Education

GUIDE TO CREATING AND INVENTING WITH TECHNOLOGY IN THE CLASSROOM

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CONTENTS

Introduction to the ‘maker movement’ 3

Why making is such a powerful educational tool 4

Making is a way of viewing the world 4

It’s relevant for the youngest and the eldest students 5

Tips for introducing ‘maker’ activities into the classroom 5

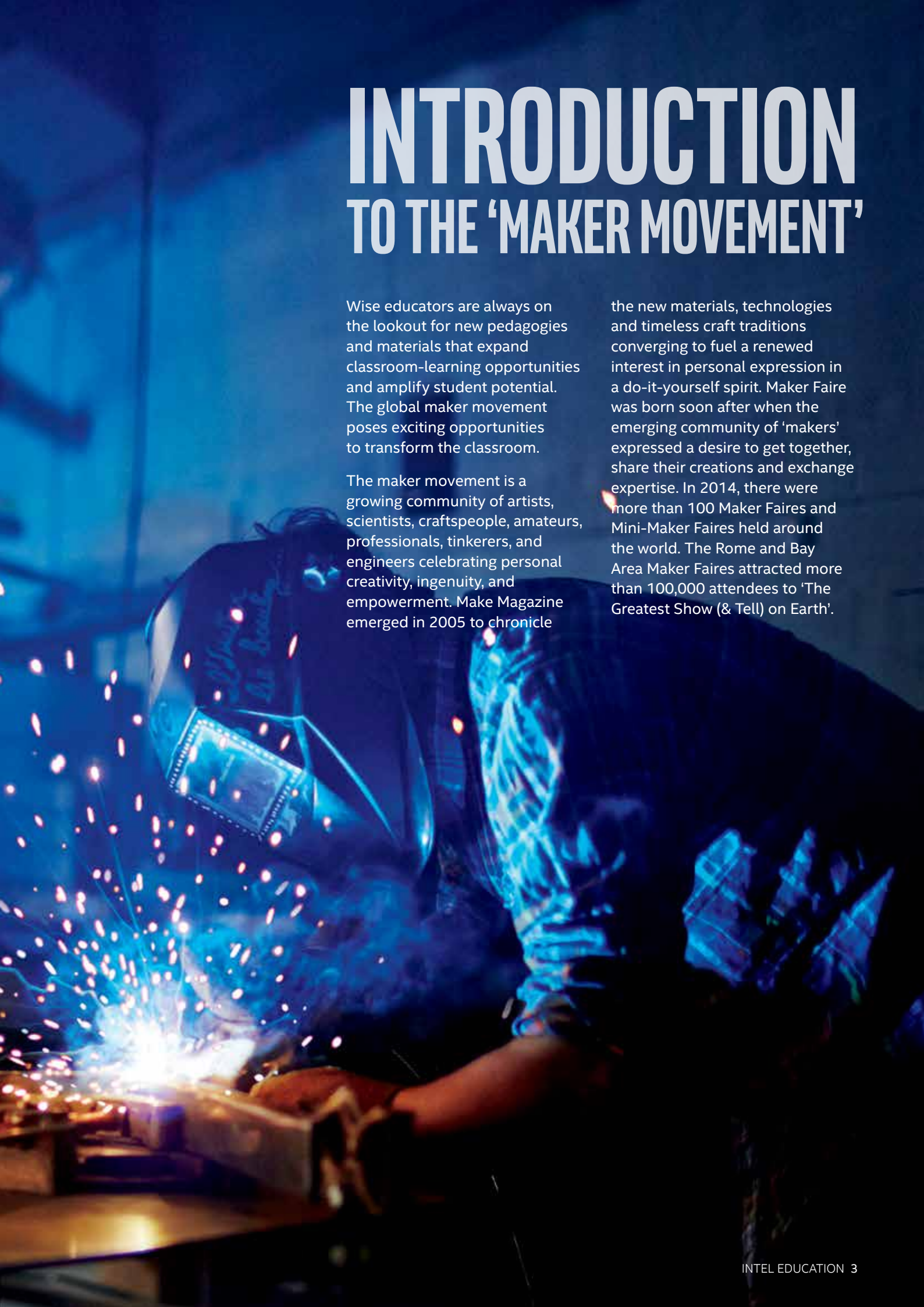
Game-changing technology 6

- Fabrication
- Physical computing
- Computer programming

Maker technologies 7

About Gary Stager 8

Additional resources 8



INTRODUCTION TO THE 'MAKER MOVEMENT'

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. The Rome and Bay Area Maker Faires attracted more than 100,000 attendees to 'The Greatest Show (& Tell) on Earth'.

WHY MAKING IS SUCH A POWERFUL EDUCATIONAL TOOL

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.

