Engaging Students in STEAM Learning

How to provide high-quality learning opportunities for all students

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Full STEAM Ahead

STEAM learning is essential for many reasons. Here are three keys to success.

As a child, geology instructor Edith Carolina Rojas was always curious about the world around her. She grew up in Nicaragua, where she was surrounded by volcanoes, and she wondered how they formed and why they were different from other mountains. She even built a make-believe laboratory in her backyard.

But it wasn't until many years later, when she was an undergraduate student at California State University, Los Angeles, that she actually considered becoming a scientist herself.

"To be honest, I didn't think I was intelligent enough to go into science," she admits.

When she was 20 years old, Rojas got to use a microscope for the first time in a biology class at Cal State. At that moment, "I felt like a real scientist," she recalls. "The child who used to play in her make-believe lab felt validated."

Then she took her first geology class, and "something really clicked." She learned about subduction and the process that creates volcanoes and how it differs from the one that creates mountains. "I thought: I have arrived," she says. "This is home. I need to explore this as a career."

Why STEAM Learning Is Critical

Rojas did not discover her passion for science, technology, engineering, arts and math (STEAM) disciplines until she reached college. Many students never become engaged in these subjects. That's troubling for a number of reasons.

Global management consulting firm McKinsey & Co. estimates there will be 50 million new technology jobs created by 2030. These high-paying jobs include computer scientists, engineers and IT administrators.

What's more, by 2030 there will be at least 300 million more people ages 65 and older than there were in 2014, McKinsey says — which will create a huge demand for health care workers such as doctors, nurses and health technicians.

Engaging students in STEAM subjects not only creates pathways to future job opportunities; it helps them become adept at solving all kinds of problems they might encounter, regardless of their chosen careers. And it prepares them to be effective global citizens because students' ability to contribute to an increasingly complex society depends on STEAM literacy.

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Keys to Success

Rojas' own experience is instructive because it reveals some of the keys to engaging students effectively in STEAM learning:

Tools. As Rojas observes, getting to use a microscope for the first time was a powerful experience. It made her feel like an actual scientist because she was using the same tool that professionals use every day.

To a student growing up in the United States, using a microscope might not seem like a big deal. But technology is making even advanced scientific tools more accessible to students of all ages, which could ignite a passion in STEAM learning early on in a child's life.

"If you look at a smartphone, it's got access to accelerometers, acoustic analysis systems, high-performance cameras," says David Evans, executive director of the National Science Teachers Association. "A decade ago, all of those things would have been considered sophisticated laboratory equipment." This exposure to the actual tools of science, he says, "is huge."

Inquiry. Using the same tools that scientists and engineers use in the field allows students to engage in authentic, inquiry-based learning, which helps bring these subjects to life.

"How you run your classroom is very important," says Rojas, who is an assistant professor of geology at the College of the Desert. "You might have students who have never left the city where they were born. But if you can bring the world to them in those 50 minutes, and if you can make the subject tangible for them by having them solve real problems, that's inspiring."

She adds: "Something truly magical happens when students are doing the actual work. Concepts are important, and we need them, but it's the application that gets students engaged and gives them that 'aha' moment."

Belief. Some students might feel intimidated by STEAM concepts. They need assurance that they can tackle these subjects and have success.

"Even on the hardest days, when the subject you're teaching is difficult, it's important to remind your students that it might be uncomfortable for them now because the topic is new, but it's not always going to feel that way," Rojas says. "Just keep telling them: 'I know it feels tough today, but this is the first time you're seeing this. Keep at it. You can do it. I got through it.'"

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Promoting Equity in STEAM Learning

Schools must focus on engaging underrepresented students as well. Here's how.

When Edith Carolina Rojas enrolled in science classes at California State University, Los Angeles, she saw many other students who looked like her: young women of color. But when Rojas, who moved to the United States from Nicaragua when she was 18, looked at her science instructors, she saw only one other woman.

"Everybody else was male and predominantly white," says Rojas, who is now an assistant professor of geology at the College of the Desert. "I began to wonder: What is going on here? Something does not add up."

Although K–12 schools and higher-education institutions have made strides in encouraging young women and minorities to enter STEAM careers, "we can do better," says Carol Jenkins, president and CEO of the nonprofit organization World Learning.

Globally, women hold less than 30 percent of STEAM-related jobs, Jenkins says. According to UNESCO, although women are entering bachelor's and master's degree programs at roughly the same rates as men, they are far less likely to pursue doctoral degrees — and the stereotypes and bias they encounter play a big role in this attrition.

