions.

Lonnie Johnson continued his curiosity through high school and college at Tuskegee University in Alabama, where he earned a bachelor’s degree in mechanical engineering, and a master’s degree in nuclear engineering. He went on to work as a research engineer at the Oak Ridge National Laboratory before joining the United States Air Force (Raatma, 2020; Schwartz, 2018). In 1979, at the age of 30, Lonnie began working as a nuclear engineer for NASA at the Jet Propulsion Laboratory in Pasadena, California. There, he worked on numerous space missions, including the Galileo mission to Jupiter and the Cassini mission to Saturn.

Johnson had an extremely important job, working for NASA. Yet, he never gave up on his imagination and curiosity, so on his free time, he would “mess around” with other ideas. Hoping to invent a better heat pump that used water instead of Freon, he created and attached a high-powered nozzle to the pump. He attached his creation to the bathroom sink, and to his great surprise, a strong stream of water shot all the way across the bathroom (Raatma, 2020; Schwartz, 2018).

Thinking of how his invention could be utilized, he came up with the idea of modifying this invention to create a children’s toy: a high-powered water gun that he named the *Power Drencher*. After several additional modifications, he came up with a new name for his creation: Super Soaker™.

Lonnie Johnson, a curious child who grew up to be a mechanical and nuclear engineer, through his excitement to “mess around” with things, became the creator of the Super Soaker™ water gun, which he sold to Hasbro Corporation. That toy water gun soon became the best-selling toy in history of the United States in 1991, earning over one billion dollars in sales.

Even in his older life, according to Raatma (2020), “Johnson is always trying new things. Some things work, and others don’t. He must use his imagination when inventions fail. He tries over and over until the product works” (p. 26).

This article only gives a few examples of how imagination, curiosity, and creativity can lead to amazing creations and inventions. Most of the examples we find are discoveries made while “messing around” outside of school, and on free time. Consider what could be done in a school setting where children are free to explore their own imaginations without being constrained by a national, standardized curriculum with limited and expected outcomes.

Another fascinating story describes the path that led Jennifer Doudna from a curious child amazed by discovering interesting things about the flora (i.e., ferns) of her home in Hawaii, to discovering the details of the nature of DNA. Doudna’s curiosity and imagination eventually led her to Harvard University, where she studied the intricacies of DNA. The chair of her doctoral dissertation committee and Nobel Prize winner, Dr. Jack Szostak, encouraged her to study RNA, of which he thought would unlock the "biggest of all biological mysteries: the origins of life" (Isaacson, 2021, p. 45).

After receiving her doctorate in physical chemistry, Doudna continued her work in one of the top RNA biochemical laboratories at the University of Colorado. From there, she accepted a professorship at Yale University, and finally to the University of California at Berkeley, where she applied her knowledge of RNA as it related to viruses, such as the Coronavirus. Doudna and a colleague, Dr. Emmanuele Charpentier, are credited with inventing and developing a gene-editing tool called, CRISPR, which was a "cut and paste" tool that could, in a sense, peer into the antivirus defense system of bacteria and alter it to allow the bacteria to detect a viral attack and fight back.

So how did a young girl who was so intrigued by ferns in Hawaii that would curl up when you touched them, begin a path that would lead her to winning a Nobel Prize in Chemistry? According to Walter Isaacson (2021) in his book, *Code Breaker*, Doudna was especially curious and looked at "nature's wonders every day, whether it be a plant that moves or a sunset that reaches with pink fingers into a sky of deep blue" (p. 5). She was always asking questions to find why things worked the way that they do.

In her early years as a college student studying chemistry in California, she realized that the experiments she conducted were simply following a recipe, with strict, inflexible protocols and right answers (Isaacson, 2021). There was no room for imagination, curiosity, or creativity. After a disappointing freshman year, she got a summer job in a biology lab working with a professor at the University of Hawaii. As she worked with the professor, she discovered how different her lab experiments could be. "Unlike in class, we didn't know the answer we were supposed to get" (Isaacson, 2021, p. 33). It was in this lab that she tasted the thrill of discovery because she had the freedom to explore her passionate curiosity. As Doudna's colleague Charpentier noted, as a scientist, "I wanted to create knowledge, not just learn it" (Isaacson, 2021, p. 121).

As the teacher may have asked in the movie, *Ferris Bueller's Day Off*, "Who has ever heard of *Richard Drew*? Anyone? Anyone?" The response to that teacher's boring questions in the movie are most likely the same responses that you are providing for that same question . . . silence. But I'll bet you a whole quarter that you have heard of the *product* that Drew came up with by just "messing around."

Richard G. Drew was born in Minnesota in 1899. As a young man, Drew played the banjo in night clubs and dance halls, which provided him enough money to enroll as an engineering student at the University of Minnesota. College just wasn't his thing, so he dropped out after just a little over a year. He enrolled in a correspondence course, studying mechanical design. Using the knowledge gained from that course landed him a job at the Minnesota Mining and Manufacturing Company (3M) which made sandpaper (Matchar, 2019).

