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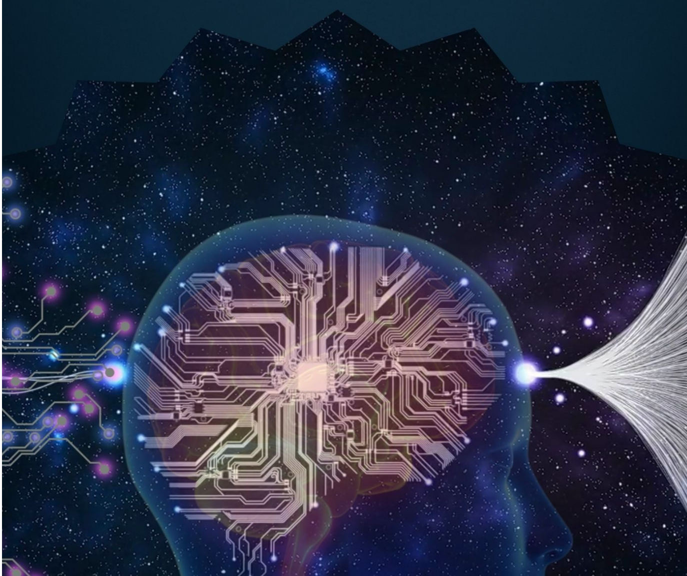
MAKER EDUCATION REVOLUTION

LEARNING IN THE 21ST CENTURY



Peter Dalmaris, PhD

Maker Education Revolution

Learning and Teaching in a High-Tech Society

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An introduction

My understanding of technology as a child revolved around my parents’ video cassette recorder and television. Everywhere I looked, there was technology that made life easier, but it was obviously in desperate need of radical improvement.Schools today do not prepare students for the future; rather, they prepare them for the past. Educators can contribute to the development of an educational system that instills in its students the qualities that we want to see in a child. I decided to write this book because I believe there is a better way to learn and teach.

Maker education revolution

Conventional education is struggling to provide the learning environment necessary to help raise the future innovators, problem solvers, and entrepreneurs that advanced societies need. Maker Education offers a model for education in the 21st century.

When I was a kid, my understanding of what technology was revolved around my parent’s video cassette recorder and television. TV stations back then would transmit a test card image. This image contained a pattern of boxes, circles and lines that a TV technician would use to fine tune the TV receiver to the channel. I remember that I could never fine-tune the receiver so that the lines were actually straight because the screen of our TV was curved. All TVs back then had curved screens because of the way that cathode ray tubes worked. There was no such thing as a flat panel display. Somehow intuitively, I knew that other people would be as frustrated about this as I was. I was sure that engineers were working on this problem. I wanted to be one of them.

Something similar was happening with the video recorder. It was an impressive machine at the time. It had an LCD screen for showing the time elapsed of a movie. It had the ability to program it with the start and end times and day of a program I wanted to record. But I vividly remember my dissatisfaction with its many shortcomings. The recording medium was a thin plastic tape inside a plastic case, with a lid that would open to expose it. The assembly was fragile, large, and expensive. The quality of the recording would degrade with use over time. The programming interface was terrible so that only someone with ample time to play with it, like a child, would ever be able to understand it and use it. I was sure that someone, somewhere was working on this problem, and I wanted to do that too.

Everywhere I looked, there was technology, albeit simple by today's standards, which made life easier, but that was clearly in need of radical improvement. Being a Star Trek fan did not make things easier. The transporter, the communicator, the talking computers, the replicator, the scanners and all the amazing things on board the Enterprise resonated with me and gave me a vision of how things can be.

A few years later, my parents bought me an Apple //e, one of the early home computers. I still have that computer. Along with it came a couple of programming books. The programming language was built-in to the computer. It was Applesoft Basic. I started programming it right away, and I felt a bit like Scotty, the Engineering Chief on the Enterprise. Now, that was technology. Now we are getting somewhere. Steve Wozniak became my new superhero, replacing Spiderman.

A few years later, I bought an electronics kit to make an LED blink with a 555 timer IC. All the documentation was basically the assembly instructions of which components go where. There was nothing about timers, LEDs, etc. I had no access to the Internet, no electronics book, and I did not know anyone who had some knowledge on these things to ask. Despite that, this is what technology was to me. Whether in a kit with all its components mixed, or perfectly assembled into a beautiful computer, I knew some engineers out there had done what needed to be done to get us closer to my Star Trek ideal.

From the video recorder to the Apple //e and then to the 555 integrated circuit, I quickly developed an intense interest in engineering and programming. But I had no access to documentation and had no-one around me to ask for help. Not only that but at school, none of my teachers was able to help me. They were all excellent in their particular subject matter, mathematics, history, geography, science, but none of them had ever touched a computer.

The fact that my school was ill-equipped to help me learn how to program my computer, or to give me some basic pointers around electronics, is simply an example of how schools do not really prepare students for the future. They prepare them for the past. I have memories of thinking how firmly I believed that computers were the present and the future, and how bored I felt at school because none of my strong interests in technology was met. School was dreadful. I felt that I was sacrificing my best hours, every day, for a purpose that I did not understand. Perhaps school was about accumulating grades; perhaps it was about, other than for gathering marks. My boredom had affected my ability to learn, and my lack of interest made it impossible to get a grade better than average. My parents were averagely thrilled about that.

I knew I wasn't stupid. I was able to learn a lot on my own. I was lucky to have parents that had no reservations about buying books and magazines. I had an encyclopaedia, a subscription to a foreign computer magazine (I remember the difficulty of buying foreign currency to pay for it), and programming books. My software collection grew and included the Logo programming language. I found a book that taught me how to do low-level programming on the Apple //e, manipulating bytes and working with 6502's op-codes. I found perhaps one of the first science kits for a home computer, that could measure temperature and lung air capacity (I used that to train my ability to hold my breath for what seemed to me like a very long time). Home was heaven. Home was where learning was actually happening, disguised as play, at least after my school homework was done.

Today, while schools have not changed fundamentally, the sheer opportunities for learning are truly stunning. Not only there is an abundance of resources, from Arduino's to robots, to connected everything, but there is a wealth of knowledge in video, text, illustrations on your computer, your iPad, even on paper, but people with knowledge are within instant reach.

The experience of sending my own children to school reminded me much of my own school years. The fixed curricula, the separation of subjects, the focus on delivery rather than the individual, the lack of sufficient time for play and exploration. The list can go on. This recent negative experience with school was also amplified by my children's dyslexia, which made it even harder for them to develop a happy relationship with learning. Learning, under these circumstances, was externally enforced. It was painful. It was seemingly pointless. And it was distracting them from the things that were most important to them.

I decided to write this book because I was convinced that there is a better way to learn and to teach. Just like engineers succeeded in creating flat screen TVs, and improved computers and networks to the extent that we no longer need video cassette players and recorders, I was convinced that there were educators who had solved the problems that I mentioned earlier. Educators who realised that learning does not need to be painful, that children with different learning needs can be cared for. I was convinced that there are educators who can help in creating an educational system that instils its students with the qualities that we want to see in a happy and successful individual rather than the specific bits of knowledge that they need.

My conviction was not arbitrary. I had spent the last 15 years as an educator myself. First as a University lecturer, and now as an online instructor. I witnessed both the limitations of traditional education as well as the potential of Maker-style education when combined with modern educational technology. My conviction is that after the pain of the past, we are now entering a golden age of education. An age in which education is better aligned with its real purpose of helping to shape happy and creative individuals. An education that helps the learner to learn how to think critically, solve problems independently but in collaboration.

An education that helps people to think like a scientist and implement like an engineer.

Technology plays a huge role in this education. I have visited high schools where I could see the effect that technology has on the quality of learning that student can achieve. Imagine four or five teenage students gathered around a wheeled robot. They are making the final preparations ahead of a yearly robot competition. They are each working on a particular subsystem, but they all understand how the robot works as a system. There's always one student that goes deeper than everyone else. He or she does the troubleshooting, can move wires around before anyone knows what's happening, does the last code modifications for an instant performance improvement. And guess what she wants to do? Become an engineer.

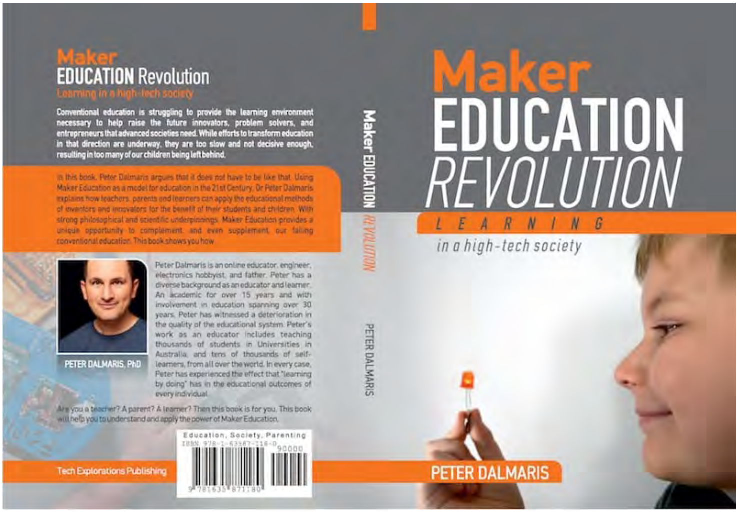
I wrote this book because I had to. I needed to organise my thoughts around what a modern educational system should look like. I wrote it so that I can systematise the elements that can help my children, with their special learning requirements, not just cope but to thrive in a world full of opportunities of any kind, but especially learning opportunities. I wrote it for my young self, struggling to keep my love for learning and curiosity alive.

I wrote it for teachers who are dedicated to creating awesome learning experiences for their students. For parents who care not just about their children's academic achievements, but also for their overall development as happy and creative individuals with their own unique set of passions and curiosities. I wrote it for the learners themselves, who are perhaps discouraged by their experiences in school and wonder if there is another way.

I sincerely hope that this book will help you change your view of what modern education should look like. Because with every successful learning, there is change.

Peter Dalmaris, May 2017

Maker Education Revolution



Learning in a high-tech society.

Available in PDF, Mobi, ePub and paperback formats.

Using Maker Education as a model for education in the 21st century, Dr Peter Dalmaris explains how teachers, parents, and learners can apply the educational methods of inventors and innovators for the benefit of their students and children.

Learn more

A brief history of modern education

The organisation of schools in the 18th and 19th centuries was very similar to that of today. Unlike their counterparts in Ancient Greece and Ancient Rome, the purpose of these schools was to raise the literacy of the “common people” to a level suitable for life as a factory worker. In twenty-first-century technological societies, little has changed in terms of educational methods.

People must be able to approach a problem with the childlike playfulness of a child and the scientific thinking process of a scientist. They must be able to think independently and design their own solutions to problems that have never been seen before. I wanted to explore this theme and demonstrate that the solution to our educational system crisis is already being enjoyed and transforming the lives of countless people all over the world.

Maker education revolution

Conventional education is struggling to provide the learning environment necessary to help raise the future innovators, problem solvers, and entrepreneurs that advanced societies need. Maker Education offers a model for education in the 21st century.

“Education is the most powerful weapon which you can use to change the world” — Nelson Mandela

In the early 1800s, mechanised textile production spread from Great Britain to the rest of Europe and beyond. Factory cities such as Manchester and Dewsbury emerged and grew rapidly during the 19th century, with new factories attracting more and more people from the countryside.

Factories were organised in rows and columns, optimised for efficiency. At each station, a worker would repeat that same movements again and again, for the duration of his shift. At the end of the shift, a fresh worker would take his place and repeat the same movements, again and again. Just like the factory was organised for efficiency, each station was also optimised for efficiency. The repetitive movements of the worker, over time, had removed anything not strictly necessary for the task in hand. The tools that he used were built for the single purpose of the task in hand. There was almost no talking at all, since talking can increase inefficiency. What had to be accomplished can be done so with minimal interaction with other workers. Each worker was trained to do one thing; one thing only and to do it efficiently.

Thanks to the way that factories were organised, each worker only had to be proficient at a very small repertoire of functions. Assemble a box, connect a couple of wires, attach a label. The workers did not need any special training, and in most cases they didn't even need to read. In fact, these factories required workers with minimal knowledge of reading and maybe of simple arithmetic; however, most of them had no schooling of any kind, and could barely read at all.

This prompted the factory owners to create in-house training, where new workers would learn the basics of factory operation. Sometimes, this even included some reading and arithmetic.

Schools, of course, existed outside of factories. Children in the late 18th and the 19th century did receive formal education in schools that was very similar in terms of organisation to those that we are familiar with today. Although attendance was not high in the early years, it did increase to eventually guarantee that the majority of the population of a country, at least in developed countries, could graduate with adequate ability to read and write.

If you walked into a typical classroom in England of the 18th and 19th century, you would see desks and chairs organised in rows and columns. At the front of the class was a blackboard from where the teacher would address the class. The students were required to always look towards the front of the class, at the teacher. Talking was forbidden, unless the teacher had asked a question. The tools of teaching and learning were very simple, but just like their factory counterparts, they were efficient: a blackboard, chalk, books, pencils and paper.

The teacher was tasked with the responsibility of conveying knowledge to the students by means of a formal presentation. The students would be required to follow the instructions issued by the teacher, which included reading and writing tasks. The teacher would also quantify the knowledge accumulated by students by issuing formal or informal tests, and then rank the students based on the results of those tests.

Indeed, the purpose of these schools, unlike their counterparts in places like Ancient Greece and Ancient Rome, was to increase the literacy of 'common people' to a level adequate for life as a factory worker. This was the mantra of conventional, classroom-style schooling back in its early days, and, as I argue in this book, it still is.

Indeed, little has changed in the methods of schooling in our advanced 21st-century technological societies. Not only there is a striking resemblance between schooling in the 18th/19th and the 20th and even 21st centuries, but the emphasis is still in maximising efficiency and productivity (measured as the volume of product that exits the production line in a given unit of time) is the common denominator between traditional schooling and factories.

Modern factories may not be powered by coal and steam, but they typically still require workers with a basic and common level of education. Modern factories require workers, that can work harmoniously together thanks to a common set of assumptions and beliefs, optimised to deliver specific outcomes. Without doubt, comparing the level of education of the average person today to a person from the 18th century is like comparing a Tesla Model X to a Ford Model T. Yet the uniformity, rigidness and high output rate requirements of that era, to name just a few similarities, still exist in modern schooling.

Unfortunately, the citizen of a modern, technologically advanced and hyper-competitive society of the 21st century needs to be prepared to navigate a world that is far more complicated than that of our 18th-century counterpart. Globalisation, hyper-competition and frictionless commerce, rapidly advancing technologies, social change, global and localised conflicts, climate change and mass migration are only some of the high-stake issues that a modern citizen must be able to comprehend and act upon.

Even the factories, traditionally associated with low-skill work, are being transformed. Robotics, artificial intelligence and automation have evolved to a level of effectiveness enough to be rapidly replacing human labour with machine labour. This inevitable process is causing massive unemployment to people in many industries around the world. Millions of people are left out of work, with no real prospects of ever catching up in the work market. This is the generation that is loosing out in this process of modernisation, and largely depend on social policies and social safety nets for ensuring the basics for their survival, if they are available.

Will the next generation of people that are growing up now be more fortunate? Will these next generations be able to adapt to a world where machines, more and more, are taking over jobs that traditionally used to be done by humans? Not just factory jobs, but jobs across the whole spectrum?

This kind of disturbance in the connective tissue of societies is not new. People went through similar experiences during the shift from the early agrarian and feudal societies to the those of the industrial revolution. Mechanisation and automation changed the ways that large populations made a living, and it did take them generations to adapt.

But this time, it is very different. The speed, breadth, and depth of changes are far bigger and more impactful than what we have every seen in the past. The speed by which technology has moved in to redefine whole industries, combined with its global reach, means that there is not escape. People have to adapt because they can't hide from the change.

I believe that there are unique opportunities for people in a world where automation is everywhere. But to strive in such a world, we have to exploit and believe in what is unique in humans. Imagination; creativity; drive; curiosity; empathy; self-awareness; feeling. These are some of the traits present in every human, and the raw ingredients of products like art, science, language, society, and culture.

Going forward, more than ever before, our ability to thrive in a world where machines play a more significant role than ever before, depends on our education. How we learn, teach, and magnify our uniquely human traits.

So, we have to think about school, since this is the institution with the critical task of educating the young, and preparing them for the future.

Are our schools an outdated version of the same schools that contributed immensely during the Industrial Revolution? The same schools that produced the millions of workers that powered factories and paved the way to our modern way of life?

In this book, I argue that the answer to this question is 'yes', and that a solution in modern education's dead end lies in the core of human ingenuity and creativity.

The system is broken, like an old machine. A 200-year-old machine, to be more precise. It was designed for a world that does not exist anymore. In the US, the industries that contributed the most in the Industrial Revolution—manufacturing, construction, mining and the like—comprise of less than 20% of the total output. Even in those industries, much of the demand is for people with highly developed skills in leadership, management, engineering and finance. In Australia, and other developed countries, the statistics are similar.

A modern society increasingly needs people who have a diverse range of skills. It needs people who are innovative and creative in order to generate new wealth for themselves and those around them. They need to be adaptable in order to be able to respond to rapidly and ever-changing conditions, locally and internationally. They need to be able to think independently, and to be able to set fulfilling courses for their lives.

These are people that approach a problem with the playfulness of a child and the thinking process of a scientist: people that can engineer their own solutions to problems that perhaps have never been seen before. People that thrive in complex, competitive, ever-changing and open societies.

What kind of educational system can help people become scientists, engineers, philosophers, humanists and politicians, all at the same time?

It must be a system that advocates that the individual is at the centre of the learning process. A system that believes that the scientific method and technological competency is a key component for personal and social growth and prosperity. A system that fosters collaboration and innovation, that focuses on the learner instead of the teacher, in adaptability instead of obedience, in creativity to support and enhance abstract thinking. A system that emphasises a growth mind set rather than the fixed mind set was a main characteristic of the 19th, 20th and 21st-century human.

I wrote this book because I wanted to explore this theme and show that the answer to our educational system crisis is already being enjoyed and transforming the lives of countless people around the world.

An education system in crisis

What is the purpose of education, and how can it best be achieved? Many centuries ago, philosophers attempted to answer this question.

The Prussian education system of the late 18th and early 19th centuries was designed to instill blind obedience to authority while also reinforcing class and race prejudice in children. The factory model remained virtually unchanged in the majority of the developed world until the end of the twentieth century. Only 16% of 30-34-year-olds have completed some form of formal education. This foreshadows the future of education: informal, on-demand, skill-based, and lifelong. Is our educational system in crisis?

Maker education revolution

Blurb to be added

“Education is what remains after one has forgotten what one has learned in school.“

— Albert Einstein

This book is about education. As responsible parents and guardians of children, we must ask ourselves: what is the purpose of education, and how can this purpose be best fulfilled?

This is a question that philosophers tried to answer, many centuries ago. Aristotle wrote extensively on this topic. In his book “On Education”, while only a small part survived to our days, we learn that for Aristotle, the fulfilled person is an educated person.

This leaves the question on the purpose of education somewhat open. But in answering it, perhaps we should first try to agree on what a ‘fulfilled’ and ‘educated’ person is. Then, we can explore the next logical question, which is what an education that enables a person to be fulfilled looks like.

John Locke, like Aristotle and many others, left significant works on education. In Essay Concerning Human Understanding and Some Thoughts Concerning Education, he argues that “education makes the man”:

“I think I may say that of all the men we meet with, nine parts of ten are what they are, good or evil, useful or not, by their education.” (1)

What are the core characteristics of a fulfilled person? Let’s flip the question and ask the opposite: What are the characteristics of a person whose life is not fulfilled? Perhaps a life full of fruitless struggles, difficulties, mediocrity and sameness, dependant consistently on externalities? A life that feels confined to the rules and wishes of others, trapped and disappointed with the system?

Contrast that to the life of a fulfilled person, who welcomes struggles and difficulties as they, more often than not, lead to personal and collective growth and progress. The fulfilled person welcome struggle because it is an opportunity for learning. Through these struggles, the fulfilled person becomes a better version of themselves.

A fulfilled person enjoys the endless vitality and diversity of life, the freedom represented by the opportunities to produce value, whether this value is material or spiritual. A fulfilled person feels safe because of their ability to adapt and respond to the unavoidable risks of being alive.

These are some of the characteristics of a fulfilled life.

Aristotle, Locke and many others discussed all this in detail, and they also suggested a method and an outline of what kind of education can help people attain fulfilled lives. They argued that an education should emphasise a holistic and balanced development, from a young age. Play is a big part of such education, and so is physical training, music, debate, and the study of science and philosophy. This kind of education develops both body and mind, equally.

And lastly, learning happens throughout life, adjusting for the different stages that a life naturally goes through.

What is the experience and outcome for most of us as graduates of formal, traditional education? Boredom. Seemingly pointless struggles. A feeling of being trapped in a system tuned to churn out graduates. In many of us, these feelings only got stronger as we grew older in this educational system. Finding a way out, towards fulfilment, become continuously more abstract and elusive.