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.

GAME-CHANGING TECHNOLOGY

We may be at an historic moment where technology changes dramatically. *Invent to Learn* identifies three categories of game-changing technology.

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.

Physical computing

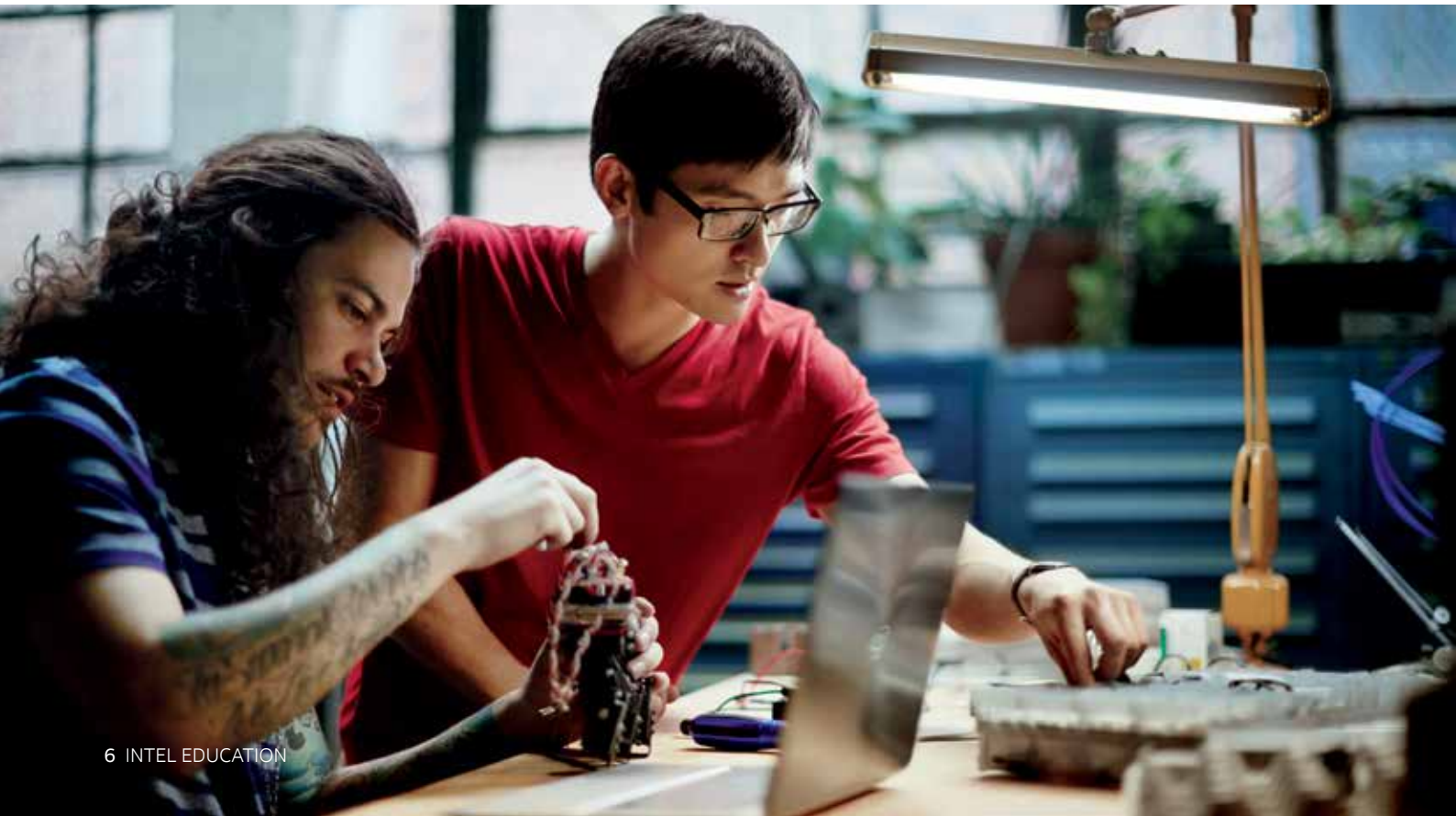
You might think of physical computing as robotics, but more broadly it is the ability to add interactivity and intelligence to everyday objects. Arduino and other microcontrollers (including the Intel Galileo and Edison), LittleBits, wearable computing, programmable robots, Internet of Things – compatible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

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, and more powerful materials just around the corner.



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.

The MaKey MaKey turns the world into a computer interface. Imagine that your laptop's keyboard is broken and you need to replace it with saucers of milk, or you wish to make a piano out of bananas. The MaKey MaKey makes this possible by converting closed electrical circuits into keystrokes. Not only is the MaKey MaKey an easy on-ramp to physical computing, but the MaKey MaKey is also an invitation to programming so that homemade controllers have something cool to control.

