MAKER EDUCATION

Why Making Is Essential to Learning

JULY 18, 2016

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Making is as old as learning itself. While the maker movement (http://www.edutopia.org/topic/maker-education) may only be about a decade old, the human desire to create dates back to the earliest forms of human activity, from making stone tools to drawing on cave walls (Halverson & Sheridan, 2014; Martinez & Stager, 2014). Thinkers such as Pestalozzi, Montessori, and Papert (http://www.edutopia.org/blog/maker-movement-shoulders-of-giants-sylvia-martinez) helped paved the way for the maker movement by stressing the importance of hands-on, student-centered, meaningful learning. Instead of viewing learning as the transmission of knowledge from teacher to student, these thinkers embraced the idea that children learn best when encouraged to discover, play, and experiment.

More recently, maker education (http://makered.org/) is being used as a way to connect do-it-yourself informal learning to classrooms. Driven by new technologies such as 3D printing, robotics, and kid-friendly coding, making is emerging as an effective way to introduce students to STEM, particularly women and minorities. By incorporating elements of making into the classroom, educators can bridge the gap between what students are passionate about and what they're learning in school.

The Science of Hands-On Learning

At the heart of making is the idea that all students are creators. Instead of just memorizing material for a test, students are encouraged to use what they know to design and build projects, whether it's hacking everyday objects to make music (https://www.youtube.com/watch?v=RRwqutcy5B0) or using a 3D printer to build a mechanical prosthetic hand for a child (http://www.edutopia.org/blog/innovative-ed-what-if-thinking-making-room-suzie-boss) .

Hands-on learning plays a key role in maker education. A typical makerspace looks more like a workshop than a classroom (http://www.edutopia.org/blog/designing-a-school-makerspace-jennifer-cooper) , with tools, art supplies, and computer parts filling the room. Textbooks, if present, are more likely to be used as references -- a tool to help students design and build their projects -- unlike traditional classrooms where memorizing the textbook itself may be the goal.

Maker Education: Reaching All Learners

At Albemarle County Public Schools, making fosters student autonomy, ignites student interest, and empowers students to embrace their own learning. "One of the things that we've discovered is that maker education with kids gets them engaged, gets them passionate about the work, gives them opportunities to pursue things that they're interested in," says Superintendent Pam Moran. "And as a result, it really raises the level of work that kids are doing, and it starts to make sense. School makes sense."

Research shows that hands-on learning is an effective way to teach students science. A 2009 study found that eighth-grade students who were involved in hands-on science projects demonstrated a deeper understanding of concepts than students who were taught with traditional methods such as textbook readings, lectures, and tests (Riskowski et al., 2009).

Why is hands-on learning effective? We can look to neuroscience for insight. Students who *participate* in science experiments, instead of just observing them, have a deeper conceptual understanding of science. Through brain imaging, researchers found that physical experience activates the sensorimotor region of students' brains, which helps reinforce what they're learning (Kontra et al., 2015). If students use their hands as well as their minds, they're essentially learning twice.

Maker Mindset: Teaching Students to Ask Questions and Embrace Mistakes

Maker education is more than just tools and technology. Dale Dougherty, the creator of Maker Faire, sees making as a way to develop one's full potential: "Fostering the maker mindset through education is a fundamentally human project -- to support the growth and development of another person not just physically, but mentally and emotionally" (Dougherty, 2013).

Making encourages students to pose their own questions and pursue answers in an organic way. In contrast to a "single correct answer" approach, making is a mindset, a way to approach problem-solving through experimentation and play. Mistakes are a part of learning, since they show that students are pushing the boundaries of their capabilities. Every mistake made is an opportunity to incorporate feedback into a new design, a way to solve challenges previously unforeseen. To quote Claude Lévi-Strauss (https://en.wikipedia.org/wiki/The_Raw_and_the_Cooked) , "The scientist is not a person who gives the right answers, he's one who asks the right questions."

In a culture of high-stakes testing, students can be too focused on finding the right answers, when they should also be thinking about the right questions.

Questioning can be a powerful form of learning. Research shows that students learn more deeply when they can apply classroom-gathered knowledge to real-world problems. Asking questions provides context that helps reinforce student learning, and it helps students transfer their learning to new kinds of situations, including ones outside of the classroom (Barron & Darling-Hammond, 2008).

A Powerful Force for Inclusion

One of maker education's more exciting trends is its ability to attract students who may be underrepresented in STEM fields. Despite being 57 percent of the undergraduate student population, women make up only 19 percent of engineering students. Black and Hispanic students, who make up 29 percent of undergraduates, constitute only 15 percent of engineering students (NSF, 2015).

Why are women and minorities underrepresented in STEM? One possible reason is the style of teaching typically used; a 2014 study compared college-level biology courses taught in a traditional lecture format with an active-learning format (providing more student guidance and interaction) and found that when active learning was used, average exam scores increased, with black and first-generation students benefitting the most (Eddy & Hogan, 2014). In other words, active learning can be a powerful tool to help make STEM more inclusive.

With its focus on creativity, art, play, and do-it-yourself projects, making has the potential to appeal to a wide range of interests. A 2014 report found that girls who participate in maker programs develop stronger interest and skills in computer science and engineering (Wittemyer et al., 2014). By engaging in making, girls can gain the skills, knowledge, confidence, and self-efficacy necessary for a successful career in STEM.

True learning is a continuous cycle of curiosity, investigation, experimentation, research, and reflection, all of which are key features in making. While maker education is often defined in terms of 3D printers and Arduino boards, it's really the *culture around making*, rather than the act of making, that makes it essential to learning.

Notes

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