Modern schools, with their underpinning in the Industrial Revolution, were shaped in the early 20th century after the Prussian education system of the late 18th and early 19th century. This system was designed to service nation-building at a time of significant upheaval and social restructuring. It was optimised towards teaching children blind obedience to authority, and reinforcing class and even race prejudice (2). In the US, the Prussian system was particularly influential in the mid-1800s, when it was used as the model for creating a similar system in Massachusetts. The primary driver behind the adoption of the Prussian model was the latter’s emphasis on social cohesion, a very important outcome for a young nation.

The factory model in schooling, another attribute of the Prussian system, emphasises efficiency, uniformity and standardisation as paramount principles. The factory model survived almost unchanged in most of the developed world until the end of the 20th century.

The Prussian system was engineered for a specific purpose, and it was very successful at that. That is why it is still entrenched in modern national educational systems. However, the primary purpose of the Prussian system was not to help its graduates achieve fulfilment in their lives.

Today, schooling is undergoing change towards a more student-centric approach, but this change is slow, and understandably so. A system that has endured for centuries cannot be replaced within a few years or even decades. It is encouraging to see that there is recognition for the need to change and adapt to the new realities that societies face today across the spectrum of stakeholders. From students to teachers, and to the government officials and executives that make policy decisions and implement such policies. For example, in the US, the core purposes of K-12 schooling include civic, emotional and cognitive development. In the 2009 document, ‘The Shape of the Australian Curriculum’, policy makers pledge their commitment to “supporting all young Australians to become successful learners, confident and creative individuals, and active and informed citizens” (3).

Do these pledges materialise in the actual schooling system? In Australia, using participation in lifelong learning activities as a metric, we know that just 16% of 30-34-year-olds have participated in some form of formal learning. People in the 60-64-year-old bracket had a participation of just 3%. Participation in informal learning is much higher in all age groups. People in the 30-34-year-old bracket participated in informal learning at a very high 75.2%, and even people in the 60-64-year-old bracket participated at 64.2%.

One way to think about these numbers is that people will naturally learn what they want, outside of formal institutions. This is indicative of what the future of education may be: informal, on demand, skill-based, lifelong. As soon as people leave behind the burden of formal education, they abandon it. In Australia in particular, and this is probably true in other developed countries, people with higher incomes and higher educational qualifications are more likely to participate in both formal and informal education.

Interestingly, people who are unemployed had a participation rate in non-formal education at a very low 11%. Perhaps these people are excluded from learning opportunities because they have no workplace with the policies and systems in place to manage their personal development, or because they never gained the appreciation for it during their schooling years.

Is our educational system in crisis? The evidence seems to suggest yes. Is it changing in response? The evidence, again, seems to suggest that the answer is yes. Are people thirsty for non-conventional education? Again, the statistical evidence suggests that the answer is yes.

The change is not fast enough though. The world changes at a much faster pace than what the system is able to absorb. The good news is that, thanks to advancements in communications and educational technologies, and developments in many related fields of technology, we can all participate in high-quality and enriching, lifelong learning, starting with young children. Let’s look at the good news next.

Interesting readings

1. Locke, John. Some Thoughts Concerning Education and of the Conduct of the Understanding. Eds. Ruth W. Grant and Nathan Tarcov. Indianapolis: Hackett Publishing Co., Inc. (1996), 10; see also Tarcov, 108.
2. Compare Central Society of education, Volume 3 Taylor and Walton, 1839
3. Review of the Australian Curriculum: A statement by the Australian Curriculum, Assessment and Reporting Authority

Think different: learners in charge

MOOCs have provided an incredible opportunity for millions of people to gain access to educational resources. From nuclear physics to supercomputing, liberal arts to philosophy, the Internet and educational platforms can teach anyone anything they want to know.

There have never been more opportunities to learn, more resources to learn from, or more enjoyable ways to learn.

Maker education revolution

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“Those who play rarely become brittle in the face of stress or lose the healing capacity for humor.” — Stuart Brown

To a large extent, the conventional, industrialised education system has indoctrinated people over several generations to believe that learning is something that happens at school, under the guidance of a teacher. So many people were brought up to believe that learning ends when school ends. The belief that knowledge is sourced from an authority, and is accessed in a passive way, was common in the 20th century.

This is changing.

In the last few years of the 20th century, and increasingly more recently, a new understanding of the mechanics of learning is starting to make headways. The Internet, affordable personal access devices like laptops, tablets and smartphones, and abundant learning materials like books and CD/DVDs, has made education accessible to a lot more people. The diversity of topics available to learn today is also staggering compared to what was available 20 years ago. From nuclear physics to supercomputing, and from liberal arts to philosophy, whatever a person wants to learn can be learned.

The Internet has been a catalyst for this learning revolution. Rapid advances in fibre optic cable connectivity has connected continents across the globe so that data can flow at almost the speed of light, and knowledge can be accessed within moments. Discovery engines like Google, have organised the world’s stored knowledge so that anything can be found, no matter where it’s stored. The proliferation of artificial intelligence powered, speech-based user interfaces like Siri (1), Google Assistant (2), Alexa (3) or Cortana (4), mean that people that can’t read or write can find the knowledge they are looking for. Dyslexia or illiteracy is no longer a barrier to entry to the Internet of Knowledge.

Organised collections of educational materials, like Wikipedia, Khan Academy and even YouTube (also a popular destination for people looking for entertaining cat videos), powerful and low-cost access devices, primarily laptop computers and tablets, and the maturity of content creation technologies like video cameras and presentation software have resulted in the explosion of the number of people who not only consume educational content, but also create it.

One of the results of all the, is the emergence of an online education marketplace in which experts create and publish their content at very low costs or free. Learners can find content in their area of interest very quickly and on-demand, and consume it when they are ready, without any obligation to operate under schedule.

One of the original contributors toward this education marketplace was MIT through its OpenCourseWare (5) initiative (MIT OCW). Starting in 2001, MIT began the process of publishing the content of the courses it already offered in its campuses to a worldwide audience, for free. Anyone could access this content, and learn from it. Videos from the actual lectures and world-class professors, course notes, workbooks and assignments were all were made available to anyone with a computer and access to the Internet. By 2015, 80 MIT courses had all the lecture videos recorded and published as part of OCW. In total, content from over 2300 MIT courses were made available online.

In 2011, OCW started to offer courses specifically designed for independent learners. These are called OCW Scholar courses. They offer more in-depth coverage of the topics presented in a way that is more compatible with the needs of self-learners.

MIT was not the only elite institution publishing its content for everyone to access. Stanford publishes many of its courses online, for free, specifically targeting independent lifelong learners worldwide. Whether you wish to learn (or relearn) calculus, big data, cryptography or storytelling, Stanford has a course for it.

But it isn’t only elite universities that are adjusting to a changing world. The educational industry as a whole is responding as well. Many startups were set up to specifically address the market need for online education, anytime and anywhere. They implemented a variety of different models as themselves are still trying to understand what works and what doesn’t. These tend to fall under the general descriptive term of ‘Massive open online course’, or MOOC.

After pioneering providers like MIT OpenCourseWare, OpenLearn (6) (Open University) and Stanford Online (7) showed that online education is a viable and engaging way to provide massively personalised education on a massive, global scale, many new profit and not-for-profit organisations began to participate.

Udacity, Coursera, and MIT edX, to name a few, appeared after 2011 and became successful and established MOOC platforms. They are still dependent on traditional high-education institutions for their content and legitimacy. Their success prompted entrepreneurs to attempt the next step in the evolution of MOOC, by creating platforms targeting content creators with no formal affiliation to a degree-granting institution, for students who are interested in more informal educational experiences.

Khan Academy (8) has innovated in the way that complex topics are presented to students of all ages. This is a not-for-profit organisation with financial backing in the form of donations from the Bill and Melinda Gates Foundation, Google and many others. The videos produced by Salman Khan are innovative in their use of electronic ink on the screen instead of a marker on the whiteboard, and his ability to deconstruct complicated topics, from mathematics to history, to simple, short lectures that the student can assimilate quickly. Khan Academy also uses gamification, a term used to describe the use of techniques and practices from the video game industry to make tests feel more like a game. The expected result, is that through gamification, student engagement with the content is increased.

Another MOOC that has shaped independent learning over the last few years is Udemy (9). Udemy’s innovation was in its decision to tap on the expertise of people outside of established, conventional education. For Udemy, anyone can be an instructor, just like anyone can be a learner. But unlike Khan Academy, Udemy is a for-profit business, and shares the revenue it earns directly from students with its instructors. This business model has resulted in thousands of people with a passion for teaching to monetise their dedication and skills by producing courses that thousands, and in some cases hundreds of thousands, of students can access for a small price.

The emergence of MOOCs in its many forms has been an incredible opportunity for millions of people to access educational resources. We can argue that this kind of revolution in the way that knowledge is disseminated has only been observed twice before in human history: after the invention of the Gutenberg press in the Holy Roman Empire by Johannes Gutenberg, a German goldsmith in 1440, and after the invention of the World Wide Web in 1992 by Tim Berners-Lee, an English scientist at CERN in Switzerland.

While there is a lot of educational activity activity in cyberspace and the Internet through the various MOOC platforms, the opportunities for learning are not confined there. There is plenty happening in the ‘real world’. The effect of globalisation, and global trade and the dramatic advancement in manufacturing, has led to countless high-quality physical educational products at very low prices. While in the 1980s and 1990s hardly any school would have been able to afford a microscope for doing biology experiments or an electronics kit for learning electronics, these learning tools are now within comfortable reach of most people, at least in the developed world.

A microscope with 200 times magnification can be purchased for $50 and can give a child a detailed view of the microcosm. The microscope can even be connected to a computer via a standard interface so that these images can be captured and shared online with friends and colleagues, or digitally enhanced and optimised with free image manipulation open source software.

Children can learn electronics with the help of inexpensive kits that contain microcontrollers, motors, lights, mechanical components, wires and prototyping areas. They can even program robots before they can properly read and write by using graphical programming languages.

People can convert their home into a chemistry lab with a $50 chemistry kit, and use it to learn how digestion works by observing how carbohydrates, proteins and lipids react to different digestive enzymes.

“Learning never exhausts the mind” — Leonardo Da Vinci

People can convert their backyard or their balcony into an observatory and learn about the Moon, the planets in our solar system, constellations and galaxies using a $100 telescope.

Mineralogy, geology, palaeontology, crystals, physics, medicine, electronics and much more is all within reach of more learners than every before, using near-lab-quality materials and a good dose of experimentation.

Aristotle said that learning should be done best by doing:

“Anything that we have to learn to do we learn by the actual doing of it … We become just by doing just acts, temperate by doing temperate ones, brave by doing brave ones.” (10)

The good news is that, in almost every conceivable way, the best time in human history to be learning anything is today. There has never been more knowledge to learn, more resources to learn from, and more fun ways to learn.

Interesting readings

1. Siri
2. Google Assistant
3. Amazon Alexa
4. Microsoft Cortana
5. MIT Open Course Ware
6. Open Learn (Open University)
7. Stanford Online
8. Khan Academy
9. Udemy
10. Aristotle Niconachean Ethics, Book II, p.91

The importance of technology education

Engineering, technology, and science generate wealth, prosperity, and growth.

Between 2000 and 2008, nearly two-thirds of the UK's growth was attributed to innovation. Science and technology are becoming increasingly important to both developed and developing countries. In Australia and elsewhere, immigration fills the gap between the number of engineers and scientists required by industry and what universities produce.

How can we change the negative stereotypes that are so damaging to young people's perceptions of what it's like to be an engineer or scientist?

Maker education revolution

Conventional education is struggling to provide the learning environment necessary to help raise the future innovators, problem solvers, and entrepreneurs that advanced societies need. Maker Education offers a model for education in the 21st century.

"Children have real understanding only of the which they invent themselves." — Jean Piaget

Engineering, technology and science creates wealth, prosperity and growth. Yet fewer young people are interested in pursuing them as a career. Why? And what does that mean for our continuing prosperity as individuals and societies?

Let's consider some numbers first. A joint statement from the

UK Academy of Medical Sciences, the British Academy, the Royal Academy of Engineering and the Royal Society suggests that in the UK, between the years 2000 and 2008, nearly two-thirds of the country's growth is attributed to innovation (1). Much of this innovation has been either directly in engineering, science and technology, or there is a direct relation to them. Further, the statement shows that continuous investment in research has long-term economic and social benefits.

Thanks to the continuing investment in science and technology over a long period of time, UK research has resulted in 14 out of the top 100 medicines in use today (second only to the US), globally. And 95% of mobile phones in use today contain technology developed in the UK.

The same statement says that there is a trend towards increased emphasis on technology and science training among many of the world's nations. For example, in 2013, President Obama said that "Now is the time to reach a level of research and development not seen since the height of the Space Race" during his State of the Union Address. Indian Prime Minister, Manmohan Singh, has called for his country to "endeavour to harness the tools of science to cater to the needs of the underprivileged and to bridge the gap between the haves and the have-nots."

Across the board, developed and developing countries are realising that science and technology are vital to the long-term stability and prosperity of their people. China's spending in science has been increasing at a rate of 19% since 2000, and now consumes 1.7% of its GDP. Brazil tripled its spending on research and development between 2000 and 2008. Singapore is doing the same. Finland is spending almost 4% of its GDP on science and technology research and development; Germany has committed an additional 12bn Euros to science and technology education and research.

The stakes are high, and the competition is growing.

Science and technology is vital to everything, from individual prosperity, to nation building and growing, and to addressing global problems like that of energy and the environment. To be able to successfully address these challenges, small armies of properly trained scientists and engineers will be needed.

Australia is struggling to produce these scientists and engineers (2). Australia’s Chief Scientist, Professor Ian Chubb, addressing attendees at a maths and science education symposium in Canberra, said that Australia needs a strategy to boost its international standing in science, technology, engineering and mathematics (STEM) or risk falling behind (3).

STEM education does not intend to convert all students into scientists or engineers, but to equip them with the ability to think like a scientist or an engineer.

The ability to systematically evaluate evidence, plan and execute a plan, self-correct based on new evidence, document and communicate findings, and much more, are all attributes that are very strong in STEM activities, but can be very useful across a vast range of activities. Imagine what science-like journalism would be like, or retail sales, or even community work.

Science and engineering, and the scientific approach in almost every aspect of life in an advanced society can also be seen as an unbeatable advantage for any country. Authors like Niall Ferguson, in his book Civilization: The Six Killer Apps of Western Power, recognise the six ‘killer apps’ that allowed several Western European countries to dominate globally: competition, science, property rights, medicine, the consumer society and the work ethic. Of these killer apps, all but the work ethic require a great deal of science and engineering (as the application arm of science) to get right and improve over time based on new evidence. Designing a healthy and fair competitive system, a property legal system, a health system and the framework in which a consumer society can function all require systematic design over long periods of time. This is science and engineering at a large scale!

Once we expose more students to STEM education, we need to be able to convert more of them to becoming engineers and scientists. In Australia, and elsewhere, the gap between the amount of engineers and scientists required by industry and what universities produced is filled by immigration. However, considering that the same immigrants are claimed by other countries, this approach is not enough (4).

Reversing the engineer and scientist stereotype is not easy. Popular imagination expects engineers to wear hardhats and mismatched socks, and engage in boring conversations. We imagine scientists as peculiar people that wear lab coats and smell of sulphur. In many cultures, being a lawyer or a police detective is glorified on TV. In the same shows, scientists are typically depicted as reclusive eccentrics that talk and behave like robots. Dr Spock from Star Trek, my personal movie hero, and Dr Emmett Brown from Back to the Future often come to mind. These are entertaining characters, but only the hard core among viewers would want to be like them.

We know that almost every child is naturally attracted to science and engineering. LEGO’s success can attest to this.

How can we change the negative stereotypes that are so detrimental to young people’s perspective of what life as an engineer or scientist is like, so that they want to become one themselves (5)?

Here are some ideas.

We can engage real scientists and engineers to visit schools on a regular basis and talk about their work. Engineers from different ethnic backgrounds and cultures, male and female, quirky or “normal”. Give children the opportunity to interact with them, even work on projects where the visiting engineer can be the mentor for a while.

Organise for children to visit engineers and scientists where they work: at the lab, the factory floor, the design studio, the construction site. In the mind of a child, nothing can imprint reality more than the real-life experience of witnessing something with their full senses engaged.

Ask real engineers and scientists to talk about their work and why it is important. A water engineer can explain to a class that her work results in the people of a large city having access to tap water, on demand. An electrical engineer can explain that their work makes it possible for them to turn on the lights at night. A medical researcher can explain that their work helps them recover from the flu.

Just imagine the impact that an engineer telling their story of designing spacecraft that will mine asteroids in the near future will have on a young mind's imagination. There is nothing more powerful!

The best way to satisfy the increasing demand of every society for more engineers, scientists, mathematicians and artists is to show learners examples of them as real people: what they do, and the impact that they have in the real world and directly in their lives. In the true spirit of Maker Education, learning by making is the best way to learn. Similarly, there is nothing more powerful than being inspired by reality, the achievements of real people who are like you and me, and who, through hard work, determination and a long-term vision, have influenced the lives of millions in a very real way.

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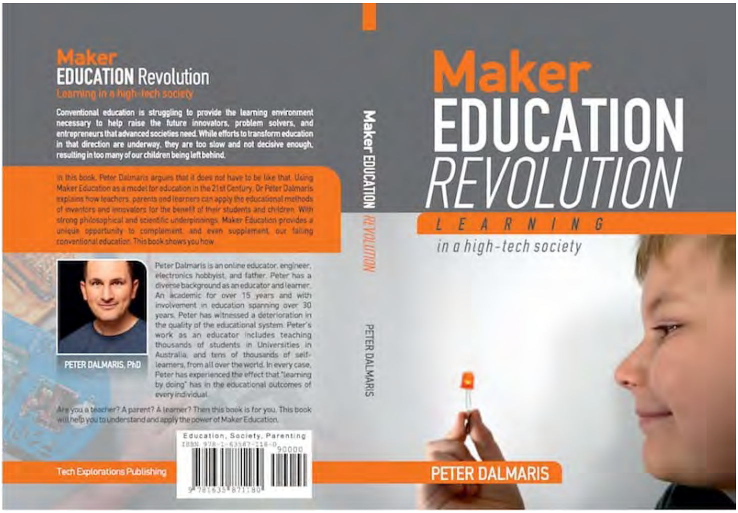
4. Building the nation will be impossible without engineers
5. The engineering stereotype: Why young

[people don’t want to become engineers]

Interesting readings

- [Engineers play a critical role in Innovation and Entrepreneurship]

Maker Education Revolution



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The role of the Arts in technology and education

At the Rhode Island School of Design, an initiative began to include a ‘A’ for Arts in STEM, making it ‘STEAM’ (Science, Technology, Engineering, Arts, Mathematics). Computer-generated images, video, virtual reality, 3D printing, and high-tech tools for artists are transforming art.

The Maker Movement is redefining arts and crafts, as well as science and technology, as highly personal and social endeavours. Everyone is a maker, and as a result, everyone is also an artist. The arts can be utilised to naturally introduce children to the world of making.

Maker education revolution

Blurb to be added

“There is no greater education than one that is self-driven.” — Neil deGrasse Tyson

While the common perception of the Maker Movement and Maker Education is that emphasis is given to the unification of technical competencies, especially craft and engineering, the importance of the arts as a source of balance, inspiration, and, of course, good taste, is increasingly being recognised.

An initiative to add ‘A’ for Arts in STEM, making it ‘STEAM’ (Science, Technology, Engineering, Arts, Mathematics), began at the Rhode Island School of Design (RISD), and is gaining wide adoption among schools, corporations and individuals (1).

The arts have been traditionally regarded as a completely separate learning direction to that of engineering and science. It is often hard to see how painting, sculpting and design can contribute meaningfully to a growth in the national GDP and to individual success. However, that way of thinking and viewing economic, commercial and personal reality is shortsighted. Today, with the benefit of many years of research in creativity, innovation and personal growth, we know that the arts are as essential as mathematics.

The arts cover an extremely diverse range of human expression and activity. Art can be visual, auditory or performing. It can be a medium for the expression of beauty, ideas or emotion. The arts are associated strongly with attributes such as creativity and interpretation.

Although artists can use virtually any kind of material to create art(-efacts), there is an increasing wave of artists using electronics and computer as a new medium for art. Computer-generated imagery, video, virtual reality, 3D printing and a new generation of high-tech tools for artists are transforming art.

Thanks to this convergence, artists and engineers are starting to recognise that they have complementary skills. The tools that an engineer can use to create the schematics for a diesel combustion engine can be used by an artist to design a fire-breathing dragon. When it comes to making and Maker Education, learners can learn a lot about creativity from artists. Creativity is a core ingredient to innovation.