In the United States, women occupy just 24 percent of STEAM positions, according to figures from the Department of Commerce. A 2015 analysis by The Verge revealed that among seven of the largest high-tech companies in the U.S. — including Google, Microsoft and Facebook — only 29 percent of employees, on average, were women.

High-Quality Instruction Is Essential

For poor and minority students in particular, "the barriers are often resource-related," says David Evans, executive director of the National Science Teachers Association. Access to high-quality STEAM instruction is a key challenge standing in the way of encouraging more minority students to pursue STEAM careers.

Finding appropriately trained teachers who have deep content knowledge in the STEAM disciplines is a challenge for all schools, but especially those with large underserved populations. Yet, when educators have a strong background in the content areas they are teaching, "their students tend to perform better," Evans says.

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Knowledgeable and well-trained teachers are more likely to engage students' interest in STEAM subjects because they can lead students in rich conversations that spark curiosity and inspire students to learn more. They also have a better sense of the exciting things going on in those fields and how STEAM learning connects with the real world.

Understanding real-world applications is critical to igniting students' passion. When Rojas landed an internship with the U.S. Geological Survey as an undergraduate student at Cal State, she got to see how geologists work behind the scenes — "not just to find answers, but also to help us stay safe during a natural disaster," she says. "I loved that, because you're doing the science but you're also serving the public." Motivated by her experience, she went on to become a geologist.

The Importance of Role Models

Providing access to high-quality instruction is an important strategy for inspiring girls and minorities to consider STEAM careers, but so is exposing them to STEAM professionals who look like they do.

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Rojas describes one of the most powerful moments she had as a student: "I was at a conference with the Geological Society of America, and I saw a Colombian woman with an accent thicker than mine. She worked for the National Science Foundation and was a college professor as well. This woman had made it. I could see that she was everything I wanted to become — and all of my goals became real. Everything seemed attainable."

Giving students role models they can aspire to is a compelling reason to pursue diversity in hiring STEAM faculty. But educators can also bring STEAM professionals with a variety of backgrounds into the classroom to talk with students, either in person or online. For instance, a company called Nepris matches teachers with STEAM experts and hosts video conferences to connect students with these professionals.

When Rojas met the female geologist from Colombia, "I saw somebody who looked and sounded like me," she says. "It validated my struggle, and it showed me there was a place for me in science."

Gender Gap Persists in AP Courses

Although the gender gap among students in STEAM-related Advanced Placement courses is shrinking, and girls outnumber boys in taking the AP Biology exam, they still lag behind in physics and computer science, data from the College Board reveal:

Subject	2018 exams	Male	Pct.	Female	Pct.
Computer Science	137,320	98,882	72%	38,438	28%
Physics	278,867	181,465	65%	97,402	35%

Robotics to the Rescue

Robotics programs can engage students effectively in STEAM learning

Robots have captured students' imaginations for decades, from the sci-fi movies of the 1960s to the hugely popular Transformers series today. So it's no surprise that K¬–12 robotics programs have exploded in recent years as a way to engage students in STEAM learning.

In fact, some K–12 leaders have begun using the term "STREAM" education, adding an "R" to refer to robotics instruction.

"Robotics programs have become wildly successful in schools," says David Evans, executive director of the National Science Teachers Association. "Literally millions of students are participating in them. I think that's a measure of how exciting the work is. It's got an element of competition and of building things."

Robots provide a very engaging platform for learning STEAM concepts, Evans explains: "They capture students' imagination. And once you get students engaged, then the work of robotics becomes work they want to do. They want to learn the math and the physics and the coding required."

Aiming to tap into the popularity of robotics, a number of companies have introduced robotics kits designed to make the topic more accessible for students, such as LEGO Education, Pitsco Education, BirdBrain Technologies and Sphero.

In building and coding their own robotic devices, students are not only learning important STEAM concepts; they're also learning key skills such as problem solving, creativity, collaboration and persistence.

"Learning about robotics in a K¬–12 setting can foster the next generation of innovation and provide a venue for students to tackle global and local challenges," says the Consortium for School Networking (CoSN) in a joint publication with the now-defunct New Media Consortium. For instance, student teams participating in the 2017 FIRST Global Robotics Games addressed the international water crisis by developing solutions to store drinkable water, filter contaminated water and find new sources of clean water.

The FIRST robotics competitions are among the many student robotics tournaments that have sprung up worldwide in which teams of students build and program robots to

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accomplish a defined task or complete a goal the fastest. Recognizing the teamwork involved in these events, many U.S. states — including Connecticut, Minnesota and Texas — have named robotics as an official high school sport, the CoSN report says.