The MaKey MaKey is inexpensive and easy to install (no drivers or software needed), making it the perfect starter technology for maker classrooms.

Website: **makeymakey.com**

PROJECT IDEAS

- Make musical instruments out of cardboard that play musical notes or any sound effect
- Create a video game controlled by fruit
- Build a Rube Goldberg machine that triggers animations on the computer
- Wire your school stairs like a giant piano
- Write a play with MaKey MaKey interactive costumes that trigger sound effects when touched by other actors

LittleBits are snap-together magnetic electronic components that allow you to prototype powerful inventions and explore electronic circuits. Students can build interactive machines capable of responding to stimuli, communicating with the World Wide Web, or just making a wacky joy buzzer – all without worrying about syntax. The library of LittleBits elements is ever expanding with recent bits making MP3 files, the Internet of Things and Arduino programming possible with the playful bits.

Website: **littlebits.cc**

PROJECT IDEAS

- Make a home security system that responds to a secret knock
- Build shoes that light up when you dance
- Make a robot that paints
- Build a musical synthesiser
- Build a digital clock

The Hummingbird Robotics Kit is perhaps the best kit for budding robotics engineers. It provides a simple interface for motors, lights, servos, and a variety of sensors to be combined with found materials, broken toys, or recycled junk to build intelligent robots. These robots may be programmed in a variety of software environments (including Scratch and SNAP!), providing maximum flexibility and age range. Best of all, there is an Arduino Leonardo board on the flipside of the Hummingbird controller. This provides a smooth transition from the Hummingbird ecosystem to the infinite possibilities of microcontroller engineering.

Website: **hummingbirdkit.com**

PROJECTS

- Build a dog that responds to sound and light by barking and wagging its tail
- Create an interactive background for a stop motion animation film
- Build a robot that illustrates a poem
- Animate a famous work of art

The Circuit Scribe pen and Circuit Stickers allow you to make interactive paper-based projects with conductive ink or stickers capable of logic, sensing and lighting. These technologies are also useful for prototyping inventions as a first step towards building more durable machines. A word of caution, these materials are still in their infancy. They will get better.

Circuit Scribe: **electroninks.com**

Circuit Stickers: **chibitronics.com**

PROJECT IDEAS

- Create an electronic greeting card for your favourite holiday
- Draw a musical instrument and connect to the MaKey MaKey to play notes on the computer
- Experiment with logic circuits on paper
- Build a colour changing light up photo frame

The Intel® Galileo and other Arduino Microcontrollers

The open-source Arduino and its variants, including the Intel Galileo and Edison, are at the centre of the physical computing revolution. These low-cost and increasingly powerful 'brain boards' (as Super-Awesome Sylvia calls them) are smaller than a playing card, but pack a big punch. Each Arduino board features a number of ports for inputs (sensors), outputs (motors, lights, switches, etc.) and power.

While Arduino seems more raw than educational robotics systems designed specifically for the classroom, the tradeoff is rewarded in increased flexibility, power and a lower price. Commonly found electronics components, along with broken appliances or toys may be used with a microcontroller. New features and functionality are added to Arduino by snapping on shields that allow for all sorts of automation tasks. Students, hobbyists and professionals are using Arduino in countless contexts.

PROJECTS

Students can use a microcontroller in many ways as part of a system for automatically watering a plant when it gets thirsty; to control a greenhouse; in a festive photo booth; or as the 'brain' in your robot. Of course, Arduino may power whimsical creations as well. Kids in a New York City classroom used Arduino to add lights, sounds, and motion to a LEGO pirate ship. Connecting to the emergent Internet of Things allows your Arduino boards to not only respond to local sensory data, but to create a physical alert when your stock price drops or to warn of inclement weather during recess.

Arduino: **arduino.cc**

Intel Galileo 2 education: **intel.com/content/www/us/en/do-it-yourself/galileo-maker-quark-board.html**

Intel Australia Innovation Toolbox: **innovationtoolbox.intel.com.au**

The Lilypad is a machine-washable Arduino version used for wearable computing and 'eTextiles.' Instead of connecting sensors and actuators with wire, soft circuits are made with conductive thread. While it may be simple to think of the Raspberry Pi as the computer and Arduino as the external peripheral, boards like the Galileo or Arduino Yun are blurring these boundaries by placing a computer and microcontroller on one board. Even the Raspberry Pi has pins for connecting to the outside world. Expect such developments to continue.

Lilypad Arduino: **lilypadarduino.org**

Education

About Gary Stager

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

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