The purpose of art varies, but most people agree that it is to satisfy a basic human need for harmony, balance and rhythm. This was identified by Aristotle, 2000 years ago:

“Imitation, then, is one instinct of our nature. Next, there is the instinct for ‘harmony’ and rhythm, meters being manifestly sections of rhythm. Persons, therefore, starting with this natural gift developed by degrees their special aptitudes, till their rude improvisations gave birth to Poetry." Aristotle (2)

Through art, we may also experience the mysterious, and express our imagination (3). It is hard to ignore these attributes when it comes to making. They are all powerful ways to satisfy basic human needs and enrich every aspect of our lives, including education, technology and business.

We can see art in everything that a maker makes. Constructing a robot or a useless box (4) requires engineering, of course, but the same sense of balance and imagination that an artist will apply to create a painting or a sculpture. Even though engineering often seems disconnected from those basic human needs, and it seems totally utilitarian, disconnected from its human designer, in making, things are very different. Every artefact has the signature of its maker in the way that it looks, the way that it is made, the way that it works. It is a one-of-a-kind.

And just as you can see the change in style and expressivity in the work of any artist, you can see the same in the work of any maker, as their skills, taste for symmetry and beauty, and confidence improve over time.

Dougherty, the publisher of Make magazine, said that…

"We often frame arts and crafts as being very personal and we often frame science and technology as being impersonal. Yet I think the Maker Movement is re-framing both arts and crafts and science and technology, so that they are understood to be highly personal and social, yet with shared skills and capabilities. It doesn't mean they are the same thing, but our culture has tended to separate them and create distance when we should be looking for cross-links and connections. Creativity lives at these intersections."

It seems that art is part of making, and just like everyone is a maker, as a consequence everyone is also an artist.

Let’s have a look at a few examples of how the arts can be part of making and maker education in particular.

The arts can be used as a natural way for children to enter into the world of making. Painting, sculpting with sand, colours and shapes all come naturally to children and they don’t need to be prompted to use them and make art (6).

Art can be used as a way to scaffold and complete a project. For example, the maker, being informed of the concepts of shape and symmetry, style and colour selection, can create an artefact that is both functional and aesthetically pleasing.

Educators have developed strategies that help to integrate arts into making specifically or into an education curriculum in general (7).

For example, visual arts can be used to allow students to express their learning by creating visual representations of their understanding. Being geography, biology, math or engineering, the scope for using visual arts to enhance learning is vast.

Another strategy can be borrowed from general music classes. Call and Response is a learning technique involves two musicians (8). One ‘calls’, meaning that she plays a musical phrase. The other one ‘responds’, meaning that he plays a different musical phrase in response to the first one. This technique builds on natural human communication and how a normal conversation takes place, with two people interacting verbally.

Because art is intrinsically personal, it is a perfect medium through which a person can express themselves uniquely. Consider a new box of Lego. It contains all the pieces necessary for building the toy, as described by the step-by-step instruction booklet that comes with the box. Typically, a child will construct the toy according to the given instructions. There is not much self-expression happening there, it is simply a process of the child becoming familiar with the Lego mechanics, and the various pieces. But what happens in the end, almost every time, is that once the construction as-per the instructions is complete, the child will start improvising. He will find a piece from an old Lego construction and add it to the new toy. He might move a piece from one part of the toy to another. He might just take it apart and start anew, with a completely new design, not following the instructions. The art within the child will come out eventually. Allowing for this to happen is extremely important, and is an effortless way to integrate art into making.

Over time, principles and techniques from the arts can also be introduced, so that the maker has a more elaborate array of artistic tools to use.

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5. Creating a Movement: What Makes Up Maker Faire
6. Project-Based Learning as a Context for Arts Integration
7. Use Arts Integration to Enhance Common Core
8. Call and response (music)

Interesting readings

- STEAM no STEM mission statement
- Picking up STEAM: How the arts can drive STEM leadership
- Full STEAM Ahead: Why Arts Are Essential in a STEM Education
- Arts Integration: Resource Roundup
- Project-Based Learning as a Context for Arts Integration
- Common Core in Action: Using the Arts to Spark Learning
- How to Infuse the Arts Into Core Curriculum (and Why It Matters)
- Making Matters! How the Maker Movement Is Transforming Education
- Sir Ken Robinson on how technology is transforming education

MER CTA

Drive in Making

Motivation can be internal, such as the need to survive and be safe, or external, such as monetary rewards and social prominence.

Both drive and a growth mindset are naturally present in children, according to research. Maker Education focuses on nurturing and enhancing our natural desire to learn for the sake of learning.

Maker education revolution

Conventional education is struggling to provide the learning environment necessary to help raise the future innovators, problem solvers, and entrepreneurs that advanced societies need. Maker Education offers a model for education in the 21st century.

“Steve Jobs, Bill Gates and Mark Zuckerberg didn’t finish college. Too much emphasis is placed on formal education – I told my children not to worry about their grades but to enjoy learning.” — Nassim Nicholas Taleb

Research in human performance over the last 50 years has shown something that surprised everyone in the business of getting people to work harder, faster and better.

In the first instance, scientists discovered that while people respond to external motivators, like monetary rewards, praise and status, in the short term, these motivators quickly lose their efficacy. When these motivators wear out, people tend to find it hard to maintain a high level of performance. Instead, what works much better is what the scientists called ‘drive’ (1). Drive is an internal, intrinsic motivator that pushes people to seek novelty, challenges, and the desire to explore, learn and improve their capabilities. But drive is more fragile than external motivators; it needs the right environment to survive and thrive.

In the second instance, researchers found that people create mental models of themselves in the world that are critical in shaping how they navigate through it, via their actions and behaviours. In general, there are two broad models: in the first one, people believe that their skills and abilities are fixed. No amount of work will change anything. Setting high goals is pointless. This is the fixed mindset. In the second one, people believe that their skills and abilities are not fixed. Through hard work and planning it is possible to improve every aspect of their performance. Setting high goals is not only pointless, but an obvious behaviour of someone who truly believes they can achieve them. This is the growth mindset.

Research shows that both drive and the growth mindset are naturally present in all of us in childhood (2). Somewhere, during the process of schooling and engaging with society as adults, many of us lose them both. Even then, though, both can be regained and used to transform lives and careers in a powerful and meaningful way.

Let's look at drive, first (and examine the role of the mindset in the next chapter). Harry F. Harlow, a professor of psychology at the University of Wisconsin in the 1940s, was interested in the behaviour of primates. In an experiment in 1949, he used rhesus monkeys to conduct a two-week experiment on learning. He created a simple mechanical puzzle that is easy for humans to solve. His expectation was that the monkeys would find it harder. The researchers placed the puzzle in the monkeys' cage and waited to see their reaction. What happened was very interesting. Without any external motivators, like food or prompting, the monkeys immediately became interested in the new object in their environment and began playing with it. They seemed focused, determined and to be genuinely enjoying the experience. It took them around 60 seconds to solve the puzzle.

Up to that point, in psychology, the accepted theory of motivation told a different story. Motivation can be either biological in nature, like the need to survive and be safe, or external, like the promise of monetary rewards and social prominence. This was the premise on which the Industrial Revolution was built, in which the factory system relied on monetary compensation to incentivise people to do menial and often dangerous work.

But what Harlow found, at least in primates, was that there is another force, drive, that is just as powerful, and perhaps even more so. Drive is what made the monkeys solve the puzzles. They did so for personal gratification, because they found it interesting and derived joy in doing so.

How might ‘drive’ translate to humans? Many years later, Edward Deci, who in 1969 was a Carnegie Mellon University graduate student, became interested in Harlow’s research. Harlow never continued his research with human subjects, and Deci decided to do just that. He devised an experiment in which two groups of students were given a challenge in the form of Soma puzzle cubes. The experiments were designed to see how much of the interest that the subjects showed to solving the puzzles was due to their intrinsic motivation (i.e. their drive, how much they enjoyed solving a puzzle) versus how much was due to external motivators, and in particular in the form of monetary rewards (3).

What Deci found was incredible, even so many years later. Here is what happened.

The experiment lasted for three days. In the first day, both groups were given the puzzles, and asked to reproduce a particular pattern, with no reward. At some point, the researcher would leave the room pretending to need to transfer data to a computer, and asked the students to do whatever they wanted in the next eight minutes. They could choose between doing nothing, reading one of the magazines or newspapers left on the table, or continuing to play with the puzzles.

On the first day, where there was no reward offered for solving a puzzle, students in both groups behaved in a similar manner. They continued to be interested in the puzzle for two or four minutes, before they lost interest and did something else.

On the second day, group A was offered a monetary reward for each puzzle solved, while group B was not offered a reward. After a couple of sessions with the researcher in the room, the researcher, just like on the first day, left the room pretending to have to copy the data in a computer, and left the students alone for eight minutes. Again, the students were told that they could do anything they wanted during this time. How did they behave? As common sense expected, students in group A seemed to be much more interested in the puzzles, spending more than five minutes messing around with them. The behaviour of the students in group B was the same as on day one. Why did students in group A show such strong interest? Perhaps they wanted to improve their chances for earning more monetary rewards on day three?

On day three, the experiment was repeated, but this time students in group A were told that there was no more money to be won. During the eight minutes of 'break' students in group B, who had never been paid to solve a puzzle, actually spent a bit more time with it. Perhaps they were getting fond of it and wanted to try out or learn new patterns. But the students in group A, that had been paid in the experiment the day before, spent significantly less time with it: a minute less than the time they spent on the puzzle on the first day of the experiment.

This suggests that even though all subjects enjoyed this task the same before an external reward was offered, the level of enjoyment was influenced in a negative way once a reward was offered and then removed.

Deci concluded that "When money is used as an external reward for some activity, the subjects lose intrinsic interest for that activity" (3). Often, external motivators like money not only don't help in achieving a better outcome, but they make it less likely to achieve a better outcome.

One of Deci's conclusions of these experiments is that humans have an "inherent tendency to seek out novelty and challenges, to extend and exercise their capacities, to explore, and to learn."

This is particularly important in the context of the Maker Movement since drive seems to be the core motivation for why makers do what they do.

In pure making, we cultivate the intrinsic drive that the rhesus monkeys and human experiment subjects had for doing something for the pure pleasure of doing it. It is why Wikipedia succeeded while Microsoft's Encarta didn't. It is why Linux runs the Internet today. It is why the Open Source movement has shaped much of the development of the Internet and the information superhighway.

In these examples, thousands of individuals worked and still work for long periods of time against the common perception that humans respond to monetary and other external rewards. The authors of Wikipedia articles, the authors of the code in Linux, Apache and SQLite are not compensated with money. In fact, they probably ignore money-making opportunities. Instead, they are following their internal drive to create something bigger than themselves, something deeply meaningful.

Maker Education is about the process of cultivating and strengthening our intrinsic drive to learn for the sake of learning, and make for fun. The process is more important than the tools, technologies and by what specifically it is that we make. This is a classic case of 'the journey is more important than the stopovers'. Even the destination is not important, since it is different for each one of us.

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Interesting viewing

- TEDxManhattanBeach – Paulo Blikstein – One Fabrication Lab per School: the FabLab@School project

Mindset in Making

A person who has a fixed mindset is predisposed to negativity. A person with a growth mindset is actively interested in improving.

The most important response from teachers and parents is a long-term intervention that will assist the student in developing a growth mindset. Studies show that the mindset of a student is a good predictor of their performance in life.

Maker education revolution

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“Don’t let schooling interfere with your education.” — Mark Twain

Carol Dweck is a professor of psychology at Stanford University (1). Her main research interest is motivation, personality and development.

One of her important contributions to understanding personal development is in helping us understand intelligence. Where does intelligence come from? Is it something we are born with, or is it something that we learn? Dweck’s work is packaged in her Implicit Theories of Intelligence (2).

While there is no widely accepted definition for intelligence, a statement that describes the term broadly is this:

Intelligence (is) generally described as the ability to perceive information, and retain it as knowledge to be applied towards adaptive behaviours within an environment or context (3).

In Dweck's Implicit Theories of Intelligence, people's approach to their own intelligence lies on a continuum. At one end of this continuum is the approach by which intelligence is a fixed quantity. You are born with it, and it does not change. This is called the 'fixed mindset'. According to Dweck:

"In a fixed mindset, students believe their basic abilities, their intelligence, their talents, are just fixed traits. They have a certain amount and that's that, and then their goal becomes to look smart all the time and never look dumb." (4)

At the other end of the continuum is the approach that intelligence is something that a person can gain over time, through learning, hard work, training. This is called the 'growth mindset'. According to Dweck:

"In a growth mindset students understand that their talents and abilities can be developed through effort, good teaching and persistence. They don't necessarily think everyone's the same or anyone can be Einstein, but they believe everyone can get smarter if they work at it." (4)

People are not always aware of their natural predispositions towards one or the other end of the continuum, but their mindset can be tested and measured nevertheless. These mindsets manifest themselves in a variety of ways. Two important ones are the attitudes towards failure and learning of new skills.

Imagine that you are a young university student, and you just had a hard day. You received a bad mark in a mid-term exam, lost your train ticket and got fined. When you called your best friend to talk about your day, he told you that he was too busy at that moment. How would you respond? What would you do?

Putting this question to people that lean towards the fixed mindset end of the continuum reveals this fixed aspect of their personality. Negative thoughts and attitudes dominate.

– “I feel like a total reject.”- “I am an idiot.”- “I am a loser.”- “I am worthless and dumb.”

A person with a fixed mindset comprehends what happened as a direct consequence of their worth and capability as an individual. They would react perhaps by deciding not to make an effort to become better since the capacity to do so is not within them. They would try never to get themselves in a position where someone else would have to assess their capability. They would stay in bed and do as little as possible.

Notice that nothing in the day of this person was terminal and catastrophic. A bad mark does not mean failure in the semester, and a lost train ticket can be easily replaced. Their best friend was most likely truly busy, perhaps with a pending assignment deadline, and would have called back as soon as he could. But the fixed mindset is primed for negativity.

If you give the same question to a person who leans towards the growth mindset, you will see a totally different response:

– “I need to try harder in class. I should have been better prepared for the test.”- “I should have placed my train ticket in my wallet the night before the test. I was thinking about the test in the morning and forgot to take it out of the drawer.”- “I will talk to the teacher to figure out how to improve my scores.”- “My friend is too busy at the moment, I know he has a big exam coming up.”

It is a totally different way to deal with adversity. A person who is thinking according to the growth mindset is actively interested in improving. They don’t see their current performance as a direct consequence of their self-worth and capability, but as an indication and a datapoint of where they are, and how much work they need to expend in order to improve the performance to the next level.

Several experiments by Dweck and others show that the mindset of a student is a good predictor of their performance in life, and that, most important, mindset is malleable. It can be changed. In one such study, Dweck researched fixed and growth mindsets in a New York public secondary school. In total, 91 students completed the study. They were in seventh grade, and were relatively low achievers. At math, they were at the 35% percentile nationally. They came from a poor socio-economic background, with almost 80% of them being eligible for free lunch.

The students were divided into two groups. Forty-eight were placed in the experimental group, and 43 in the control group. The students were allocated to the two groups so that on average, there was no significant difference in math performance. For example, the term average math score for the experimental group was 2.38, and for the control group 2.41, on a 4.0 scale.

These math scores were used as a baseline of group performance. Using a questionnaire, the researchers measured the students' initial motivational profiles. This included metrics for theories of intelligence, learning and performance goals, beliefs about effort, and attributions and strategies in response to failure at the beginning of the fall seventh-grade term. All students were told that they had the opportunity to participate in an eight-week workshop where they would learn about how the brain works. The aim of this workshop was to help them achieve better grades. Their participation was voluntary, and they would receive a certificate in the end.

Both groups received training about things such as the structure and function of the brain, anti-stereotyping lessons and study skills lessons. The experimental group, however, received training in incremental theory intervention, participated in discussions about learning and intelligence, and learned about brain plasticity and how learning makes people smarter. These interventions were specifically designed to reinforce and cultivate a growth mindset, and to convince the participants that it is possible to improve their performance through work and effort. The control group, however, received lessons on how to improve their memory instead of getting an incremental theory intervention.

At the end of the eight-week intervention program, the math score for the experimental group was significantly higher than the control group. More important, the trajectory of the math performance for the experimental group was upwards, while that of the control group was unchanged, downwards.

The trajectory of the math performance for the experimental group, from the time before Dweck began the study to the time that Dweck began the intervention was downwards, and a steeper angle than that of the control group. The experimental group's performance was in fast decline.

Between the time when Dweck began the intervention and the time when the experiment ended, the experimental group had made a complete turnaround. The intervention managed to not only stop the downwards performance trend, but it reversed. Scores started to increase and continued to increase until the end of the experiment.

The testimonial from the school math teacher that participated in the study is as revealing as the numbers are:

"L., who never puts in any extra effort and doesn't turn in homework on time, actually stayed up late working for hours to finish an assignment early so I could review it and give him a chance to revise it. He earned a B1 on the assignment (he had been getting Cs and lower)."

"M. was [performing] far below grade level. During the past several weeks, she has voluntarily asked for extra help from me during her lunch period in order to improve her test-taking performance. Her grades drastically improved from failing to an 84 on her recent exam."

What can we conclude from the work of Carol Dweck and many others who have confirmed and extended her findings?

A student’s belief in their own ability to improve is detrimental to their current and future performance. Growth mindset is the an approach to personal development that says that intelligence is not fixed, but malleable. It is hard to imagine an effective learning environment in which students are not assisted to develop such mindset. Learning cannot take place unless the learner believes that she can learn, and becomes an active participant in this learning.

If a student believes that her intelligence is fixed, if she has a fixed mindset, the most important response from teachers and parents is an intervention that will help the student to develop a growth mindset, over time. There is no point doing anything else. The fixed mindset belief will simply guide the student to developing strategies to avoid work that she sees as pointless, and avoid situations in which grading and performance evaluation is likely. In general, a severely fixed-mindset student will do everything possible to make sure that things don’t get any worse (as they see it), rather than striving to improve on the skills they lack.

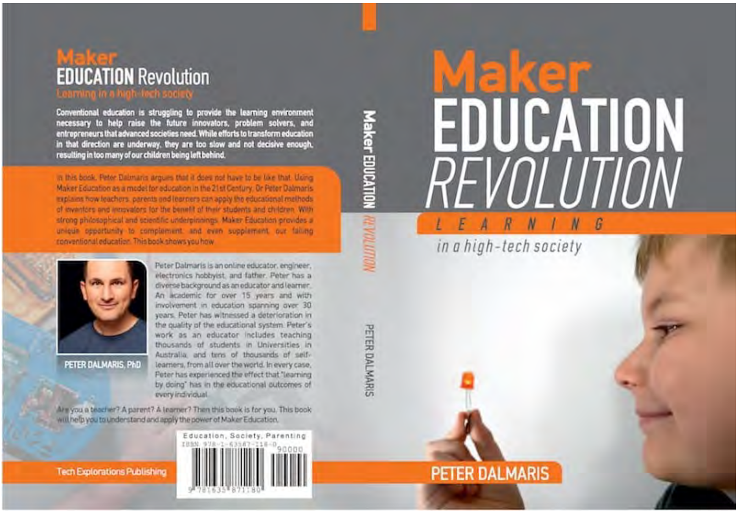
References

1. Carol Dweck
2. Dweck, C.S.; Legget, E.L. (1988). ‘A social-cognitive approach to motivation and personality’. Psychological Review. 95: 256–273. doi:10.1037/0033-295x.95.2.256, Implicit theories of intelligence
3. Intelligence
4. Stanford University’s Carol Dweck on the Growth Mindset and Education

Interesting readings

- [The Maker Mindset by Dale Dougherty]
- [Capture the Learning: Crafting the Maker Mindset]
- [Certificate Program Helps Educators Grow a “Maker Mindset”]
- [Must-Haves for Developing a Maker Mindset]

Maker Education Revolution



Learning in a high-tech society.

Available in PDF, Mobi, ePub and paperback formats.

Using Maker Education as a model for education in the 21st century, Dr Peter Dalmaris explains how teachers, parents, and learners can apply the educational methods of inventors and innovators for the benefit of their students and children.

Learning like an inventor

Inventors are aware that inventions take a long time to produce results. Nikola Tesla believed that in order to be an effective inventor, one must be completely immersed in their work. Tesla, like Da Vinci, had a track record of mostly failures interspersed with successes.While we don’t have to go as far as Nikola Tesla in our quest for knowledge, we can learn a lot from him and incorporate some of his qualities as an inventor into our daily learning.

Maker education revolution

Conventional education is struggling to provide the learning environment necessary to help raise the future innovators, problem solvers, and entrepreneurs that advanced societies need. Maker Education offers a model for education in the 21st century.

“To invent, you need a good imagination and a pile of junk.” — Thomas A. Edison

Inventors are said to be children that never grew up. With their minds unchanged from their childish passion for curiosity and experimentation, they are the essential lifelong learner.

Indeed, the thinking process that inspired Leonardo Da Vinci to design a flying machine that was heavier than the air and of a five-year-old toddler making a tower of Lego pieces are probably very similar. The main difference between the two inventors is that Da Vinci had the advantage of a lifetime of lessons learned from experimentations, each one consisting of several cycles of trial and error.