While after-school robotics clubs and activities are making a big difference in STEAM learning, Evans cautions that K–12 leaders need to make sure students have a chance to participate in robotics instruction in their classrooms as well.

"We need to give all students these opportunities, and not just those who are able to take part in an after-school club," he says. "Sometimes something as simple as transportation can be a barrier to participation — especially for students who are already underserved. That's why I'd like to see more effort to bring these programs into the regular curriculum as well."

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Robotics by the Numbers

Robotics instruction isn't just a useful way to engage students in STEAM learning. It can also put students on a pathway to successful careers. As robots transform a host of industries, from manufacturing to the military, here are some figures illustrating the anticipated growth in this field.

2.5M Estimated number of industrial robots in use by 2019.

565% Expected growth in robotics worldwide from 2016 to 2021.

$266B Estimated value of the robotics industry by 2021.

(Source: NMC/CoSN Horizon Report: 2017 K–12 Edition)

Virtual Reality Can Make a Real Impact on STEAM Learning

Edtech companies have been promoting the benefits of augmented and virtual reality as emerging instructional tools for many years. Now, students are finally starting to reap these benefits, as augmented and virtual reality are helping to bring STEAM concepts to life.

"It's very exciting," says David Evans, executive director of the National Science Teachers Association. "I think we're still in the early phases, but we're beginning to see much more use of these technologies."

Augmented reality (AR) is a technology that layers computer-generated enhancements on top of existing reality. Virtual reality (VR) is a fully immersive experience in a computer-generated environment.

For a long time, the hype around these technologies exceeded their usefulness in the classroom. But now they're beginning to make a real impact on teaching and learning, as

hardware costs have come down and new applications have emerged that make AR and VR accessible in most schools.

VR headsets range widely in price, with powerful options becoming more affordable every day. Acer makes a Windows Mixed Reality Headset with a street price that's less than $250. At a basic level, Google Cardboard sells for less than $10, although students need smartphones to use Google Cardboard viewers.

Students are using these technologies to experience places that would be difficult to travel to physically. For instance, they can use Google Expeditions to take virtual field trips to Antarctica or the International Space Station. Or they can take a tour of the solar system with apps such as Titans of Space.

In addition, AR and VR can make abstract concepts seem much more real than if students simply read about them in a textbook. An augmented reality app for Windows 10 called Lifeliqe, for example, brings science to life with interactive 3D models that

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blend augmented reality with a digital curriculum aligned with Next Generation Science Standards (NGSS).

When students push the blocks together, they can see those elements combine to make a new substance. If students touch hydrogen blocks to an oxygen block, they'll see water virtually form within the cubes.

"To be immersed in an environment is a different experience," Evans says. "It involves more of your senses than just reading."

AR and VR technologies can also make scientific experiments more available to students.

"Doing laboratory work requires a lot of setup," Evans observes. "There are safety issues, and there are significant expenses involved in having appropriately equipped science labs. This limits the number of real science experiences that

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students can have. But with augmented or virtual reality, you can expand this dramatically."

He adds: "As long as we don't go too far and think this is a way to replace having actual, personal experiences, I think the opportunity for enriching students' experiential learning of science using augmented and virtual reality is huge."

Use of AR and VR Is Small — But That Could Change Soon

While augmented and virtual reality are being used in only a small number of classrooms to date, STEAM educators at the high school level are using them at twice the rate of other teachers — and they figure prominently in students' visions for the future of education.

5% of teachers say they're using AR or VR in their classrooms

9% of high school science teachers use AR or VR technologies.

11% of high school computer science/technology teachers use AR or VR.

33% of high school students say VR is a must in their school of the future

47% of middle school students see VR in their vision for the ultimate school.

(Source: Project Tomorrow, 2016 Speak Up survey results)

Making Their Mark

Makerspaces are inspiring a new generation of STEAM innovators

What better way is there to immerse students in STEAM learning than by having them design and build their own bridges, circuits, computers and other objects? That's the idea behind school makerspaces, and it's easy to see why they have taken off.

"When you present students with a roomful of materials and let them invent and explore, you're tapping into one of the most effective kinds of learning, which is learning by doing," says David Evans, executive director of the National Science Teachers Association. "You would never learn to play the piano by listening to lectures about music theory and the physics of the piano. You would sit down at the keyboard and start making sounds."

While tinkering and exploring, students learn not just STEAM concepts like how an electrical circuit works, but also creativity, problem solving and other "soft" skills that employers desire. Perhaps best of all, their learning is driven by their curiosity.

