Wise educators are always on the lookout for new pedagogies and materials that expand classroom-learning opportunities and amplify student potential. The global maker movement poses exciting opportunities to transform the classroom.

The maker movement is a growing community of artists, scientists, craftspeople, amateurs, professionals, tinkerers, and engineers celebrating personal creativity, ingenuity, and empowerment. Make Magazine emerged in 2005 to chronicle the new materials, technologies and timeless craft traditions converging to fuel a renewed interest in personal expression in a do-it-yourself spirit. Maker Faire was born soon after when the emerging community of ‘makers’ expressed a desire to get together, share their creations and exchange expertise. In 2014, there were more than 100 Maker Faires and Mini-Maker Faires held around the world.

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In our book, *Invent to Learn – Making, Tinkering, and Engineering in the Classroom*, Sylvia Libow Martinez and I situate the maker movement in the classroom by recognising how it builds on progressive traditions. Learning-by-making stands on the shoulders of Pestalozzi, Montessori, Froebel, Dewey Piaget, Vygotsky, Malaguzzi, and Papert. Making supercharges project-based learning, not only by expanding the breadth, depth, and complexity of potential projects, but also by offering experience during which learners ‘taste’ mastery. While learning-by-doing has long been recognised as a powerful educational context, there is a euphoria associated with bending a material or system to your will and making something work. Similar satisfaction accompanies attempts that fail spectacularly and invite debugging.

Piaget teaches us that ‘knowledge is a consequence of experience.’ The maker movement supplies classrooms ideas, tools, and constructive materials to expand the breadth, depth, and range of potential projects, the primary unit of classroom experiences. Such diversity also appeals to a more inclusive population of students and welcomes parents with skills to share their expertise in the classroom.

### Making is a Way of Viewing the World

Making is a way of viewing the world with the personal confidence and competence necessary to overcome any obstacle you encounter, even if only to discover that you have more to learn. In the 21st century, making is the best thing schools can do to prepare students to solve problems their teachers never anticipated.

Children in schools where making is embraced report that their ability to navigate the world improves. They look at themselves, the challenges they confront and their potential through an enhanced pair of epistemic lenses. When the same materials, technologies, tools and practices are found in the physics lab, art studio and auto shop, schools can stop sorting children into winners and losers. We have long overvalued learning with one’s head. The future is going to require citizens who are equally capable of learning with their head, heart and hands.

Making is about authentic learning – being a novelist rather than being taught English. Being a composer, filmmaker, engineer, mathematician, scientist or historian.

### It’s Relevant for the Youngest and the Eldest Students

If your educational objectives are as modest as improving mathematics achievement in the existing curriculum, programming and engineering provide a rich setting for learning and using mathematics. Engineering is the concrete manifestation of theoretical principles and is critical to our modern society. Yet, ironically schools have long behaved as if engineering is a reward for a select few students who successfully endure twelve years of abstractions.

If young children were encouraged to tinker and engage in engineering experiences, they would enjoy a richer, more concrete context for learning the mathematics and science valued by school. Many curricular frameworks, including the Next Generation Science Standards in the USA, advocate for the sorts of hands-on, experimental, project-based, creative engineering experiences embodied by the maker movement.

### Why Making is Such a Powerful Educational Tool

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### Tips for introducing maker activities into the classroom

- **Making should permeate every corner of the school and every minute of the school day.** If you want to set up a specific area for creative making, classroom centres, libraries and informal ateliers all make great maker spaces.
- **When space is limited, not every tool, technology or material needs to be available at once.**
- **The best makerspaces give students agency over their own learning.** They are flexible, adaptable spaces that offer the learner options, for example, a space to collaborate when needed, but also a quiet space to think or read.
- **Remix, Reuse, Recycle.** Making do with available materials is a principle of engineering and the ethos of the maker movement. Scarcity is the mother of ingenuity and breathing new life into old stuff is a step towards saving the planet. So don’t throw out all of your old computers when you get new ones.
- **Do encourage students to read other people’s computer programs and modify them to suit their needs.** Build a materials library where a lovely assortment of junk may be given new life in student projects.
We may be at an historic moment where technology changes dramatically. Invent to Learn identifies three categories of game-changing technology.