Nikola Tesla, another prolific inventor, just like Da Vinci, had a track record of mostly failures, peppered with a few successes. Some of his successes changed the lives of millions of people. His inventions relating to the generation and transmission of alternating current electricity, for example, have been instrumental in the development of our modern societies.

What are some of the characteristics of inventors like Leonardo Da Vinci and Nikola Tesla? What can we discover from them about the nature of learning? And how can we use their approach to learning to create better educational environments for all of us, and especially our children?

Nikola Tesla was a prolific reader. He is often quoted to have said: “Of all things, I liked books best.”

From an early age, he devoured books. As a young man, he depended on Mark Twain’s works to help him through a difficult period in his life that involved recovery from serious illness and evasion of conscription in the Austrian-Hungarian Empire Army in the 1870s. Within books, Tesla discovered strange new worlds of thought, of facts and theories. He found inspiration, and he found answers to the many questions that troubled him. He found a way to escape reality when he felt tired and overworked. His curiosity about everything is demonstrated by the sheer quantity and variety of topics of the books that he read.

Tesla was an introvert. He enjoyed spending days in his laboratory, experimenting and tinkering. Tesla believed that to be an effective inventor, one must be absorbed in their work. By this, he did not mean that inventors should work in isolation, but that deep introspection, and quiet, quality time contemplating their central problem is absolutely necessary. In a modern world where distraction is everywhere around us, twenty-four hours a day, seven days a week, every week, this is something important to remember. In a way, the Internet and our access devices have connected us to the extent that we are never alone, but have taken away the ability to be alone, think deeply about something, or simply be bored. Invention and creativity can’t be rushed, yet at work and school all work is neatly given a fixed amount of time and resources to complete.

Tesla believed that the optimal way to solve a problem requires a balance between the theoretical and experimentation (constructionist) approach. He criticised Thomas Edison of not using modelling and abstract thinking to evaluate a problem, instead relying predominantly on experimentation. This, according to Tesla, resulted in an unnecessarily large waste of time. On the other hand, too much concentration on abstraction, not backed by experimentation in the real world, results in outcomes that are intangible and hard to understand. This is important in the context of learning. Tesla seems to agree with the opinion of the philosophers who believe that learning should be rooted in reality.

There is no substitute for hard work, even for the geniuses among us. Tesla was a legendary hard worker. In his autobiography he spends a lot of time describing many of the activities that in today’s hyper-efficient world would be seen as wasteful and unproductive. Contrary to modern attitudes towards efficiency and punctuality in everything we do, creative and original work cannot be project managed. Specific performance key performance indicators, deadlines, objectives and rigid reporting may work well in an industrial, performance-oriented environment, but do not work at all for inventors. Learning, like inventing, involves considerable effort that cannot be scheduled mechanistically or managed like a process. Inventing is not a nine-to-five job, neither is learning.

Inventors don’t work in isolation. They learn from each other. Whether it is breakthroughs or mistakes, whether they are colleagues or competitors, inventors are well aware that they are better at what they do by learning from others, and by knowing what has happened or is happening around them.

Tesla’s work on the wireless transmission of power involved physics and electrical components that are also useful in the transmission of radio signals. Tesla’s student, Guglielmo

Marconi, apparently used some of Tesla's patented work in wireless power transmission to build his revolutionary radio transmission device in 1895. Marconi also used radio transmission techniques developed by Herz and others.

Inventors are people, and by no means do they always act with a high moral standard, defying natural human emotions like jealousy and even contempt. When Marconi's company achieved the successful commercialisation of his radio equipment and its stock value soared, Tesla sued for patent infringement. After Tesla's death in 1943, the US Patent Office eventually upheld Tesla's radio patent number 645,576. This is what happens in the real world of invention and problem solving: collaboration, stealing or simply borrowing of ideas. In contrast, the conventional education system expects and demands that students should work in isolation to complete assessment tasks and assignments.

Inventors understand that inventions take a lot of time to deliver results, especially if the problem they are solving is large and complicated. This long-term view of work and life in general goes against the expectations for fast results in all levels of modern life. Personal instant gratification in the age of on-demand TV and express shipping of goods purchased on the Internet, the accelerated production cycle of all kinds of products, from cars to electric toothbrushes represent significant achievements of our modern civilisation. They also present challenges, as they condition us to think short term even though we know that anything that is important needs a long-term approach. Schools too, expect fast results from students. A new concept taught in class today will be tested tomorrow, then another new concept will be taught the day after, before the student has the opportunity to fully internalise the new knowledge.

Tesla's view on personal development was that it is tightly connected to invention. Invention brings about a constant opportunity to learn and test the new knowledge; it is an integral part of the learning process. Life, in a way, is a journey of problem solving. Inventing is problem solving. Whether you are solving a problem of irrigation in your garden or climate change, the pursuit of a better solution will push you to explore new possibilities in areas you would not have thought otherwise. Through invention, the process of creating a tangible output, you will be able to test those possibilities and select the best ones for further evaluation.

Over his lifetime, Nikola Tesla worked in an extremely diverse field of topics: alternating current, light, oscillators, X-rays, radio, remote control, just to name a few. He produced 278 granted patents in 26 countries. Tesla even imagined a ‘death-ray’ type weapon in which a high-energy beam would destroy targets at large distances, and robots, in the form of a remote-controlled board that he actually built in 1898.

Inventors do not feel confined to a narrow area of ‘expertise’. They tend to be polymaths, and capable of absorbing and utilising knowledge from any area if it provides the means necessary to solve a problem and complete an invention. Again, this contradicts common practice today in which, whether at school, university or the workplace, the key to efficiency is the total specialisation to a specific niche. Again, a remnant of the Industrial Revolution, it has influenced greatly how schooling is done, with learning outcomes neatly allocated within well-defined areas of knowledge.

Tesla, just like Da Vinci and so many other inventors who have defined our way of life, was far from perfect, but he was uniquely human. He expressed regret for not marrying and dying alone in a dark apartment:

“Sometimes I feel that by not marrying, I made too great a sacrifice to my work …”

But he also expressed pride for his achievements. He saw his life as one of contribution to the world. Just like we can learn from the achievements of Olympic athletes, inventors like Tesla and Da Vinci were extreme individuals whose achievements can teach us a lot about learning and creativity.

While we don’t have to become as extreme as Nikola Tesla in our pursuit of knowledge, we can learn a lot from him and we can apply some of his attributes as an inventor in our day-to-day learning.

Interesting readings

1. The invention of radio
2. Nikola Tesla
3. List of Nikola Tesla patents

Inventors and their process of make, test, learn

Above all, an inventor is a learner. Inventors solve real-world problems by developing physical solutions. They must make a series of decisions, apply knowledge from various domains, and investigate and learn about any new unknowns.A young inventor will follow a simplified, intuitive version of the inventor process. Play is a method for discovering potential solutions to problems. Observing inventors or children playing can teach us a lot about learning.

Maker education revolution

Blurb to be added

“The progressive development of man is vitally dependent on invention. It is the most important product of his creative brain.” Nikola Tesla, My Inventions

A core aspect of the inventor’s process of work is that anything they do is grounded in the real, tangible world. They solve problems of the real world by creating physical solutions. They follow an iterative process according to which every design decision they make is implemented, validated and improved upon.

Using the data they extracted from each iteration, they make new decisions: “Should I replace component A with component B?”; “Should I try a new configuration for this sub-circuit?”; “Is my current design capable of solving the problem to specification”?

Inventors create tangible outcomes to validate and improve their knowledge.

Inventors also seem to enjoy what they do immensely. Given a choice of spending their time in a lab working at an exciting problem, or at a tropical beach having cocktails and sunbathing, they will always choose the lab!

Being an inventor is hard. It is hard on the body and the mind. Thomas Edison, perhaps America’s greatest inventor, said:

“Genius is one percent inspiration and 99 percent perspiration.”

But there is a lot more to the story of inventing than just hard work. Let’s dissect in some detail the cognitive skills that, over time, an inventor develops in order to be able to achieve their goal.

At the very start of the process, an inventor must look around, in the real world, and recognise things that are not quite right. What looks perfectly normal for other people, to an inventor it might look broken, inefficient, imperfect.

Once the problem is found, it must be evaluated and if determined important enough to solve, to at least try to solve. The process, which heavily resembles a systems thinking approach, can be approximated to the following steps:

1. Detect a problem.
2. Evaluate its importance (is it worth solving?).
3. Conceptualise and analyse the problem (understand the problem in every possible detail).

4. Devise a draft architecture for a solution.
5. Analyse the problem into functional components.
6. Implement a prototype solution and evaluate it.
7. Collect performance data from the prototype solution.
8. Evaluate the performance data and use it to reassess prior assumptions at all previous steps, i.e. is the problem still important? Is the solution practical and worth the effort?
9. Evaluate the possibility that this iteration has produced an acceptable solution. If yes, this is your solution. If not, reiterate, and try to get closer to an acceptable solution.

Within this process, the inventor will have to make a series of decisions, apply knowledge from different domains, investigate and learn any new unknowns.

During this process, the inventor must put into work a wide range of core skills. Here are some of them:

1. Synthesis (the skill of selecting and combining a variety of components into a working system)
2. Analysis (the skill of examining and identifying the parts that make up a problem)
3. Efficient context switching between synthesis and analysis (creating a solution requires constant switching between

synthesis and analysis)
4. Contextual awareness of their environment (ability learn from others, evaluate changes in the environment that may effect prior assumptions about the problem and the proposed solution)
5. Ability to discern what is important and what is not (the ability to remove noise from the information available in the world)
6. Fanatical note taking (as memory is fallible, valuable passing thoughts can contain they key to solving a problem)
7. Adaptability (as new information becomes available, use it to improve the understanding of the problem and the proposed solution)
8. Play as a way to discover possible solutions to problems

In almost every step of the invention process, there is learning. This is because, according to most definitions of the word, an invention has to be something new, at least for the inventor.

Imagine a child putting together a four-wheeled robot. She has never really done something like this before. She may have heard about four-wheeled robots in the past, she may even have read instructions on how to assemble one and about the components that are needed. But until she actually creates this robot, she will not know it. The learning will come by actually focusing on the process of creating the physical artefact.

The young inventor will, intuitively, follow a reduced, intuitive version of the inventor process.

Imagine now that she starts to assemble the robot, diligently following the step-by-step information printed in an instruction manual. Oh, no! She mis-wired a motor, and the robot’s wheels spin in the opposite direction to what she expected! What happens in her mind now?

First, she will realise that something is not right with the assembly. Her robot is not moving as expected.

Second, she will focus on the part of the robot that seems to be behaving incorrectly, the rear wheels.

Third, she will look at the component that actually makes the wheels move, which is the motor. She will realise that the motor is causing the wheels to move the wrong way.

This will prompt her to investigate motors, and why they work the way they do. Her desire to fix her robot will prompt her to either look up this information on an online resource, or ask someone that might know the answer. She may even remember having a similar problem in the past, and recall her existing knowledge on the topic. One way or another, she will find the answer and realise that the problem can be fixed simply by swapping the wires that power the motor.

The process of creating her invention exposed her to several opportunities for learning. Although she had never built a four-wheeled robot before, she had the goal in mind and worked diligently across several fields. Most likely, she did not even realise that she did, since in her experience all of these fields are integrated into one: making a four-wheeled robot.

Electronics, mechanical engineering, programming, systems thinking and electromagnetism are just some of the cognitive components that the inventor needs in order to put together this physical device.

Learning felt like playing, and making was just the method based on which learning becomes playful and engaging.

This is typical inventor behaviour. A problem is an opportunity for learning.

She now takes out her smartphone and takes a photograph of her creation (an equivalent of an inventor's fanatical note-taking habit). She adds this text annotation to the photo: "My first four-wheeled robot! Beware of how you connect the motor or it won't move the way you expect!". She posts the photo and the quick description to her electronics hobby group on Facebook. A response comes back just a few seconds later from a friend:

"What kind of motor did you use? And the microcontroller, what is it? And can you share the code?"

To which she replies:

"For the rear wheels I used a cheap 5V DC motor, and for the front ones a mini-servo motor. I used an Arduino, I love it! And here's my code on GitHub! Have fun!"

Despite the legends around supposedly lone inventors like Tesla and Edison, the process of invention is very collaborative, even when people are not in te same room. Inventors will always build their work on top of the work of others, and reciprocate by sharing their work with others.

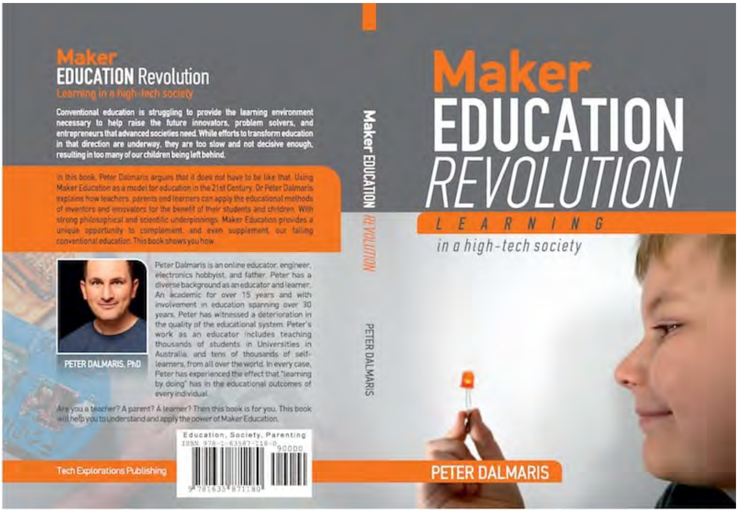
An inventor is, above all, a learner. The learning that the inventor does is guided by the inventor's objective, which is the creation of a physical object that is new, at least to them, and perhaps has never existed until it is captured in the inventor's mind, and turned into reality by their hands.

We can learn a lot about learning by observing inventors, or children playing.

Interesting readings

1. The process of invention: Now and then

2. The Wright Way: The Process of Invention



Maker Education: A new education revolution

The Maker Movement is a social movement comprised of independent inventors, tinkerers, and designers. Makers, who resemble computer hackers from the 1960s and 1970s, create real-world artefacts.Maker Education emphasises hands-on learning. It encourages students to take responsibility for their own learning by solving real-world problems.

Maker education revolution

Blurb to be added

“Tell me and I forget. Teach me and I remember. Involve me and I learn” — Benjamin Franklin

Inventors are revolutionaries. They change the way we live by solving everyday small and large problems. Their inventions are tangible proof of what is possible when our mindset and way of thinking goes against the grain of the established way of doing things.

Henry Ford showed that cars can be made in massive numbers and cheaply at a time when car manufacturing produced expensive cars for the few and privileged. Steve Jobs and Steve Wozniak showed the every home can have a computer, and that anyone can learn how to program them. Peter Diamantis and Elon Musk showed that private space flight and the commercialisation of space is possible.

In education too, it is now possible to think against the grain.

The fundamental components for building superior educational experiences now exist. The academic research is rich with evidence-based best practices in every context imaginable. The educational materials, like textbooks, lecture videos, and computer programs, are plentiful and easy to find across multiple delivery channels. And the opportunities for hands-on experimentation and learning are also abundant.

For the last ten years, we have witnessed the evolution of a truly remarkable education paradigm that addresses the core of the problems in conventional education by applying the principles of inventor learning. It is called Maker Education. Its modern origin can be loosely traced to 2006 when the first Maker Faire event took place in San Mateo, in the San Francisco Bay area. A year earlier, the hallmark Maker publication, Maker Magazine, was published for the first time. Maker Magazine was inspired by the century-old Popular Mechanics magazine.

The social success of Maker Magazine is that it gave millions of people a name for what they do, an identity, and a sub-culture. People have been tinkering and making things for thousands of years, but through Maker Magazine these people assumed a strong identity, and a name for what they do.

The magazine, as well as other similar publications, defined the Maker Movement. The Maker Movement is a social movement that includes independent inventors, tinkerers and designers from all walks of life, educational and cultural backgrounds. These people tend to define themselves as 'Makers'. While they resemble the computer hackers of the 60s and 70s, which nurtured the pioneers of personal computing and the likes of Apple and Microsoft, Makers create real-world artefacts using technologies that a few years ago belonged in industrial research and development labs.

Makers use technologies like three-dimensional printers, CNC cutting machines, laser scanners, laser cutters, open source software tools for designing models of objects like printed circuit boards and enclosures for electronic parts, and cheap, massively produced components. Makers favour open source technologies whenever they can find them, or they create their own when they can't.

The Maker Movement is big. In the US alone, some estimates suggest that 135 million adults consider themselves to be Makers (this information is provided by Atmel, a maker of microcontrollers, which is an essential component of Maker creations). The value of the 3D products purchased by makers in 2017 is estimated to be around US$6 billion, expected to climb to US$8.41 billion by 2020.

Perhaps the most important outcome of the Maker Movement is the effect it is having on education. Maker Education favours a hands-on approach to learning. It advocates that learners take responsibility for their own learning by solving real-life problems. Just like makers are self-reliant problem solvers, in Maker Education learners are in charge.

In San Diego's High Tech High, students are Makers (1). The Makers, ranging from kindergarten to Year 12 students, learn by "making, doing, building, shaping and inventing stuff". Principal Larry Rosenstock, CEO and founder, explains that students spend most of their day working together in projects that give them the opportunity to apply knowledge that comes from different traditional 'disciplines'. These disciplines are normally taught separately in conventional schooling, neatly separated by textbooks, classrooms and instructors. High Tech High is more like a 12-year-long kindergarten. Just as in kindergarten, children have the freedom to explore their curiosities. Throughout their time at High Tech High, students retain that freedom.

Consider a typical day at High Tech High. A humanities and an engineering teacher work together to devise a project for their students. The humanities teacher's objective is to encourage his students to learn about the ancient civilisations of the Mayans, Greeks and Romans, and specifically their rise and fall. The engineering teacher wants his students to learn about geared systems and how to use them to transmit energy. Their combined project involves challenging the students to create a physical contraption in which interlocking cogwheels tell the stories of these civilisations. As the wheels turn, a different era is recounted. The students are broken down into groups of five, and begin their research: history and engineering, self-directed. Each group may return with a different interpretation of the objectives, but in each case the assignment is solved, in their own way.

What happens at High Tech High is an example of how Maker-style Education works. Self-directed learning, a conducive learning environment in which the educator is there to provide the direction and just enough support to help the student pursue their learning interest, and where the learner can find the tools they need to create their inventions. Collaboration is built into the environment, with teamwork designed so that learners support and motivate each other. This is an example of how a high-performance work environment is used to achieve high-quality learning outcomes.

All student work is open for visitors to the school to see, and learn from. Students become used to the ideal that they themselves are teachers for others. In the case of the civilisations project, the students' six-foot-diameter geared wooden wheel that encoded their understanding of why civilisations rise and fall was an exhibit in the school's annual exhibition. Exhibits and exhibitions like this transformed the school into a museum and art gallery at the same time.

What is the life outlook for students like the ones in High Tech High? Or any other young Maker? Tony Wagner, author of Creating Innovators: The Making of Young People Who Will Change the World, observes how the world's greatest innovators evolved through childhoods filled with creative play which led to the development of deeply entrenched curiosities. These became intrinsic motivations that guided their life and career goals throughout their lifetimes.

Perhaps more importantly, because as children these innovators were used to constant failure and recovery, like failed experiments, assumptions and materials, they developed to be resilient adults, able to not just cope with the setbacks of life but to persist and thrive. For them, what others see as difficulties or problems are opportunities for learning and growth.

In Maker Education environments, failure is not punished with a low grade. It is seen as another opportunity for learning.

In the sections and chapters of this book we will look at how Maker Education works and discuss practical ideas of how you can implement a similar environment in your own school or homeschool.

Interesting readings

1. High Tech High
2. Maker culture
3. Why the Maker Movement Is Important to America's Future
4. Maker Faire history
5. The origins of the Maker Movement
6. Why the Maker Movement Matters Part 1
7. Does the Maker Movement Matter?
8. Forget 3D-Printed Knick-Knacks: The Maker Movement Is Entering a New Phase
9. Maker movement reinvents education
10. Creating Sustainable Performance

The philosophy of Maker Education

The philosophical foundations of the Maker Movement and the Maker educational style can be found in the writings of great philosophers. Aristotle was among the first to recognise the link between education and quality of life. Students, according to John Dewey, should be able to interact with and experience their curriculum.Constructionism, developed by Seymour Papert, widely regarded as the father of the Maker Movement, was influenced by Jean Piaget's constructivism. According to constructivism, a learner constructs a personal understanding and learning of the world through their experiences.

Maker education revolution

Blurb to be added

"If a child can't learn the way we teach, maybe we should learn the way they learn." — Ignacio Estrada

The philosophical underpinnings of the Maker Movement and the Maker style of education can be traced in the writings of ancient philosophers, like Aristotle. Aristotle spent a large portion of his life thinking about education and learning. Although not a maker himself in the modern sense of the word, Aristotle was perhaps one of the first to recognise the relationship between education with quality of life. He is credited with having said that "the fulfilled person was an educated person".