"Makerspaces provide the kind of engagement we'd like to see," Evans says. "Students are invested in their learning because they're working on things that are of interest to them."

This constructivist approach to learning has been around for a long time. But what's new today is the sophistication of the tools available to students for creating. Students can use free modeling software and 3D printers or laser cutters to design and create things they would have needed a machine shop to produce before — and electronics kits like littleBits, Makey Makey and Raspberry Pi make it possible for students of all ages to build circuits, controllers and computers.

The challenge facing educators is how to channel students' passion and creativity in ways that advance learning. One way to do this is to give students specific problems and challenges that align with curriculum goals.

"The kinds of problems you give students, and the things you want them to learn, will inform your decisions about the kinds of materials you'll put in your makerspace," Evans says. Think about the interplay between the assignment, the materials and your learning goals when considering how to leverage makerspaces for STEAM learning.

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Beware of Gender Bias in School Makerspaces

A national study of school makerspaces by Drexel University researchers found evidence of disturbing gender bias in makerspace culture.

Among the 30 makerspaces they studied, 76 percent of leaders were men and 24 percent were women. Though participation in school makerspaces was nearly equal among girls and boys through eighth grade, in high school the participation among girls dropped to 25 percent.

Examining the materials used to recruit makerspace instructors and students revealed they may contribute to gender bias by using male-gendered imagery. In addition, boys were twice as likely to hold leadership positions in group activities.

"This evidence suggests a persistent, but possibly unintentional, culture of bias," the study says. "More must be done to achieve an inclusive culture of gender equity."

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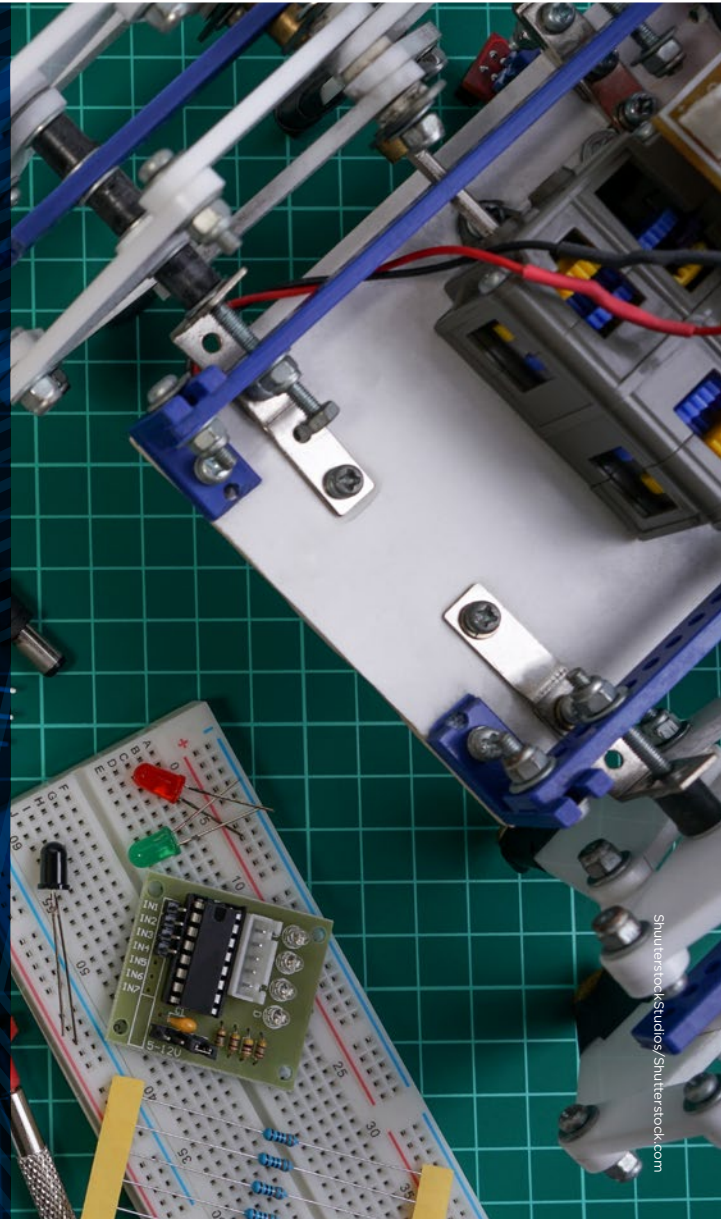
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