As a part of his job with 3M, he would deliver sandpaper to automobile shops, which used the sandpaper to smooth the finish on cars that were scheduled to be painted. At that time, the painters would use glued-on newspaper to mask off areas that were not to be painted, such as windshields, mirrors, and headlights. But the problem with this method was that the glue didn't stick to the car very well, and it kept falling off. To add to the problem, the sticky glue residue was difficult to remove. Workers became very frustrated with the inefficiency of the gluing method. So, while on the job at 3M, Drew began experimenting with better ways to hold the newspaper to the cars. He tried coating various materials with vegetable oil, tree gum, and many other sticky substances.

One day, Drew was approached by William McKnight, a company executive at 3M, and Drew's boss, who told him to "stop messing around and get back to doing his regular job" (Matchar, 2019, para. 6). Drew obeyed his boss's command while at work, but on his own time, he kept "messing around," trying to find a solution to the painter's problem.

"Eventually, in 1925, he found a winning formula: crepe paper backed with cabinetmaker's glue mixed with glycerin. But this first version of masking tape only had adhesive on the edges. When the painters used it, it fell off. They allegedly told Drew to take his 'Scotch' tape back to the drawing board, using the term to mean 'cheap,' a derogatory dig at stereotypical Scottish thriftiness" (Matchar, 2019, para. 7). After five years of refining his "masking tape," Drew received a patent on his product.

The same year he invented his "Scotch" masking tape, Drew developed a semi-transparent tape using recently invented cellophane. However, the adhesive that he used was amber colored instead of transparent, so he continued to experiment with other materials until he came up a colorless adhesive. He also designed a machine that would apply the adhesive to the cellophane. Remembering his earlier days at 3M, Drew recovered the Scotch name for his product: Scotch Tape™. "The tape was released just as America plunged into the Great Depression, a time when 'mend and make do' became a motto for many. People *used Scotch tape for everything* from mending ripped clothing to capping milk bottles to fixing the shells of broken chicken eggs. At a time when many companies were going under, tape sales helped 3M grow into the multibillion-dollar business it is today" (Matchar, 2019, para. 9). Remarkedly, every year, the 3M company sells enough Scotch Tape™ to cover the Earth's circumference 165 times!

William McKnight, Drew's boss, who told Drew to "stop messing around," eventually was promoted to the Chairman of the Board of Directors at 3M, and finally realized that allowing researchers to spend free time experimenting with various ideas could lead to new and innovative products. McKnight then implemented a 15% rule, which allowed workers to spend 15% of their time on what he called "passion projects." When announcing this new program, he said that it would encourage experimental doodling. He said, "If you put fences around people, you get sheep. Give people the room they need" (Matchar, 2019, para. 11).

Drew went on to invent many other products during his career at 3M. Before he died, he made the statement that there is great joy in "finding something valuable in something not even sought out" (Matchar, 2019, para. 12). After Drew died in 1980, he was initiated into the National Inventors Hall of Fame.

Interestingly, 3M's 15% rule has become the model for many other corporations, such as Google and Hewlett-Packard (Black, 2016; Matchar, 2019). Google says that, perhaps, 20% of their new ideas and products have come from their version of the 15% rule. Art Fry, the inventor of the Post-It™ notes, used the 15% rule to develop that product while experimenting with a removable adhesive that would allow bookmarks to easily be removed from church hymnals (Kretkowski, 1998).

Conclusions

So, the question demands an answer: If million-dollar corporations have unbelievable success with giving their employees free time to use their imaginations, their curiosity, and their creativity to develop new and innovative ideas and products, why is our education system ignoring such opportunities for students?

Oh, I know what you are thinking. Many schools are beginning to implement their own version of the 15% rule, which they now call "Genius Hour" (Genius Hour, 2021). The Genius Hour encourages teachers to provide time for students to "explore their own passions and encourages creativity in the classroom" (Genius Hour, 2021, para. 1). Students are given time during the school day to choose their own *passion projects*. Genius Hour based their approach on Google's 20% rule. Google found that employees who spent 20% of their time using curiosity and passion to create their own projects were "happier, more creative, and more productive" (Heick, 2021, para. 4). Would this same approach do the same for students? I think the concept of supporting students' passion projects is a great idea, and I wish that every school would implement a similar program.

So far, however, many of the schools that are currently using that program are not giving students time to be imaginative, curious, and creative to come up with their own ideas and products. Rather, many schools simply use the so-called Genius Hour to do teacher-directed projects that have expected outcomes. For example, in the program, teachers are encouraged to facilitate "the student projects to ensure that they are on task" (Genius Hour, 2021, para. 5). Being "on task" actually belies the title of the program and suppresses student choice and autonomy. But, I suppose, if students are free to follow their own creative ideas, the Genius Hour concept could be a positive step in the right direction if the priority is students' imagination, curiosity, and creativity – not attendance to the required task.

Instead of implementing a school version of the 15% rule or Genius Hour as a separate "reward" time, why can't we build such a program directly into the STEM CS curriculum? The results just might set students on a path from just "messing around" to the next Nobel Prize! As previously stated, educators should be more concerned with enabling students to develop their imaginations, creativity, curiosity, and to me, the most important quality of all: to instill a sense of wonder in our students – not simply covering the standardized curriculum. If students are free to exercise those qualities, they will become so immersed in following their own interests, the content *just happens*. I firmly believe you cannot stop it from happening. In considering STEM content versus a sense of wonder and the joy of learning: It shouldn't have to be a choice!

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