Aristotle also emphasised that learning must be balanced, with play, physical training, music, debate, science and mathematics all playing a role in developing healthy minds and bodies. He pointed out that learning is lifelong and best done by doing (1):

“Anything that we have to learn to do we learn by the actual doing of it… We become just by doing just acts, temperate by doing temperate ones, brave by doing brave ones.”

In more recent centuries, philosophers and educators have worked diligently in trying to understand learning and education in a modern context, as these are shaped by the industrial education paradigm.

John Dewey, an American philosopher and reformer, has greatly influenced the thinkers that eventually shaped the Maker Movement. He believed that students should and in fact must be allowed to interact with and experience their curriculum, and that they should be encouraged to take active part in their own learning.

“Give the pupils something to do, not something to learn and the doing is of such a nature as to demand thinking; learning naturally occurs” — John Dewey.

Dewey is perhaps one of the first, if not the first, modern educator who argued that education should strike a balance between the delivery of knowledge and the wants and personal needs of the student. At that point, in the late 1800s, students were merely the recipients of facts and figures delivered by teachers across the classrooms of the developing and industrialising world.

Dewey became a proponent of hands-on learning and experiential education, which is related to experiential learning. Experiential learning is the process of learning through doing and reflecting on doing. On the other hand, experiential education involves both a teacher and a student and is described as the process of learning via the direct experience of the learner within the learning environment and the content.

All this was refined into concrete terms by later educators and practitioners. Seymour Papert, widely acknowledged as the father of the Maker Movement, developed constructionism. Constructionism is the theory of learning which arguably best explains the efficacy of Maker-style Education.

Papert's constructionism is, in turn, heavily influenced by Jean Piaget's theory of constructivism. In constructivism, a learner will construct a personal understanding and learning of the world through their experiences and their reflection on those experiences. In constructivism, passive learning does not lead to a real learning experience, only to a memorisation of facts.

A student of Piaget, Seymour Papert, through his constructionist approach, created a framework that can be used to apply Piaget's core constructivist ideas. According to Papert's constructionism, students learn by applying what they already know in practical projects designed to expose them to new knowledge. The role of the teacher is that of the coach. Step-by-step guides and lectures can be used as learning tools where it makes sense, but they are not necessary. In Maker-style education, the critical component in constructionism theory is that according to the theory, the student will learn best if they actively create tangible artefacts in the real world.

This is Papert's definition of constructionism (2):

"The word constructionism is a mnemonic for two aspects of the theory of science education underlying this project. From constructivist theories of psychology we take a view of learning as a reconstruction rather than as a transmission of knowledge. Then we extend the idea of manipulative materials to the idea that learning is most effective when part of an activity the learner experiences as constructing a meaningful product."

Papert demonstrated his theory by creating educational tools, some of them still in use today. He was one of the first educators to advocate the use of computers by students for the purpose of learning anything, not just computing.

This was in the 1960s, the very early days of computing. In those days, computers cost more than a car, and were used by specially trained technicians or scientists on specific academic and commercial applications. Papert suggested that children should be allowed to play with these machines, and should be encouraged to connect them to external appliances like lights and door locks. The children could then write programs and create interfaces to programmatically control appliances from the computer. This was the precursor of what today we recognise as “physical computing”, in which microcontrollers like the ones embedded in the Arduino prototyping platform, allow people to experiment with interfacing computers with the world around them.

Over the years, Papert developed various educational technologies that connected the computer programs and software with the physical world or treated computer science and algorithm design games. All this was designed to help learners learn through experience.

For example, the Logo programming language was developed in his MIT lab. In Logo, the learner can write a simple program to control a turtle icon on the screen. The turtle leaves a trace behind it as it moves around the screen, which eventually can become an elaborate drawing. The learner can see the result of an instruction in the program immediately on the screen and use that as instant feedback that can be used in the process of improving or extending the program.

Papert also created a physical turtle, the “Logo Turtle”, that exists in the real world in the form of a small robot. The movement of this robot can be controlled by the same program as its virtual counterpart. Logo Turtle is fitted with a collar marker so that it can draw a line on a sheet of paper as it moves on the paper’s surface. With the physical version of the turtle, learners can study robots and transfer their knowledge from the more abstract world of bits and bytes to that of atoms. Logo was developed in the 1960s, to make it fun for children to play with computers, and is still in use today as one of the oldest high-level programming languages.

Papert worked directly and indirectly on several other impactful projects, always informed by the principles of constructionism. For example, Lego's Mindstorms robotics kits have been heavily influenced by Papert's work, and even bear the name of his important 1980 book, Mindstorms: Children, Computers and Powerful Ideas.

In this book, Papert explains how "the child programs the computer and, in doing so, acquires both a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building."

Lego Mindstorms is a robotics educational platform that children use today in classrooms and homes across the world to learn how to build and control robots while they play. They are a colourful and engaging way to learn skills that traditionally require tedious and long study in a classroom environment.

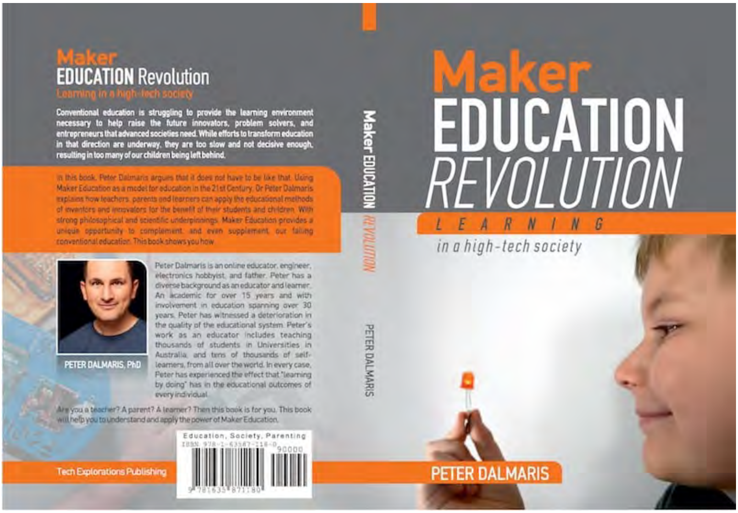
Maker Education is essentially an education paradigm by which learners learn by exploring their own curiosities, and by using real-world artefacts to construct and reflect on their learning. In the remaining chapters in the section of this book we take a closer look at what this means in practically.

References

1. Aristotle Nicomachean Ethics, Book II, p.91.
2. Sabelli, N. (2008). Constructionism: A New Opportunity for Elementary Science Education. DRL Division of Research on Learning in Formal and Informal Settings, 193-206. Retrieved from http://nsf.gov/awardsearch/showAward.do?AwardNumber=8751190

Interesting readings

- [Aristotle and education]
- [The maker movement: A learning revolution]
- [Maker Movement: philosophical emphasis]
- [On education and teacher education]
- [Experiential Education]
- [Experiential Learning]
- [Constructionism]
- [Jean Piaget]
- [Constructivism]
- [Constructivism]



The story of a learner in charge

Leo is an intelligent nine-year-old child who suffers from severe dyslexia. Leo was unable to find a classroom environment that fit his needs. While homeschooling, Leo and his dyslexic brother, Ari, are free to follow their interests in any area they choose.We developed an environment in which we, as parents-teachers and mentors, guided the children's education to guarantee that they met the basic literacy standards. Beyond the core literacy goals our responsibility was to support Leo and Ari in whatever they wanted to study. In Maker-style education, the student is in charge, while the teacher serves as a facilitator and mentor.

Maker education revolution

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“Education is what remains after one has forgotten what one has learned in school.” — Albert Einstein

In a Maker-style education environment, the learner is in charge of their own learning. What is this like? What is it like for a child to be free to shape his own learning, day in and day out?

Leo is a nine-year-old boy, intelligent and severely dyslexic. Leo is my son.

Leo is having a lot of difficulty in learning how to read. For dyslexic people, symbolic characters (letters) on paper or on a screen are very hard to decode. What to you looks like a perfectly shaped letter, to Leo it looks like a random smudge of ink. Converting the letters of a word into sounds, especially when those same letters produce different sounds when used in different words, is often a psychologically painful experience. For dyslexic people, reading is a constant struggle. Often, by the time Leo finishes reading a small sentence, he has forgotten what the one before it was about. Dyslexic people often suffer from low self-esteem and frustration, the result of being unable to do something that comes naturally to so many other people, and most of their peers at school.

In the US, Australia and the UK, around 25% of the population has dyslexia. In the US alone, this figure represents at least two million students aged from 3 to 21 years old.

Leo was unable to find a school environment that was compatible with his particular learning needs. We enrolled him in several schools, both private and public. Even with a full medical diagnosis of his condition and with the assistance of child psychologists, in every school and regardless of how much the teachers tried, Leo felt like he was not learning anything. He would come home in the afternoon tired and frustrated. His mind, like that of every child, wanted to learn, but his environment was simply not designed to match his needs.

His particular strengths and strong interests were ignored because there was no place for them in any of the schools. There was no class for Minecraft, zoology, and astronomy. Not only was Leo unable to progress in the core curriculum literacy areas of English and mathematics, but he was not able to apply him self on the things that he enjoyed.

Even though Leo is part of the 15% of the population with this specific condition, in his class he was the only diagnosed child. The rest of the class had to move through the curriculum, whether he was ready or not. The schools were not equipped in terms of teacher skills, equipment and classroom design to cater for Leo's specific needs.

We decided that home schooling was the best option available. It was the only reasonable choice available. We started homeschooling Leo when he was seven years old, along with Leo's brother, Ari, who is also dyslexic. Our objectives were to remove frustration from the children's lives, and to restore their love for learning. To achieve that, we designed an environment in which we, as the parents-teachers and mentors, gave a direction of study in which the children cover the basic literacy requirements, especially reading and mathematics. But beyond the basic literacy outcomes, our role was to simply assist Leo and Ari in whatever they choose to learn.

When it comes to basic literacy, we sourced learning materials specifically designed for dyslexic children, and took an evidence-based approach. In small daily doses, the children train in the practical aspects of reading, writing and calculating.

But for the rest of the time that they now had available every day, both children were encouraged to pursue their interests. At seven years of age, Ari has an intense interest in drawing and construction. Ari spends considerable time experimenting with different kinds of paints, markers, pencils and papers, as he creates his elaborate drawings, usually depicting a funny scene from a movie or real life. He often uses Minecraft on his computer to create similar scenes, or scenes from a superhero movie. Ari has also started creating his own videos on his computer, recording his gaming sessions. He said to me that he wants to be a famous "Youtuber", and outlined his plan for his gaming channel, the types of videos that he will produce, the channel logos, name, and thumbnails. For him, it's not about "what he wants to be when he grows up". It's about what he wants to be now.

Leo has intense interests in life in the medieval times, especially the lives of knights, their armour and weapons. He also has a very strong interest in animals and zoology and in particular dinosaurs. He devours any information he can find on these topics. He prefers video documentaries because of his difficulty in reading, but he now uses a reading pen that automatically converts text to speech. With this technology available to him, the world of books is now widely open. Leo devours audio books and podcasts on science, technology and comedy. He can hold a conversation about the Big Bang, the formation of the solar system, and climate change science with any adult.

Although that we, as their parents, have created the environment that allows them to pursue these paths of learning, they own the directions they move. They decide how much time to spend in an activity, and as long that does not impede normal family life, that is fine with us. They have never, to my recollection, only spend exactly 45 minutes on any activity!

Both children are free to pursue their interests in their particular areas, using any materials available to them: TV documentaries, Internet resources like Wikipedia and YouTube, podcasts, cinema, libraries, zoos, museums, books and magazines.

But they are not simply consumers of information. They are externalising their knowledge by making things. For example, when Leo goes on a bush walk, he takes photos of any small animals, insects or plants that he finds interesting. He he will use the Internet to find out the names of anything he captures in a photo. The pictures that he takes become part of his educational track record, and the best pictures are printed, labelled and sorted inside a physical picture book. Each bush walk is an opportunity for learning, something similar to Aristotle’s Peripatetic school.

Leo’s interest in animals, and in particular dinosaurs, is satisfied by learning as much as he can about them, but also by combining it with his other interests. He has created several triceratops and impressive dinosaur habitats in Minecraft, and is trying to learn how to write Minecraft programs that can spawn virtual dinosaurs in the game.

Leo is also planning to create a robot dinosaur. This has prompted him to start learning programming in the form of Scratch, the visual programming language developed at MIT Media Lab. He also needs to learn about robotics, especially motors, actuators, mechanical levers, joints and rotors. Leo has already created with his first few Scratch programs to control motors and lights, and that is before he can comfortably read.

Ari's pursuits are similar in intensity and diversity but different in direction. Ari, my younger son, is interested in comedy and his passion is taking him through a natural learning curve that involves watching and listening to comedy scripts, and reading comedy acting books with the help of his parents, audiobooks or his reading pen, and that has resulted in Ari making his own comedy clips. One time, while boarding an international flight at Chicago O'Hare Airport, Ari managed the unthinkable: he stopped one TSA officer from carrying out his duties in a serious and focused way and caused him to roll on the floor, laughing loudly! His impersonation of Arnold Schwarzenegger as Terminator is hilarious. Much of this personality is also spilling into his YouTube gaming channel.

Ari's interest in comedy led him to create involved drawings in which he depicts a comedic scene. He often tells us a joke while using the picture that he made to describe it. Like his brother Leo, Ari is an expert Minecraft maker, and he creates comedy inside his virtual Minecraft world. He especially likes village comedy, in which funny things happen to villagers, their dogs, chickens and cows in a picturesque virtual village.

After watching a few episodes of ventriloquist and stand-up comedian Jeff Dunham and his sidekicks Walter, Ahmed and Jose, Ari now wants to make his own comedy puppet, and call him Einstein. But he wants his puppet to be a human-like robot, which is leading him onto a path of programming and robotics, just like Leo, with an emphasis on artistic expression, unlike Leo's emphasis on accurate biological simulation.

Ari and Leo's journeys are very different to each other, despite the fact that they have a similar learning difficulty that prevents them from joining conventional education, live in the same household, with the same parents, and the same learning environment. Their intrinsic interests and passions are different enough to manifest in unique learning paths, that they choose and we, their parents and mentors, facilitate.

Both children show a strong interest in learning as much as they possibly can about the subject that they have chosen, from any source they can find, and then produce their own real-life, concrete creations. These creations are uniquely personal and have never before existed. They embody the children's current understanding of whatever it is that they are learning.

For us, all this was the unintentional consequence of allowing Leo and Ari the free time to become consumed by their own passions and a flexible environment in which to do it. The paths that they have travelled in pursuit of their passions are unique to them, but the way in which this learning is materialising is common across people, not just children, everywhere.

In Maker-style education, the learner is in charge and the teacher is the facilitator and mentor. It is constructionism.

Interesting readings

- Scratch
- Peripatetic school
- Aristotle history
- Understanding dyslexia

Learners and mentors

Students in Maker Education are regarded as responsible individuals who are concerned with their own development as individuals and as Makers. The teacher is no longer solely responsible for developing curriculum specifications.

One important core responsibility of the traditional teacher that the Maker Education mentor does not carry over is that of preparing the student for standardised tests.

Maker education revolution

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“What is a teacher? I’ll tell you: it isn’t someone who teaches something, but someone who inspires the student to give of her best in order to discover what she already knows.” Paulo Coelho, The Witch of Portobello

In Maker Education, is the teacher necessary? What does it mean to be a teacher in a Maker education environment?

In conventional education, the teacher is tasked with transmitting knowledge to the student. The teacher has the primary responsibility for selecting, creating and delivering the curriculum that the student must absorb and learn. In most countries, the responsibility for selecting and creating the curriculum for the students falls upon a central education authority, in which case the teacher is responsible for the delivery of this curriculum to the students.

The teacher is also responsible for preparing the students for standardised tests and for evaluating students' performances. Another important responsibility for the teacher is to provide individual support to each student in order to help them reach a minimum standard of competency in a particular subject area. This support is both academic and psychological, requiring the teacher to take on the role of surrogate parent. As a surrogate parent, the teacher is also responsible for the safety and wellbeing of the student during school hours, and for communicating with the student's parents on issues relating to their child's academic and psychological development.

In a Maker Education-style environment, most of the responsibilities that teachers are accustomed to and expected to perform remain. The teacher is still responsible for the safety of the student, for providing psychological and academic support, and for communicating academic and psychological development issues to the parents. However, the Maker Education teacher is no longer primarily responsible for setting the specifics of the curriculum, for preparing the students for standardised tests and for evaluating them based on those tests.

In Maker Education, the teacher is the facilitator, or the mentor, that assists the students in their own learning journey. The traditional curriculum is replaced by a student-led exploration, just like Leo and Ari's explorations that I described previously.

Being a mentor makes the teacher a far more important person in the student's (mentee's) life. As a mentor, the teacher becomes an advocate and champion for the student. The mentor is the person who will provide the ongoing encouragement that the student needs, especially when things get hard. The mentor provides or finds the necessary resources, like equipment, books and access to online tools, and advises the mentee when appropriate. As a champion, the mentor will advocate for the mentee whenever an opportunity arises, for the sole benefit of the mentee. And of course, the mentor will also play devil’s advocate, and challenge the mentee as they try to get past important junction points in their learning adventures.

The mentor and mentee relationship is two-way. The mentee has to learn how to nurture this relationship. The mentee must work in order to develop the various skills and knowledge outcomes that they want to achieve. Whether it is developing skills in mechanical design or canvas drawing, the mentee/student is solely responsible for working out what it is that they want to achieve.

The mentee is responsible for communicating these goals to the mentor, as clearly as possible. The mentor can help the mentee in determining these goals, but must be careful not to be a strong influence who actively steers the mentee towards a particular direction. Goal setting should be fully aligned with the mentee’s intrinsic passions.

The mentee is also responsible for identifying the resources that they need and discussing them with the mentor, who will then work towards providing them.

Continuous learning is another responsibility of the mentee. The mentee should take advantage of every opportunity presented to them to learn. It could be a newspaper article on a topic that they care about, a TV documentary or an opportunity to make something. Whenever or wherever this opportunity comes from, the mentee is solely responsible for the decision to take it or not.

In Maker Education, students are regarded as responsible individuals who care about their own development as persons and as Makers.

One important core responsibility of the traditional teacher that is not carried over to the Maker Education mentor is that of preparing the student for standardised tests, conducting the tests and evaluating the performance of the student based on those tests. Maker Education does not have formal testing.

This does not mean that the maker student's work is not evaluated on its merits. Far from it. Because a core outcome of the student's work is the physical artefact, the evaluation of this artefact is a proxy for the student's ability to understand and act on what it is that they are learning. If the artefact is a working machine, does that machine work as intended? Is it using the most appropriate materials and components? Is the workmanship good? Does the machine look pleasant to the eye? What can be improved?

Any physical artefact, whether a machine, a drawing, or a musical composition, can be evaluated based on specific criteria that can be communicated.

But the most important way to evaluate maker work is to submit it to the evaluation of others. This is often done by staging school or makerspace exhibitions. It can be done by publishing details of the work in blogs, the school website, or the school's Youtube channel. Text, video, audio, photogram, illustrations, all come together to document and communicate the outcome of a student learning. Makers will show the world what they have made, and the world will provide constructive feedback.

This type of evaluation ensures that a student's performance is not evaluated in the form of a standardised test, but based on the place that the artefact takes in the world. The attendees of the exhibition, the readers of a blog post or subscribers of the school's Youtube channel, will use their own criteria to evaluate the artefact, thus will be able to offer their own unique perspective to its creator. This kind of feedback is invaluable and cannot be obtained through standardised tests.

Standardised tests are often out of context (i.e. the realities experienced by the student) and are usually designed to allow the teacher, school or other authority to conduct them at a large scale, repeatedly. The purpose of a standardised test is to classify students, not to help them grow.

Of course, there are certain minimal learning outcomes that must be achieved before a student is able to take on more responsibilities. For example, the student must be able to read, write and calculate at a minimum level before they can go on to conduct their own research and development work. Skills such as reading, writing and calculating are taught in a formal way, compared the informal learning environments in a Maker Education environment. However, even this area of learning, that mostly affects children younger than 10 years of age, is changing. Technologies like the C-Pen Reader make it possible for children with developmental delays, like dyslexia, to be able o read without assistance. With a C-Pen Reader pen, the student can access any printed book without teacher or parent help.

Online resources such as Wikipedia and Encyclopaedia Britannica also have accessibility features that make it possible for children who can't read to use them via text-to-speech interfaces. Modern computer operating systems also have similar accessibility features.

Thanks to such technologies, the barrier to entry into self-managed education from an early age is lower than it has ever been in the past. The traditional teacher, transformed to a mentor, is the student's/mentee's partner in their learning journey, not the driver.

Interesting readings

- Roles of the Mentee and Mentor

Learn by Play

A term used in education and psychology to explain how children make sense of the world is “learning through play.” Children can explore, identify, take risks, and comprehend the world around them through play.

