Inspiring the Next Generation of Scientists and Engineers: K–12 and Beyond

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Challenge-based learning fosters critical thinking and raises student interest in science, technology, engineering, and math (STEM) and in STEM careers. Hands-on, mentor-based programs like FIRST connect youth with industry professionals to solve real-world problems in innovative and creative ways and to develop 21st-century life and work skills.

21st-century workforce requires adaptability, creative problem solving, innovative thinking, and lifelong learning. To prepare future workers, teachers must go beyond traditional lectures and engage students to become critical thinkers and active learners. Active-learning pedagogies include challenge-based learning, in which students take greater responsibility for their education and participate in hands-on activities to create a product or solution that is shared with their peers.

Challenge-based learning has another important benefit. By the time children reach 8th grade, only 20 percent are interested in science, technology, engineering, and math (STEM); this number falls to 16 percent by 12th grade. Challenge-based learning raises student interest in these subjects and in STEM careers.

At a time when students tend to disengage from STEM, programs like FIRST (For Inspiration and Recognition of Science and Technology; firstinspires.org) have a powerful impact in reversing this trend.

See www.computer.org/computer-multimedia to watch videos of FIRST teams in action.
by inspiring youth in grade school and beyond to become science and technology leaders. Founded in 1989, FIRST offers four STEM-based programs for those aged 6–18: FIRST LEGO League Jr., FIRST LEGO League, FIRST Tech Challenge, and FIRST Robotics Competition (see Figure 1). These programs offer project-based, experiential learning to more than 450,000 K–12 students worldwide. Students work in teams with adult coaches and mentors to accomplish a specific science-based or engineering challenge. The programs are held in various settings including schools, youth organizations, universities, and industry. They can be part of a class or conducted as an out-of-school activity.

FIRST programs incorporate numerous strategies to actively engage youth, including hands-on experiences that challenge them to solve relevant, personal, and real problems in innovative and creative ways; development of 21st-century skills through competitions requiring teamwork and collaborative learning; and student-led learning with adult modeling and mentorship (see Figure 2). Infusing all these efforts are the FIRST values of Gracious Professionalism (demonstrating respect for others, being a good sport, and sharing knowledge) and “Coopertition” (competing like crazy but also helping others).

To solve a given challenge, teams explore multiple technologies and methodologies including CAD; 3D printing; Java, C++, LabVIEW, Google Blockly, LEGO MINDSTORMS Ev3, or LEGO WeDo 2.0 coding; Android app development; basic mechanics, electronics, and control theory; Internet research; and website design. Students brainstorm, design, strategize, prototype, iterate, build, test, and evaluate their solution, which, depending on the program, could be a unique robot or simple motorized machine.

For example, FIRST Tech Challenge teams tasked their robots to autonomously navigate around a playing field and perform a variety of complex actions, such as shoot balls into a high goal (see Figure 3). Some teams solved this problem using computer vision technology; for instance, using its Android camera to look at reference images on the field perimeter, a robot could calculate its location on the field and then move to the appropriate spot to complete its automated task (view a video of this at firstinspires.org/computer-vision).

More than 12 years of formal evaluations have demonstrated the positive impact of FIRST programs. Early findings from an ongoing longitudinal study indicate that, compared to their peers, students who participate in FIRST are

- 2.9 times more likely to show interest in STEM,
- 2.3 times more likely to be interested in a STEM career,
- 3.7 times more likely to be involved in STEM activity,
- 2.4 times more likely to show gains in STEM identity, and
- 2.7 times more likely to show gains in STEM understanding.

These measures are even higher for girls, an important result given the underrepresentation of women in STEM fields.

In addition to STEM outcomes, FIRST participants develop work and life skills to become the innovators of tomorrow, such as cooperation, experimentation, time management, and communication. Industry values the role challenge-based learning plays in developing its current and
future workforce. Companies like Qualcomm, Rockwell Automation, Rockwell Collins, Boeing, and Google (and government agencies like NASA) not only support FIRST teams but encourage their own employees to be FIRST mentors and coaches. Teachers also facilitate the student-led learning central to FIRST programs (see Figure 4). As a result, learning is not limited to youth participants—adult volunteers strengthen their skills in teamwork, project management, leadership, and communication; gain greater confidence; and experience more job satisfaction.8

REFERENCES