**Maker Technologies**

The great thing about the technologies listed here is that they may be combined for infinite possibilities. Seymour Papert said, ‘If you can make things with technology, you can make more interesting things and you can learn a lot more by making them.’ In fact, clever students may use each of these technologies in combinations we cannot imagine. Determining which technologies best suit a task is an important skill for students to possess. In combination, their power is greater than the sum of the parts.

**Computer programming**

The reasons for learning to program extend way beyond vocational aspirations. Programming makes all of the other technology work and should be considered the new liberal art. Programming prepares children to gain agency over an increasingly complex and technologically-sophisticated world. It answers the question Seymour Papert first posed in 1968, ‘Does the computer program the child, or the child program the computer?’

New block-based programming languages like Scratch, SNAP!, Beetle Blocks, Pocket Code, Tickle, and Google App Inventor make programming the screen and physical world accessible to children. They build on the grand tradition of programming environments usable by children where powerful ideas are encountered, established by Logo and MicroWorlds.

Projects that two years ago were considered science fiction may now be a year 2 student's Mother's Day gift. Educators should, in the words of 13 year old maker movement hero Super-Awesome Sylvia, 'get out there and make something!' It's the best way to prepare for the cooler, cheaper, more powerful materials just around the corner.

**Physical computing**

You might think of physical computing as robotics, but more broadly it is the ability to add interactivity and intelligence to everyday objects. Arduino and other microcontrollers (including the Intel® Galileo and Edison), LittleBits, wearable computing, programmable robots, Internet of Things – compatible objects, sensors, and new conductive materials all bring physical computing to life for even young children.

**Fabrication**

Until recently, everything you made with a computer lived on the screen or on paper. 3D printers, laser cutters, and CNC machines make it possible to design and manufacture real things. It is becoming increasingly possible to make the technology you need when you need it. When the artifacts become real, the learning process is more authentic. The true power of 3D printing isn’t the ability for every year 7 student to make an identical Yoda keychain, but for students to experience the process of design.

Intel® was built by Makers, who envisioned a world of possibilities and instilled a deep connection to innovation. We support the Maker Movement because it encourages curiosity, creativity and build confidence in young people with technology-related subjects. Our deliberate focus is to get students involved with the movement and introduce young makers to the possibilities of STEM in revolutionary and innovative ways.

Learn how we’re supporting the next generation of innovators at www.intel.com/innovate

About
Gary Stager, Ph.D.

Gary Stager, Ph.D. is the co-author of Invent to Learn – Making, Tinkering, and Engineering in the Classroom. He is a popular speaker around the world and an award-winning teacher educator with more than thirty years’ experience teaching learning-by-making with technology.

Gary currently works as the Special Assistant to the Head of School for Innovation at The Willows Community School in Los Angeles. He is also the founder of the Constructing Modern Knowledge summer institute and may be reached at gary@stager.org

Additional Resources

Intel® Engage
An Online Community for Educators Transforming the 21st Century Classroom.
engage.intel.com

Invent To Learn
The ‘Making, Tinkering, and Education in the Classroom’ website is the home of a groundbreaking book by Sylvia Libow Martinez and Gary Stager. The website includes recommended books, articles, videos, tutorials and hundreds of links to resources and professional development for making, tinkering and engineering in the K-12 classroom.
inventtolearn.com

Sylvia’s Super-Awesome Maker Show
Ten-year old Super-Awesome Sylvia and her father produce a whimsical video show showing how to build fun electronic projects.
superawesomebook.com

Making the Case for Making in Schools
Authors Gary Stager and Sylvia Libow Martinez speak to teachers and parents about changing schools to be more authentic places for learning.
inventtolearn.com/video-making-the-case-for-making-in-schools

Make Magazine
The bible of the Maker Movement.
makezine.com

Instructables
A DIY online community full of project ideas.
instructables.com