Playing as a learning instrument is almost completely overlooked in adult education. The value of play in learning is emphasised in Montessori, Reggio Emilia, and Maker-style education. Allowing children to learn through play teaches them to find and confidently follow their own paths.

Maker education revolution

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“The goal of early childhood education should be to activate the child’s own natural desire to learn.” — Maria Montessori

In Maker style education, playing, making and learning are intertwined into one.

I often use the word “play” in place of making or learning because very often it really is no different.

The objective of a Maker Education is to help learners become self-reliant, confident, creative and innovative individuals. Playing is about enjoyment and recreation, it has no other purpose. Certainly, it has no practical purpose.

What does research show about playing and learning? ‘Learning through play’ is a term used in education and psychology to describe how children make sense of the world around them, and develop their social, cognitive and emotional skills that they will need as adults. Through play, children interact with other people, real or imaginary, objects and their environment. In the course of play, children are challenged to solve problems and both to adapt and influence or change their environment.

There is strong evidence to suggest that play affects brain development, and stimulates improved memory skills, language and behavioural development (1).

There is also a large amount of evidence that play is associated with intellectual and cognitive benefits in children (2). Play allows children to explore, identify, take risks and understand the world around them, some of the core skills that we recognise in Makers and well developed adults.

Despite the evidence, the role of playing in learning is often underestimated, especially as children grow older. Playing as an instrument for learning is almost completely ignored in adult education.

Successful learning through play involves five elements (3):

1. Play must be pleasurable and enjoyable.
2. Play must have no extrinsic goals; there is no prescribed learning that must occur.
3. Play is spontaneous and voluntary.
4. Play involves active engagement on the part of the player.
5. Play involves an element of make-believe.

How is play different to work? Apart from the five elements outlined above, a major distinction is that work is usually externally directed while play is mostly self-chosen activity with no specific goals. Play resembles the exploration of the unknown, while work has specific utility and specifications that must be met.

This difference is important as it helps educators avoid the mistake of creating a play activity that in reality is work. For example, a common tool for trying to help people memorise words in their effort to learn a new language is the use of flash cards. Even though educators often describe this activity as "let's play flash cards", in reality they are prescribing work. The activity has very little room for exploration, has a specific goal and is externally prescribed.

Over the last forty years, a lot of research has been published to help us understand the relation between playing and learning. This research has also led to play-based learning programs that have been used with children for even longer than that.

For example, the Montessori Method has been used since its founder, Maria Montessori, opened her first classroom in 1907. Montessori schools follow a constructivist approach in which self-directed play is at the core of the learning process. Children are given ample uninterrupted blocks of time, usually around three hours, to engage in an activity of their choice from a range of possible activities. The children can move around freely in the classroom, interact with other children and with the teacher. The teacher's role is to observe, facilitate and assist if necessary.

Another method that emphasises play in learning is the Reggio Emilia approach. Like Montessori, Reggio Emilia emphasises the importance of self-directed learning, the ability to freely explore the real world around them, the interaction with other people, and also the importance of expression. A core principle of the Reggio Emilia approach is that "children must have endless ways and opportunities to express themselves".

Other similar approaches to learning in which play is emphasised include Steiner/Waldorf Education, Sudbury

Schools, the Summerhill School in Suffolk, England, and Charlotte Mason schools, to name but a few.

Why are these schools so popular among parents and students? How do they relate to the Maker-style Education?

The common element between them and Maker-style Education is that children are encouraged to play as a pedagogical way of supporting their learning experience. Facilitating play as a way to learn accustoms children to find and confidently follow their own paths. This has significant consequences in adult life.

Take the example of a five-year-old child presented with a set of wooden blocks.

In the first instance, the teacher says to the child: “I will show you how to create a tower using these blocks. After I finish, you can try.” The teacher proceeds to carefully place a large block on the table, followed by a slightly smaller block on top of it, followed by another, smaller block on top of that. In the end, the teacher places the final, tiny block at the top of the tower, and informs the student that the tower is now ready. “Your turn!”

In the second instance, the teacher says to the child: “How about you take these blocks and make a tower as high as you can!” No demonstration, no building instructions, no specifications. Just an abstract objective that the student is free to interpret and act on using their prior knowledge of what a tower is, and some experience in building with blocks, if any at all.

In the first instance, we have a work assignment. The young child, not yet trained in following instructions, will start with the intention of building a tower like the one that the teacher demonstrated, but soon he will become sidetracked. He might go on building an object that is closer aligned to his own ideas of what a tower looks like, or give up completely and go find something to play with (as opposed to completing the work that was assigned to him by the teacher). The teacher will try to insist that the student completes the assignment, and might even demonstrate again how it should be done.

In the second instance, the student is in play mode. He tries different configurations, each time rearranging blocks so that the structure becomes more stable and taller than the previous iteration.

Did the student in the second instance enjoy his activity with the blocks? Yes! He was focused and engaged, he was living for the moment. His mind and hands created an outcome that embodied the learning that he achieved in the process. He made structural corrections, which taught him the value of iteration and gradual improvement. He developed his own quality assurance tests, and he understood why a new configuration was better than an old configuration.

While learning by playing is certainly not suitable for achieving every learning objective, it is a powerful approach for building those traits and personal characteristics that can help people respond well to high stakes and stressful learning experiences, whether they are in their older years of schooling, professional development, or life in general.

Play for adults is as important as it is for children. In a way, this is why adults tend to have hobbies. Hobbies allow adults the opportunity to escape their structured, externally controlled lives and indulge in a self-chosen and self-directed activity. Hobbies give adults the opportunity to refresh their mind and body, and enjoy many other benefits: increased levels of energy, improved creativity, better teamwork, stress-free interaction with other people, and so on.

In Maker Education, play is an essential tool to learning, just as it is for so many other schools, philosophies and learning approaches.

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Interesting readings

- Learning through play
- Montessori education
- Reggio Emilia approach
- Waldorf education
- Sudbury school
- Summerhill School
- Charlotte Mason
- Ricardo Semler, founder of the Lumiar School – WISE 2015 Special Address
- Benefits of play for adults
- Play Doesn't End With Childhood: Why Adults Need Recess Too

Deliberate practice

Deliberate practice has been demonstrated to be an effective method for achieving expert performance in a variety of competencies. There is a strong correlation between the amount of time a student spends not just practicing, but doing deliberate practice, and the student's long-term outcomes.

Playing a musical instrument, such as the violin, has a long history of instruction and practice. The best violinists have spent countless hours of solitary practice and the majority of their practice time in their teen and pre-teen years.

Maker education revolution

Blurb to be added

"Failure is instructive. The person who really thinks learns quite as much from his failures as from his successes." — John Dewey

Being really good at something is often assumed to be a special gift. Whether it is great skill in playing a musical instrument, being fast in completing arithmetic calculations, remembering phone numbers and people's names, or being a great programmer or engineer; it must be something that such people are born with. When someone achieves a high level of performance, high enough to be noticed by others, the layperson will assume that the high performer was lucky enough to be born with some kind of natural aptitude to be great at this particular task.

While the jury for the portion of ones success that can be attributed to nature versus that earn by nurture and hard work, we often fail to acknowledge the many years of purposeful and continuous practice that such people have invested in their specialty.

Research done by scientists like Anders Ericsson has documented the process that a person has to follow, over a long period of time, that is necessary for achieving a high level of performance.

Ericsson calls this “deliberate practice”.

In deliberate practice, a person pursues specific goals, set either by themselves or by a mentor or instructor, that are specially designed to improve a specific aspect of their performance.

Deliberate practice has been shown to be a way of achieving expert performance in many competencies, such sport, chess, or playing musical instruments. We can learn a lot from it and apply it in many other areas in order to significantly increase the practitioner’s skill level.

In this chapter, I will explain how deliberate practice can be applied in learning.

Let’s look at an example from Ericsson’s research (1).

Ericsson and his collaborators wanted to understand how some of the best violinists in the world achieve their level of performance. To do so, they followed a group of music students at the Berlin University of the Arts, an internationally highly regarded institution for both its pupils and its teaching staff. Famous conductors and composers, like Otto Klemperer and Kurt Weill, are graduates of this university.

For the purpose of this research, Ericsson focused on the violin students because of the university’s reputation of producing world-class violinists. Playing a musical instrument, like the violin, has a long-established method of teaching and practising, and objective measures of performance. These are important characteristics for researchers because they allow them to derive conclusions that are free of externalities, like the environment and luck.

It is very hard doing research like this in areas such as business or team sports. For example, in a game like football, it is very hard to find objective measures of performance. In football, the top-scorer's performance can be the result of both his ability to score, and his teammates' ability to pass the ball to him at exactly the right time and place, as well as create the conditions in the game to allow for scoring to take place.

The researchers started by separating their student subjects into three groups based on information they received from their teachers. The first group included super-star students. These students showed characteristics that indicated they would graduate to be the world's top performers, the best in the world, the future orchestra soloists. The second group included students that while very good, were not top performers. Finally, the third group included students from the music education department, who were on track to becoming school music teachers, not orchestra performers. Although they were very good at playing the violin, at this stage they were not as good as the students in the first two groups.

The violin is an instrument that requires a lot of practice. A single note can be played in many different ways, and even the way that a musician holds the instrument will influence the way that it will sound. Because all of the students in the study spent the same amount of time with their instructor, the researchers were able to measure how much of their improvement in skill level could be attributed to the student them self. And most of them had already been practising since around the age of eight. At the time of the research at the university, they had been practising for almost ten years.

The researchers conducted interviews, analysed diaries and witnesses numerous practice sessions. What the researchers found was that the best violinists had spent, on average, a significantly higher number of hours in solitary practice than the second group had. While the music education students, by the time they entered the University of the Arts, had spent 3,420 hours on solitary practice, the better ones had spent 5,301 hours and the best had practised 7,410 hours. All of them were clearly working hard. Even the music education students had practised for thousands of hours more than a person who might play the violin for fun. But the best of them had put in far more hours than anyone else.

Another interesting outcome from this research was that for the best violin students, the bulk of the practice time had been completed in their teen and pre-teen years. This is important because these years are particularly challenging for building any kind of skill due to the various competing interests: sports, hanging out with friends, partying, etc.

A similar study involving middle-aged violinists who work at the prestigious Berlin Philharmonic and the Radio Symphonie Orchester Berlin also agrees with this finding: practising before the age of 18 is an extremely important factor that can determine career outlook, at least for a violinist.

The researchers discovered a similar pattern in other areas, such ballet, chess, mathematics, and many more.

When it comes to using lessons from Ericsson's deliberate practice research in school settings and in particular in the context of Maker Education, we must remember that deliberate practice, in general, suggests that there is a strong correlation between the amount of time that a student spends not just practising, but doing deliberate practice, and the long-term outcomes for that student. However, the experiments were conducted in areas of knowledge and skill in which there was a long history of teaching, during which the teaching methods were fine-tuned over time to enable students to learn from best practices.

The violin, for example, has been taught for hundreds of years, and the methods of teaching have changed dramatically over the years. As a result, an average violinist today is far better in every respect when compared to legendary violinists from the eighteenth century.

In Maker Education, the areas of knowledge that are being taught tend to be things like electronics, 3D design and manufacturing, algebra, woodworking, metalworking, and programming. Most of these are modern disciplines with a lot less history of teaching in comparison to the violin or chess.

But the fact remains that early age deliberate practice can make a significant difference to the skill level that the student can reach.

How can this be? In deliberate practice, a teacher is responsible for helping the student to increase his or her performance in specific areas by prescribing practice activities. In Maker Education, the mentor is responsible for this. The prescribed activities have a goal, but in the spirit of constructionism, they also contain a high level of freedom for the student to choose their own path in achieving that goal.

Many lessons on how top performers achieve their skill come from Ericsson’s deliberate practice research. Some of these lessons are particularly useful in a Maker Education context:

* In deliberate practice, the skills taught are such that they have already been achieved by others. A mentor will not ask a student to implement a robot function that he knows is not possible with current technology or established techniques.

* Practice takes place outside the student’s comfort zone. This theme comes up repeatedly in research. Whether we are looking at the world’s top performers or music education teachers, their practice is not considered to be fun, but stressful. The best students will tolerate this stress because they can measure their improvement. They practise with the goal in mind, not for the fun of practice. The satisfaction they receive from this constructive stress stems out of achievement that they feel. Just like fun, satisfaction stemming from achievement can be powerfully motivating.

* Deliberate practice requires the student's full attention. The student must focus and become absorbed in their practice. It is not enough to blindly copy the instructions in a textbook or the instructions of the teacher.

* Deliberate practice requires fast feedback. In the case of Maker Education, for example, this feedback comes from the tangible artefacts that the student works on. An incorrect wiring will result in a circuit that is not functioning. This is the feedback that the student has to evaluate and rectify. A corrected connection will result in a working circuit; this is new feedback that acknowledges whatever the student did to deal with the situation worked.

* In deliberate practice, the student almost always builds and improves on previously acquired skills. The improvement occurs by the student and the teacher identifying a specific area for improvement, and designing and implementing exercises that specifically address that area. As a result, it is very important for students to have a very good grasp of the fundamentals in their area of study. Without this, deliberate practice will not be possible.

Can Maker Education provides an environment in which deliberate practice can take place? Absolutely! The responsibility for this is with the mentor, who must constantly offer the student opportunities for improvement, and constructive feedback.

References

1. Dr. K. Anders Ericsson

Learning at home: challenges and opportunities

There’s no denying that learning at home is challenging. Peer pressure, performance pressure, and the typical feeling of embarrassment for asking a “silly” question are all learning barriers that can be overcome at home. A prescribed curriculum must be followed within the confines of a strict schedule in a formal learning environment. Some people learn better in a group setting, while others prefer solitude, and some even have dyslexia. Learning challenges in formal learning environments are a daily reality for all children. Therefore, it is critical to consider approaches to improve learning at home.

Maker education revolution

Blurb to be added

“Play is the highest form of research.” — Albert Einstein

Today, learning is largely formalised with much of it done in school classrooms and university lecture halls. For better or for worse, this is part of the legacy of the 18th and 19th century educational systems. But at a far larger extend, informal learning takes place in homes, makerspaces, community halls, libraries, even on trains and buses.

Learning at home can take many forms. People can learn at home as part of a school project. Or they can choose to completely replace institutional school with homeschool. Or they can enrol in a distance education course. Whatever the form is, learning at home is challenging, there is no doubt about that. But in return, there are significant opportunities. In this chapter, let's explore some of the issues that impact learning in a formal environment and the opportunities around creating an environment for learning at home.

Unlike formal learning environments, like in a school, college or university, learning at home has the immediate advantage of being informal. In an informal learning environment, many of the mental blocks and inhibitions that obstruct learning are eliminated or at least reduced.

For example, a learner may be intimidated by the teachers or other learners. Peer pressure, pressure to perform and to keep up with the rest of the class, the typical feeling of embarrassment for asking a 'silly' question are some of the learning inhibitors that can be eliminated at home.

There are many more, of course. In a formal learning environment, there is a prescribed curriculum that must be followed, within the boundaries of a strict schedule. Then, there are the standardised tests. There is also the low ratio of teachers to students which makes it hard for teachers to respond to the learning needs of the individual student. Every student has to achieve certain outcomes within a specific time frame. There is little room for deviation from the curriculum and the schedule, and there is little room for adaptation to the learner's unique learning needs.

Children and adults alike respond better or worse to external conditions that can severely affect the way they learn. While some people thrive in noisy, buzzing environments, others respond by closing themselves in an imaginary bubble and becoming unresponsive, or at the other extreme become agitated and aggressive. While some people learn best by using their eyes and ears to watch and listen to a lecture, others prefer books and multimedia. Some people learn better in a group environment, while others prefer solitude.

In a formal learning environment, the learner has very little control over any of these parameters. The lucky few who are able to operate in whatever characteristics their environment has been set to by the institution or the instructor will benefit from it and will produce real outcomes. The rest will fall behind. They will often be branded as ‘bad students’, and be made to repeat the same process again. Without making any change in the learning parameters, the institution hopes that the second or the third time around, things will somehow improve for those students that didn’t make it the first time.

Consider a child with dyslexia, for example. Dyslexia is classified as a learning disorder in which the dyslexic person is having difficulty in learning how to read or interpret letters, words and symbols. Although dyslexia affects the ability of a person to read, it does not affect their intelligence. With the right interventions, a dyslexic person will become a confident reader a few years after their peers, but even then he will likely need more time to complete any reading or writing.

Research conducted by the Dyslexia Center of Utah suggests that 70-80% of people with reading difficulties are dyslexics. These same people are just as intelligent as everyone else.

In a conventional learning environment, dyslexic students are particularly disadvantaged because their special learning needs are not being met. In the US, around 60% of students that are not able to read dropout of school, with all the negative consequences that this brings to them, their families and society in general.

Let’s also have a look at another learning disorder: ADHD (attention deficit hyperactivity disorder). According to data from the American Psychiatric Association, 5% of all children in the US have ADHD. More recent studies indicate that this number is actually higher. For example, in 2011, 11% of children in the US were diagnosed with ADHD, a number that has increased from 7.8% in 2003.

A typical response to a diagnosis of ADHD in a child is to provide behavioural intervention first, if possible, and then medication. Unfortunately, the behavioural intervention approach is very labour intensive and requires a close collaboration between the psychologist, parents and teachers. This does not always happen in 'real life' due to the limited resources that both parents and teachers have at their disposal. This leaves us with over 6% of children aged between 4 and 17 years being medicated in the US. Many children with dyslexia also have ADHD, further impairing their performance in a formal learning environment.

Apart from the typical problems of the conventional learning environment that I described in the first half of this chapter, children with ADHD and dyslexia are severely disadvantaged in almost every learning setting. These, and many other similar conditions (like dyscalculia, auditory processing disorder, visual processing disorder, dysphasia/aphasia, etc.) that require learning to be more focused on the student rather than the group, are additional reasons of why looking at ways for boosting learning at home is important.

For all children, learning difficulties at formal learning settings are an everyday reality. Simply not feeling confident enough to ask a question, or low self-esteem that comes from seeing other children doing better are all challenges of growing up. Many children are able to learn how to deal with such situations on their own, and grow up to be fine individuals. Others need more help to get past these troubled years. However, for all of them, including children with the aforementioned learning difficulties, a non-conducive, conventional learning environment should not impact on their learning. The home is a place where a learning environment can be created, specifically designed to cater for the needs of the individual learner. These learning difficulties do not disappear at home, but they are addressed so that the learner can gain confidence and skills in learning.

Another important aspect of learning that is not addressed in a formal learning environment is that of freedom. The freedom to learn. The cornerstone attribute of a constructionist Maker-style Education is that the learner is given freedom to choose what it is that they would like to learn. In a formal environment, this freedom is constrained to the extent that learners feel trapped. The textbooks, the weekly lesson or lecture schedules, the deadlines and exam dates create a feeling of entrapment for the learner. This feeling, on its own, is enough to over time destroy those attributes that are most important in a learner: the built-in need to follow their curiosities and pursue their passions.

Home, or other free-learning environments like open makerspaces and libraries, are places where this freedom is encouraged. These are the places where the learner can be left free to rekindle their curiosities, and where the environment actually allows them (or better, encourages them) to pursue their passions.

Interesting readings

- Statistics On Dyslexia
- Center for Disease Control, Attention-Deficit / Hyperactivity Disorder (ADHD) home page
- Learning Disabilities and Disorders

Some of the things makers do

All of the project ideas in this article involve constructing a physical object, as Maker Education is all about learning through making. There is no material that isn't good enough in the Maker Education spirit – even a trip to the dumpster can yield a small treasure!Many of us now have the ability to design and manufacture parts for open-source robotics, art, and everyday objects. One of the maker's favourite materials is cardboard, which can be used to construct simple robots. Learners can construct more complicated and geometrically exact objects using 3D printing, 3D scanning, and design.

Maker education revolution

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"Change is the end result of all true learning." — Leo Buscaglia

In the space of Maker Education, there is an abundance of topics in which learners can lock on and engage. In this chapter, I will discuss some of the more common topics to help you get a taste of what makers typically get up to.

Maker Education is about learning through making, so all of the ideas that follow involve creating a physical artefact. Everything else, like researching, designing, composing, documenting and communicating is there to support the primary process of making.

Cardboard making

Making does not require high-tech tools and specialist knowledge. Learners can start with discounted cardboard boxes, scissors, markers and some duct tape. With these easy-to-find materials, learners can create their own jet packs. They can measure them to fit the wearer, and fit them with their own choice of accessories, like wings, extra rockets, laser guns, etc (1). Students, of course, don't stop with the jet pack. They often decide to make additions to their arsenal by creating helmets, armour, and superhero accessories using the same materials. Imagination takes hold!

Another fun project with cardboard materials is a marble run. The project involves using cardboard tubes secured against an inclined surface, or the wall. The students design elaborate paths through which a marble, powered by gravity, travels. This project requires the learner to do some planning ahead of time, simply using pen and paper with which they decide on the path of the marble before they go ahead to make it with the tubes (2).

We are all familiar with those plastic portable maze games in which the objective is to navigate a tiny marble through the maze until it sinks in a hole. Students can make their own marble maze using cardboard! Marble maze involves using the base of a cardboard box, with its sides raised so that the ball does not escape, and fitting small cardboard pieces inside the box to create the maze. The learner needs to do some preparatory work before implementing the maze in order to decide on the overall design. Really good fun, and a never-ending project since there can always be a more elaborate maze to make (3)!

If learners are looking for more challenging cardboard projects, how about a pinball machine with a large cardboard box and some additional easy-to-find materials, like paper coffee cups, old CD, and plastic spoons (4)? In the spirit of Making, there is no material that isn't good enough. Even a trip to the dumpster can yield a small treasure!

3D printing, 3D scanning and design

With cheaper 3D printers becoming available, learners can use software to design and create more elaborate and geometrically precise objects than is possible to implement with cardboard. The design and production of parts for oped-source robots, art, and everyday use objects, is now within reach of many of us.

With the availability of similarly cheap 3D scanners, it is now possible to turn a physical object into a computer 3D design file, manipulate it in software, and then use a 3D printer to turn the augmented version of the original into a new object.

Using these technologies, students can create their own toys, such as a cuff with a holder for an iPod, or materialise a scene that they created in Minecraft. Printing art projects, creating toys, prosthetic limbs or parts for projects like a quadcopter or remote control cars are also popular.

Mixed materials

Making catapults is a very enjoyable understating. In catapult making, the students can retrofit a mouse into a war machine. Typically, to make a catapult students will use, apart from the mouse trap, wood sticks, erasers, strings, wooden blocks to use for target practising and ping-pong balls as ammunition. Work on the project will expose students to principles of engineering and physics, as they have to figure out and calculate the optimal launching angle and ratio between the shooting arm length and the power of the mouse trap's spring.

Of course, there is nothing stopping the student from building up their catapult from a mouse-sized one to a car-sized one (5). A large catapult project will typically involve more custom-made parts that can be made of wood, cut to size, and include metal rods, rope and larger items as ammunition. These projects can very quickly become competitive, with makers constantly improving their catapults for things such as range and power.

Robots and robotics

Makers love to create robots because they are impressive on their own right, and because they incorporate a great deal of different technologies that require skill and patience to build. Robots are becoming part of every day life, and this relevance to reality gives them an additional amount of appeal. Each of the technologies needed to build a robot is an opportunity to learn a new skill. Robotics can keep people occupied for years, whether for fun or as a lifelong career option.

Apart from humanoid robots that makes them particularly interesting to people, robotics projects can be very focused and practical. For example, a team of school students from Seattle created the MopBot. MopBot’s objective is to mop up any water spills at the drinking fountain and the sink at school. To be able to construct MopBot, the students had to learn how to work with the Mindstorms Lego building platform, and use laser-cutting technology, a 3D printer and software like Adobe Illustrator and Tinkercad.

Simple robots can be built using cardboard, one of the maker’s favourite materials. Learners can build the body of a robot using paper, and insert various electronics inside, like buzzers, LED lights, a microphone, proximity sensor, motors, and a microcontroller and battery. The robot will be able to react to its environment by moving, making noises, and flashing its lights. All of these components and materials are easy to find in the market, and the actions of the robot can be programmed in a visual language, like Scratch, making it suitable for even very young learners (6).

Woodworking

Woodworking is considered an essential making skill, and is surprisingly easy to learn the basics of. Because working with wood often requires the use of power tools, it is recommended that adults help younger makers with their operation for the sake of safety.

With the basic precautions taken, learners can use basic tools to create art, tools or parts for their other creations. Wood is an incredibly flexible, durable and cheap material, and it looks great without much effort. Unlike the plastics that are used in 3D printing, there are no nasty smells during making.

Learners can make parts for their robots, enclosures for their gadgets or toys. From small candle holders and toy airplanes, to large benches, armchairs and coffee tables, learners can explore a vast array of possibilities that can be created from wood.

These are just some examples of things that learners make in order to learn. From absolute beginners to more advanced makers, there are plenty of things to make that require no special tools at all. It has never been a better time to be a maker!

References

1. Recycled Jet Pack Costume
2. DIY Recycled Marble Run
3. Engineering Activity for Kids – Build a Cardboard Box Marble Labyrinth!
4. Makedo Pinball Machine
5. Portable pumpkin catapult
6. Paper robot

Interesting readings

- Your Students can be “Makers”: 16 Projects

Invented by Teachers

- DIY is a safe online community for kids to discover new passions, level up their skills, and meet fearless geeks just like them
- Meaningful Making (ebook)
- Jaw-Dropping Classroom 3D Printer Creations
- Makedo is a cardboard construction system for 21st century thinking, making and play
- 9 Maker Projects for Beginner Maker Ed Teachers
- Your first robot
- Ten Easy Woodworking Projects
- Project-Based Engineering for Kids

The learning corner

Making a makerspace at home is now easier and less expensive than ever. A home makerspace is not required to have the same tools and materials as a public makerspace. In this post, I'll go over the fundamentals of setting up a home makerspace. Because distance and scheduling are no longer an issue, having a dedicated space at home increases your likelihood of engaging in making.

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“You don't learn to walk by following rules. You learn by doing, and by falling over.” — Richard Branson

Creating a space dedicated to maker learning at home is easier and cheaper than it has ever been before. A makerspace at home can be modelled after a public makerspace. A home makerspace is typically used by just a couple of family members, while a public makerspace can be used by many. In terms of tools, infrastructure and materials, a home maker space does not need to be equiped with the more expensive and large in size tools that you will find in a public makerspace, however this is not an important limitation. The infrastructure that really matters and provide the bulk of the learning opportunities are within the budget of any household that can afford a television and a computer.

In this chapter I will explore the basics of creating a makerspace at home. While anyone can use a public makerspace to get started, having a dedicated space at home makes it far more likely to engage in making since the barriers of distance and scheduling or booking resources at a public makerspace are not an issue. Still, public makerspaces are important to have access to, as I will explain later in this chapter, because it is where a maker can find more expensive or larger equipment that at some point will become necessary.

There are four basics components of a makerspace at home:

1. A desk
2. Tools
3. Materials
4. Storage

Desk

The desk is where all of the making takes place. At home, a small desk with 1m width and 60cm depth is more than enough. Desks like this, such as the TÄRENDÖ, can be purchased from IKEA for around $30. Because the process of making involves a lot of cutting, hot glueing and often drilling, it is a good idea to cover the surface with something protective. This could be as simple as a piece of cardboard cut to fit on the tabletop (total cost less than $1), or something more high-tech like a specialist cutting mat. Some cutting mats, apart from providing a tough PVC surface to cut on, also include printed lines to help make straight cuts.

I find that attaching a shelf on the desk greatly increases its utility. A shelving solution like the EKBY HEMNES from IKEA with a couple of desk shelf brackets is a good option. A shelf like this provides a space for bench instruments and tools that are frequently used to rest so that they don't occupy the limited desktop space.

The maker desk should be positioned close to power outlets so that it is easy to power computers, lights and power tools without the need for long extension cords that can become a trip hazard. A useful hack is to attach a multipower board under the table using Velcro so that any electrical devices can be connected to it instead of the wall socket. This minimises the amount of cable that is on the floor. With a basic cable management solution you can avoid the tangle of cables!

Tools

We can break down the list of tools that a home maker space should have into essential and everything else. Essential tools include things such as:

– Scissors- Masking tape- Cutting tools, like an Exactor knife, or something for larger cuts like the Craftsman edge utility cutter- Screwdrivers: at least one with a straight and one with a Phillips (cross) tip- A soldering iron kit- A multimeter- Pliers- Wire strippers- Safety goggles

Once you have these items, the list goes on:

– Clamps, for holding things together- A hot glue gun, perfect for joining cardboard, plastic and many other materials- Drill with a collection of drill bits including reamers, for creating holes- A hacksaw- An adjustable wrench- A staple gun

If your budget allows it, then things like a 3D printer, 3D scanner and a desktop cutting machine like the Silhouette Curio are more affordable than ever before and they do take making to new heights. These are more expensive tools, and not necessary if you are putting together your home maker space now, but will greatly expand the repertoire of the things that you can made once you have them.

Materials

You will also need to source the materials needed for actually making things. Fortunately, many of these things are already available in your household:

– Bottle tops- Brooms- Cardboard- Cardboard tubes- Craft paper- Glue- Needle and thread- Paintbrushes and paint- Popsicle sticks- Rubber bands- Scissors- Scrap fabric- Tape measure- Vacuum cleaner (for cleaning up the mess)- Wine corks- Yardstick- String

Simply using these materials, the maker can work on a vast array of projects. If you want to move into areas like electronics and robotics, then you will also need to source a few additional items:

– An Arduino electronics prototyping board or a Raspberry Pi computer on a board. There are many others, like the Little Bits, Makey-Makey, Beaglebone, PIC, but the Arduino and the Raspberry Pi have by far the largest user communities which means that there are plenty of resources and support. They are also the most generic items in this list, which means that they give you the largest amount of freedom to imagine your own project ideas. This is important for beginner makers.- Motors- Sensors, like infrared, ultrasonic, temperature, light, etc.- Displays, like simple character LCDs and colour TFT ones that can show graphics- Input interfaces, like matrix keyboards, and buttons- Discreet components like assorted resistors, capacitors, transistors, and LEDs- Basic integrated circuits like voltage regulators, 555 timers, shift registers, and small EEPROMs- Breadboards for creating prototype circuits- Jumper wires for using with breadboard- Battery packs- Mechanical components for creating machines like robotic arms and car racers

The list is endless, and depends a lot on the interests of the maker. For example, if you are interested in building custom robots, instead of simply assembling a packaged one, then you can source parts like grippers, brackets, hexapod foot sensors, mounting bases, gears, tracks and pulleys from a specialist retailer like robotshop.com or makeblock.com.

Storage

Over time, Makers accumulate a lot of tools and components. A storage solution is essential for ensuring that the makerspace is still a tidy and productive place. There is nothing worse for a Maker than spending too much time searching for a part they know they have because it is buried under a pile of other things in a crater box. There are a few basic categories of things that must be stored.

First, there are the bulk, small items like screws, rivets, resistors, capacitors and transistors. These items are cheap and plentiful. You should buy them in bulk. These are items that you will use in every project.

Second, there are items that are small but more expensive, like colour LCD screens and motors. You should buy those in small quantities, and at least in pairs. These are items that you will use in many projects so it is good to have a spare around, but not in every project like with the items in the first category. Items like the Arduino board also falls in this category. It is not uncommon for a maker to be working on two or three prototypes at a time, or to want to keep a finished gadget permanently. In that case, one Arduino can be allocated to the permanent project, and the spare to a new project.

Third, there are larger items that include the various tools. These are things like a digital multimeter, a soldering iron, a bench top power supply and a signal generator. You can physically only use one tool at a time so there is no need to have more than one soldering iron (unless, perhaps, for redundancy). New makers can go a very long way with a single multimeter and a simple soldering iron, and these two are the tools that you should get first for your home maker space.

Finally, there is everything else. This includes things like reference books, glue sticks, and consumables like electrical insulating tape. These are things that you should buy when a specific project that needs them comes.

Your storage should be able to accomodate all of these items. I find that something like a simple IKEA's KALLAX shelving system is perfect for the task. Small, plentiful items like resistors and screws can be stored in plastic utility boxes with multiple compartments. There are compartment boxes that allow you to adjust their internal space to fit items of different sizes. Then these items can be stacked in the shelving system.

For larger items, especially for the bulk crafting materials, you can use large containers. Again, IKEA supplies containers that work well with a shelving system like the KALLAX, which ensures that your space is clutter free.

A making space at home can become a catalyst in the development of a young maker. It is a space that the maker can customise to their style and needs, that is associated with creativity, separate from other parts of the home. Take a bit of time to think how it can look, and how you can set it up with minimal disruption to the rest of the household.

Interesting readings

- TÄRENDÖ from IKEA
- EKBY HEMNES from IKEA
- Create a Maker Space for Kids
- Maker Space from IKEA PS 2014 Wardrobe
- How to Build Your Makerspace
- How to Make a Mini Maker Space for Mini Makers
- Put a Makerspace in Your School
- Tips on how to design and set up a mini maker space made just for your kids

Learning tools

Education tools are designed to facilitate learning. They make certain that the learner has as few ‘gaps’ in knowledge as possible. Good tools make learning more effective and enjoyable. Most of what I present here are examples of educational tools (usually disguised as toys) for young self-learners. Educational tools make learning more efficient and enjoyable.

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“Arriving at one goal is the starting point to another.” — John Dewey

Good tools make learning effective, and fun. Apart from computer-based learning aids, having the right tool helps learning to mastery. Most of what I present in this chapter are examples of tools (usually disguised as toys) designed for young self-learners. It is important to note that educational tools are designed to facilitate learning; that is, to make learning happen faster, be more enjoyable, and ensure that the learner has as few knowledge ‘gaps’ as possible. Certainly, it is possible for a person to learn without such tools. However, just as elite Olympic athletes train with state-of-the-art equipment and world class coaching, learners that want to maximise their outcomes should consider investing in the best educational technology that they can get their hands on.

Construction sets have an important role in helping the learner to develop creativity and imagination. Using basic building blocks made of wood, paper and plastic challenges learners to create within the constraints of the physical world. The learner has to consider the availability of parts, their physical characteristics and gravity at every step of the building process. Construction can also take place in a group environment, in which case the learner also has the opportunity to develop emotionally, and practise their collaboration and communication skills.

Companies like the Happy Architect, Grimms and Lego offer high-quality construction kits for young children.

Construction kits can also be more specific in terms of the kinds of skills they are designed to develop. For example, Lakeshore Gear Builders is a kit specifically designed to teach gear mechanics. Octoplay sets help learners understand geometric construction. And Magnetic Polydron 3D is a kit that contains magnetised parts so that they snap together, offering another way to explore three-dimensional space construction.

In science, the possibilities are endless. The last few years have seen an explosion of educational tools specifically designed to teach science. Electricity, motion, heat, light, sound, chemistry, biology and much more can all be learned in a fun and interactive way.

The learner can understand the physical aspects of magnetic fields with a large copper solenoid (1). They can explore physics and motion with the help of a machines set with which they can construct cranes and pulleys, providing an opportunity to explore planes (2), axles (3) and levers (4). There are kits that make learning of light, colour, magnetism and sound so fun that the learner will not want to stop learning!

For learning atomic and molecular chemistry, kits can help students create a physical model of the world at the atomic level by constructing models. Model kits provide parts that represent atoms of different kinds as balls. Atoms of different kinds are available depending on the number of bonds that they have available to connect with other atoms. These kits also provide parts that represent bonds as rods, used to connect atoms together, creating molecules. The student can then create molecules based on their understanding of how atoms like that of oxygen, hydrogen, sulphur and carbon work.

Learners from 10 years of age or older can begin experimenting with real chemistry sets. Setting up a lab in the kitchen using a mix-and-combine set will give the learner the opportunity to experiment with acids and bases, react with baking soda, and progress from basic fun things like creating magic colour changes to more advanced practical things like creating a mini fire extinguisher and exploring the behaviour of atoms and molecules. Chemistry sets have always been a staple in science classrooms and will continue to be a core tool in learning about the physical world.

To explore electricity and electronics, again, there are excellent sets for every need and budget. Makey Makey is a classic choice that provides a fun way to control your computer through everyday items that people don't normally associate with computing. You can create a musical keyboard using bananas instead of actual keys, a game controller using keys drawn on paper with a regular pencil, and post tweets using letters made from alphabet soup. The learner will become enthralled with finding out elaborate ways by which they can control applications on their computer, which promotes out-of-the-box thinking and creativity.

For learners that want to explore circuits and electronics, choices like Littlebits, Electroninks, mCookies, and of course the Arduino platform are perfect. The Arduino prototyping platforms has revolutionised electronics making by bringing together a single board (the Arduino) that provides the "control centre" for whatever the maker is making. This control centre includes the capability to execute a program, and multiple input and output connectors. These connectors make it possible for the maker to connect things like lights and motors to their Arduino, so that the Arduino can interact with them. The Arduino's innovation, however, was in the software. The software that runs in the Arduino was designed so that people without a background in programming or in electronics can quickly pick up and start making their own gadgets.

An Arduino program is called a 'sketch', which is a reminder to makers that everything they make is an experiment, a sketch, and is temporary. The maker will constantly tweak their creation, whether that's a Lego block tower, or an electronic gadget based on the Arduino. Makers always iterate their creations to improve them or to simply try something else.

With the Arduino, the ability to iterate quickly was particularly important, and hence the emphasis on easy hardware interfacing using standardised inputs and outputs, and easy sketching using a simplified programming language and a bare-minimal programming interface that runs on any computer.

Apart from the Arduino, learners can choose from many other options. For example, Circuit Scribe is a pen that instead of regular ink contains conductive ink. With it, the learner can draw a circuit on regular paper, and then place electronic components on that circuit. Batteries, lights, transistors, switches and much more can be experimented with using a Circuit Scribe pen, a few common electronic components and a notebook, literally. With a tool like Circuit Scribe, experimentation can really be rapid and spontaneous, with every component being reusable, and with starting again being possible with the flip of a page.

Other examples of electronics learning tools that promote rapid tinkering are mCookies and Little Bits. With both, the learner uses electronic modules that snap-connect to each other, like Lego blocks. The modules have magnetic and colour-coded connectors so that the learner can easily figure out which way they can connect. This simplifies the task of creating functioning circuits so that the learner can focus on the creative rather than the functional aspect of making.

The motivation behind the design of tools like mCookie and Little Bits is that it is important for learners to first become comfortable with their creativity, and later, once they have experienced that incredible power, use it as motivation to learn electronics in a more fundamental way, by exploring individual components, their physics and becoming more familiar with grass-roots electronics.

There are many more tools for learning nearly everything in the context of Maker Education; that is, learning through making. Hopefully, this chapter has given you a taste of what kinds of learning tools are available in the market for learners and educators.

References

1. Solenoid
2. Plane
3. Axle
4. Lever

Interesting readings

- Top 10 Free Timeline Creation Tools For Teachers
- Grimms – natural and sustainable wooden toys
- Lakeshore Learning Materials
- MakeyMakey
- Molecule atomic kits
- Circuitscribe
- Microduino
- Littlebits

Online resources for Maker learners

There are numerous high-quality online resources for makers to find inspiration, knowledge, and practical advice. Some of them will be highlighted in this post.

To guarantee that they focus on teaching and learning, I chose resources that are not directly supported by a specific equipment vendor.

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“We have sold ourselves into a fast food model of education, and it’s impoverishing our spirit and our energies as much as fast food is depleting our physical bodies.” — Ken Robinson

There is a wealth of online resources for makers from where you can draw inspiration and practical advice. This chapter will highlight some of them.

Part of what made the Maker Movement possible as it evolved over the past 20 years is the growth of the Internet as the dominating means of access to knowledge and communication on the planet. Peter Diamantis, the executive Chairman of the X Prize Foundation, delivering a TED talk in 2012, said that the average person at the time with a smartphone connected to the Internet had more access to information than what

President Clinton had while he was in office (1). This is even more true at the time I am writing this, in early 2017!

There are numerous high-quality websites on the Internet that can be used as a source of inspiration and know-how. I list and discuss some of them in this chapter. I have selected resources that are not supported directly by a particular equipment of components vendor in order to ensure that the resources that I propose focus on topics such as teaching, learning, projects and community, rather than being a sales channel for corporates.

For some high-level inspiration, I invite you to visit ted.com and in particular to view two talks. The first one is by Dale Dougherty, publisher of Make magazine, delivered in January 2011, titled ‘We are makers’ (2). In this talk, Dougherty argues that America was built by makers, and that essentially, humans are all makers. He discusses the power of making to change the world, and the importance of technologies like the Arduino affordable 3D printers. His call to action is for everyone to start making!

The second talk is by Gever Tulley in February 2009 (3). Tulley is founder of the Tinkering School and in this talk he demonstrates the valuable lessons that children learn at his school. Once children are given tools, materials and guidance, they become imaginative problem solvers and start building. Under the right environment and circumstances, their passion can last for a lifetime.

There are many websites that contain step-by-step instructions for all sorts of projects. These projects are contributed by makers for other makers. They represent, perhaps, the best kind of project-based learning that resonates so well with the maker philosophy. An example of such a website is Instructables.com. Instructables has a special collection of projects specifically designed for children that employ mostly components that are readily available in most homes, or can be purchased cheaply from a supermarket or a crafts store (4). Example projects include how to make a rubber band helicopter that uses a propeller, a couple of craft sticks, masking tape, a paper clip, rubber bands, paper and scissors. Other example projects on Instructables that use similar materials include slingshot rockets, extending grabbers, siege engines and slingshot cars. There are dozens of projects that involve similar materials on Instructables that will keep young makers very busy.

In a similar way, Make magazine showcases numerous craft-type projects on their website. For example, in Ten Easy Woodworking Projects, makers using basic woodworking tools can learn how to make DIY wood toys for kids, chairs, puzzles, couches and coffee tables (5). In the craft category, we find projects on a diverse range of topics, like how to set up your own astrophotography rig using a Raspberry Pi, how to grow a crystal around an LED powered by magnetic induction and how to create a 3D optical illusion using a discarded clear CD case.

At diy.com you will find projects categorised by skill. For example, if you are interested in wind-related projects, like making a kite, parachute or a wind turbine, you can look them up in the Wind Engineer category. This site promotes the social aspect of sharing. It invites makers to post a picture or a video of their creation on the site for other makers to see and comment on it. It is incredible to see the great variation of implementations of the same idea. One set of instructions of how to make a wind turbine, for example, yielded dozens of implementations, ranging from dual-mode powered turbines (wind and hand), to paper cup turbines, and paper and cardboard turbines (6). The possibilities are really endless!

Apart from instructional websites, there are also explainer websites. These are resources that help learners understand how something works, be it a machine or a natural process. For example, howstuffworks.com explains almost everything, from how Stonehenge worked to how batteries and dishwashers work. There are many topics in science, health and many more to explore through. From tapping into alternative sources of power to surviving in post-apocalyptic Earth, it is all explained in howstuffworks.com.

A more academic resource is Wikipedia, of course. Wikipedia is an online encyclopaedia, the largest of its kind on the Internet. It contains over five million articles in English, and many more in other languages. Its content, in true maker fashion, is contributed by volunteers who are experts in their area of knowledge. The articles available through Wikipedia are written, updated and corrected by volunteers, and are provided with full citation. This is rare for virtually any other source of information on the Internet outside of academic publications, which typically require paid subscriptions or access to a university library. Wikipedia articles include a list of citations which provide evidence for the validity of the information they provide, and also include links to additional reading materials. While the article on wind turbines in howstuffworks.com provides a high-level description of how they work, in Wikipedia you can find a lot of details, including formulas for calculating their maximum power output, classifications, alternative designs, and of course almost one hundred citations and suggestions for further reading.

A resource that emphasises the social aspect of Maker Education is Maker Camp. Maker Camp offers free resources to people or organisations who choose to set up a physical Maker Camp in their area. In this Maker Camp, which can be set up in a local library, school or other public facility, children from 7 to 12 years of age can meet regularly over the six weeks of their summer holiday and work on a series of projects. Camps like these promote interaction and group working. A mentor and facilitator is responsible for helping the children work through the projects that they have chosen. Maker Camp is sponsored by Make magazine and Google+. Google+ provides the online space on which camp attendees can post information about their projects and describe their experiences. Anyone can apply to Maker Media to become a Maker Camp host, and if approved they will receive support to assist them with the organisation of the camp.

Finally, an online resource worth spending time on for any educator is FabLearn, supported by Stanford University and its Graduate School of Education (7). FabLearn’s mission is to disseminate ideas, best practices and resources useful to educators, policy makers and researchers from around the world in order to help them with implementing constructionist learning (e.g. 'making') into formal and informal education. From the FabLearn website, people can download the Meaningful Making ebook at no cost, that contains project ideas, best practices and relevant articles from leading educators in the space of making and hands-on education (8). It is perhaps the best place to begin your journey in Maker Education.

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1. Peter Diamantis: Abundance is our future
2. Dale Dougherty: We are makers
3. Gever Tulley: Life lessons through tinkering
4. Project-Based Engineering for Kids
5. Ten Easy Woodworking Projects
6. Wind Engineer Build a Wind Turbine
7. Fablearn
8. Meaningful Making ebook.

Interesting readings

- 9 Maker Projects for Beginner Maker Ed Teachers
- Frugal Fun for Boys and Girls
- DIY Awesome Skills for Awesome Kids
- Getting Smart
- How Stuff Works – Science
- Makercamp
- American Made – Where ideas become products

- The Makers Nation

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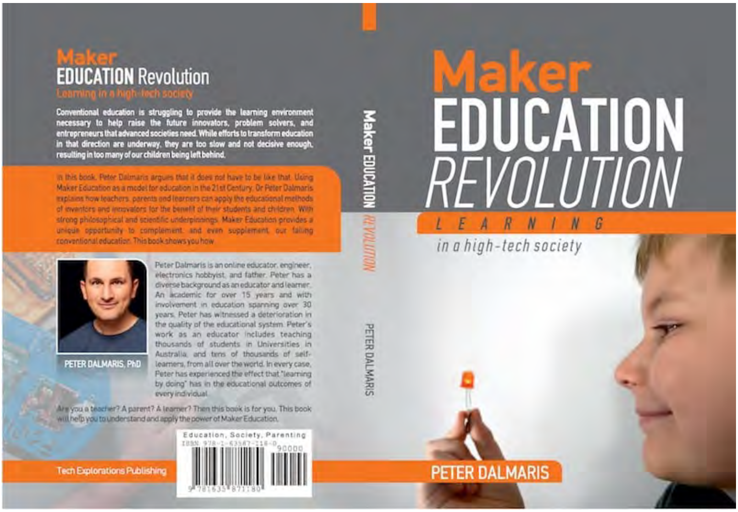

Brick-and-mortar resources for Maker learners

“Makerspaces” are gathering places for makers to converse and create. These establishments can be administered by a group such as a university or a library, or they can be run by individuals. A makerspace can help you expand your creativity and improve the quality of your work.Members not only get access to tools, equipment, and space, but they also have access to certified training programs in topics like 3D printing and CNC milling. Makerspaces can be found in almost every major city on the planet.

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“Go to a job interview and tell and employer that you can recite the 17 times table; they don’t care. Why are we still teaching it?” — Sugata Mitra

There is a wealth of ‘real-world’ resources that children makers can use as part of their learning journey. In this chapter I will give you some examples examples to help you get started.

“Making” happens in the real world since its outcomes are physical artefacts. Apart from your own space, at home or school, there are a lot of brick-and-mortar resources that you can incorporate into your learning by doing process.

What is known as “makerspaces” is the most obvious such resource. A makerspaces are places where makers meet to talk and make. These places can be run by an organisation like a university or a library, or by individuals. Most often, they are not-for-profit organisations. While members pay a fee, the money that is collected is put right back into the makerspace in the form of buying or maintaining equipment and consumables, or paying the rent and the bills.

As a member of a makerspace, you benefit by having access to relatively expensive equipment, like CNC machines that you can use to carve objects out of wood or metal, laser-cutting machines or woodworking tools. You also have the opportunity to meet skilled people that can teach you how to use these tools and with whom you can discuss the various aspects of your project. Interacting with other makers is always a source of inspiration and knowledge and should not be underestimated. Access to a makerspace can propel your creativity and the quality of your output to new heights.

Makerspaces operate in many locations. Curtin University in Perth, Western Australia, operates a free, public makerspace in its library (1). Anyone is welcome to visit and learn how to use a 3D printing machine or to play with a robot, and can attend lessons in topics like knitting and origami.

Other universities offer similar spaces. The University of Western Sydney, Australia, offers a makerspace that provides access to 3D printing services, woodworking, metal workshops and laser cutting (2). There are also workshops in robotics during school holidays.

Another example of a university-run makerspace is that of the University of Texas at Austin, USA (3). It is a place designed for students to implement their ideas using the space’s equipment and support from mentors.

Makerspaces also operate in many public libraries. In a world where information is increasingly found and accessed online, libraries are looking for a new mission, and organising makerspaces is a step towards this direction. In a library, makerspaces consist of a place where a librarian or a volunteer will assist makers with operating machines or providing feedback and advice on making. Fayetteville Free Library was one of the first ones to set up a makerspace in its premises, around 2010 (4). The space is operated mainly by community volunteers and its focus is on providing skills training to makers, new and old. Members have access to machines, equipment and space, but also to certification training programs in topics such as laser and vinyl cutting, 3D printing and CNC milling. The term ‘certification’ is used by the library to indicate that a new maker has undergone training on a particular piece of equipment and is now able to use that equipment without supervision. Apart from the classic makerspace, the library also offers a Creation Lab, which provides access to digital media creation tools, like video and podcasting equipment, and audio/video production software from Adobe and Apple.

In Australia, libraries such as the ACT Government Library in Canberra operate a full-time, well-equipped makerspace, free for anyone to use. At Surry Hills Library in Sydney, a makerspace for children operates once a month, and more frequently over school holidays (5). Children over eight years old can learn 3D printing, computer programming, animation and much more for free. There is a good chance that a free, public makerspace is open in a university library near you. You can use Google to do a quick search near your location, or just call your Council and ask.

Apart from institutionally run makerspaces, not-for-profit organisations or individuals also organise makerspaces for public use. These makerspaces are standalone, and usually require a fee for a membership to gain access. The fee is used to pay for the space’s ongoing expenses, since there is no other source of income. Makers Place is a privately run, not-for-profit makerspace in the Sydney suburb of Redfern (6). It is organised by volunteers who are passionate about the maker movement and learning by doing. Memberships, like other similar makerspaces, range from $25 per month to $75 per month. The more expensive memberships allow more frequent access to the space, and other perks like access to community projects and paid project opportunities.

OzBerry is a monthly maker meet-up in Sydney that has a particular focus on the Internet of Things. OzBerry members are interested in technologies like the Raspberry Pi, Arduino, Beaglebone and Teensy, and their monthly meetings are opportunities to discuss new learnings and trends, and showcase their creations (7). There are Maker meet-ups in virtually all major cities around the world, and you can use meetup.com to find one near you. Of course, I encourage you to join at least one of them in order to unlock the social aspect of making.

If you are representing a school, another interesting opportunity for your students is the Mobile MakerSpace (8). Mobile MakerSpace is company set up to bring everything you need in a makerspace to your school so that your students can learn how to use the equipment and start making. Apart from the equipment, you also get the people that can teach students how to use it. They will also run educational programs for teaching staff and students, which presents a low-barrier-to-entry opportunity to quickly set up a maker program at your school.

Making requires materials, not just physical space. There are many places from where you can source these materials. Of course, there is always Amazon and eBay. These are good sources for most commoditised items, like microcontrollers and electronics or mechanical parts. But sometimes you will want to visit a physical store so that you can see and touch a product, and discuss your requirements with staff. Hardware stores like Bunnings in Australia and Home Depot in the US stock a vast selection of materials and tools. If you are looking for wooden or metal raw materials, power tools like drills, saws, sanders and grinders or essentials, like clamps, pliers, tool storage, tables and screwdriver kits, then such retailers are great to keep in mind.

For craft, specialist stores like Lincraft and Eckersley's in Australia and Michaels Craft Stores in the US are perfect places to browse for craft materials and ideas. Paper, plastic, polystyrene, fabrics, markers, glues, joiners, accessories; it's all there. Makers can spend hours is such stores browsing through materials and working out which ones might work best with their next creation.

For electronics projects, stores like Jaycar Electronics in Australia and Fry's in the US represent a good choice for hunting down resistors, power supplies, transistors and electronics tools like multimeters and soldering irons. These stores stock anything electrical and electronic, from microcontroller chips to wires and breadboards.

And of course, there is Maker Faire. This is one of the highlights of a maker's calendar. There are Maker Faires and Mini Maker Faires in many cities around the world, where makers go to show off their creations, interact with other makers, and attend lectures and workshops. You can find out the Maker Faire closest to your location by searching at makerfaire.com/map.

References

1. Curtin University Makerspace
2. Western Sydney University Makerspace
3. Texas Inventionworks (formerly Longhorn Maker Studios)
4. Fayetteville Free Library
5. Maker and creator workshops in Sydney
6. OzBerry – Sydney's Monthly IoT Maker Space
7. Mobile Maker Space

Maker Movement Manifesto and the Learning Space

To create a flexible and engaging learning environment, you must be adaptable. This post examines the concepts that should guide any Maker Education learning environment to ensure that it adheres to the Maker Education spirit.

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“Don’t judge. Teach. It’s a learning process.” — Carol S. Dweck

The environment in which learning takes place is also a significant part of the process. The environment must be designed in a way that is compatible with the fundamental principles of Maker Education. Because Maker Education-type learning can happen in so many different places, like the home, the classroom, makerspace, a library, a community hall, even outdoors, there is a lot of flexibility in terms of what it actually looks like, and what kind of equipment it contains. The designer, the educator and the learners have a lot of freedom to design these elements of their learning environment.

Being adaptable is the key to creating a working/learning environment. This chapter looks at the principles that should guide any Maker Education learning environment in order to ensure that it stays within the spirit of Maker Education.

The key characteristics and guiding principles of Maker Education are summarised neatly in Mark Hatch's Maker Movement Manifesto (1). The manifesto names these principles:

- Make
- Share
- Give
- Learn
- Tool up
- Play
- Participate
- Support
- Change

The designer must take these principles and convert them into physical space. Let's take each principle at a time and consider its meaning in terms of physical space. Some of these principles are mostly behavioural in nature, while others are mostly activity-oriented. For example, 'Make' is mostly an activity, while 'Play' is mostly a behaviour. All of them have elements of both types; none of these principles are entirely of one type or the other.

'Make' is in the centre of the Maker Education learning experience. It is the activity that the learner will spend most of their time doing. To make, they will need a table or bench. Bigger is usually better, especially as projects become more elaborate in complexity and size. The maker will need to have space for the object they are building, the various components and building materials, tools and most often a computer.

'Share' is about using what you have made or what you learned from what you have made to improve the lives of others. Sharing comes naturally. When someone sees your creation, they can ask, “How did you do that?” which will trigger the sharing of your knowledge, centred around the object. In the physical space, sharing tends to take place predominantly in wide-open working spaces, rather than confined and compartmentalised spaces. Tools like whiteboards and notice boards are also great for making the sharing of ideas easier. Avoid partitions and doors, unless there is a good reason for using them. For example, it makes good sense to place a noisy machine in a separate room with a door instead of in the centre of an open makerspace.

Sharing can also be done through putting aside a few shelves in a bookcase where completed artefacts can be placed for people to see. Think of it as a display cabinet, a mini exhibition in the learning space. You can call it something like ‘This is what we made’.

Sharing happens a lot in online communities. Owning a blog is a great way to share knowledge and discoveries with learners outside your immediate community. Facebook, Pinterest, Twitter, Teachable, etc., are also great places where learners can share. These online tools are equivalent to the physical whiteboard and the display cabinet in real space.

‘Give’ is a behavioural characteristic in which you give someone something that you made. Everything a maker makes contains a small part of themselves in it. As a consequence, giving is an important gesture towards another person, an acknowledgement of appreciation, gratitude or simply good will. A learning space does not need to make any special provisions for giving, other than perhaps having adequate storage for the things that are made so that nothing has to be thrown out. Things can wait in storage until their time comes to be given out.

If ‘Make’ is the positive lead of the battery, then ‘Learn’ is the negative. These two are complementary to each other and a powerful electrical (creative) force field is created in between. You must learn before you make, and you will learn because you make. The learning environment must be designed for learning. Think about the materials needed: books, one or more computers connected to the Internet, furniture, comfort, light. You will need bookcases that are easily accessible so that books can be stored and displayed. A lot of learning happens by accessing online resources on a computer. Therefore, your learning space will need enough computers connected to the Internet so that learners don't have to compete for their use. Just like there is an abundance of knowledge on the Internet, there should be an abundance of access devices to that knowledge. There should be comfortable chairs, armchairs and couches on which the learner can sit and become absorbed in whatever it is that they are learning.

'Tool up' calls for learners to have access to the right tools for their project. These tools must be locally accessible, instead of being locked in a separate storage area. This means that a storage cabinet or similar, appropriate for the tools, should be available in the learning space.

'Play' is about exploration without goals. It is about discovery and expanding mental horizons. The maker learning environment must be playful. It must be colourful, informal. The walls can be painted in vivid colour. Creation materials like Play-Doh and Lego can be made available. Things like the Idea Wall, which is a wall covered with a white-board friendly paint of a normal white board from top to bottom, invite you to write on them and generate ideas for whatever you happen to be working on.

'Participate' is about reaching out to the people around you, close and far. It is about organising special events, mini Fairs, classes and in general opportunities for makers to get together and learn from each other. Your learning space can facilitate these gatherings. It will need to be modular and flexible to change depending on the nature of the event. For example, if you are organising a seminar, you will need more seating than usual and a projection screen. If you are organising an exhibition, you will need no seating but instead you will need more displaying furniture than usual.

‘Support’ is about thinking of making as a statement about how you believe the world should be, and to be willing to support it. A movement needs support, be it emotional, intellectual, political, etc. You can reinforce this commitment to the collective Maker Movement by doing something as simple as hanging a poster of the Maker Manifesto (2), or your own version, on a wall, or images of creations that you or other learners in the learning space admire. Decoration can stir up the right emotions, and from there activities in support of the movement may arise over time.

Finally, ‘change’ is constant. This may sound like a strange concept, but it is true. In making, everything changes, all the time: technology, objectives, skills, people. As everything changes, your learning space should be flexible enough to be able to change accordingly. Allow learners to customise their small part of the space without disrupting others. It is important for everyone to have at least part ownership of their environment, to look after it, and to know that they have the power to make changes to it if they need.

Designing a learning space is a collaborative process. Talk to everyone that is affected: teachers, students, parents. What are their concerns? What are their practical considerations? What about the kind of behaviours that they hope to encourage or discourage among those that will be using the new space? Their concerns must be recorded and addressed.

Finally, there anyone organising a maker-style learning space must consider safety. It is a very different design that promotes student engagement versus one that promotes organisation and safety. Both are necessary, so a compromise, a middle ground, must be found. Safety issues can dictate changes that would not have been necessary otherwise. Equipment requirements for things like power and ventilation also introduce constraints that must be worked around. For example, the position in the space where soldering is done should be well ventilated so that soldering fumes don’t spread and the learners are not exposed to it. Consider installing a fume extractor or make equivalent arrangements for removing the fumes. Also ensure that the electrical infrastructure is safe. Consult a licensed electrician to design and install ample power points, and include residual current devices, and powerpoints with protective shutters. Position power tools and their operating stations close to a supervisor who can keep an eye on them. None of these provisions need to get in the way of creative making, but all of them add a level of safety.

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2. The Maker Manifesto.

Can we afford to ignore Maker Education?

A core value of Maker-style education is learning by doing. In a Western or developed country, the average student will spend approximately eleven thousand hours in school. Less than 10% of that time is dedicated to teaching students how to think like a scientist or engineer.I was given the opportunity to choose what I wanted to work on for my graduate project in my final year of university. I was able to experience the freedom I had craved since childhood – the freedom to experiment and create things that didn't work. What would life be like if the joy of making, as well as the sense of accomplishment and fulfilment it provides, were at the heart of our schooling years?

Maker education revolution

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“If we teach today's children as we taught yesterday's, we rob them of their future” — John Dewey

Consider what we know about Maker Education, what I have discussed in this book, and how it has affected teacher, student and parents lives. Is Maker-style Education really an alternative to conventional education, or at least a source of inspiration and know-how for reshaping conventional education?

Learning by making is a core value of Maker-style education.

Does learning by making really work? Is this kind of learning too expensive since it requires all these tools and materials? Is it too risky to abandon a system that we are all used to, despite its weaknesses, and morph it into something new hoping that it will deliver the rewards many years or decades later?

According to OECD data from 2011, the average student in a school system of a western or developed country like Australia will spend around eleven thousand hours in school (1). This number is shared between elementary and lower secondary education. The OECD average is around eight thousand hours. The part of this time spent on science and mathematics is around 25%. In most parts of the world, almost none of this time is spent in learning-by-doing activities. The emphasis is in academic-style learning, rote learning in other words, that involves passive absorbing of facts by the learner. There is no information on how much of that time is spent on teaching students how to think as a scientist or engineer across all subjects, a core outcome of Maker Education, but an optimistic estimate would place that figure to less than 10%.

The schooling experience that most of us have is that despite all the time we spent at school, we were not prepared for life in a meaningful way. My own experience from school was that of a place where boredom triumphed. I did learn how to read and write, developed some basic social skills and created strong friendships. But how much of that was due to school and how much was due to background social dynamics and family is debatable. What is not debatable was that for me, the overall experience was overwhelmingly negative. In my school, none of my strongest curiosities were satisfied. I spent my hours trying to focus on what my teachers were saying just in case a random test was thrown in. I studied hard to please my parents and because it was the socially acceptable thing to do. I developed extreme patience, a very useful skill indeed, because I had to wait for school to finish, go home, do all my homework for the next day, until I could find a one-or-two-hour block in which I could devote myself to what I truly wanted to do: make model planes and ships, open up old and discarded machines to see what’s inside, read books on astronomy and science, and play with my Apple IIe. None of these were considered useful skills or important enough to allocate a core part of my day to them: they were all a child’s play.

Things became a lot worse in higher secondary school where 100% of the emphasis was on studying exactly the materials I needed in order to gain entry into a school of engineering. Engineering, electronics, machines was my passion, but while I was studying for these exams, a total of two or three years, I had to forget all about my passion. I had to dig into my prescribed books, memorise exercises, repeat the same study countless times until everything was perfect. Entering university was a great achievement, but it didn’t feel like that to me. Everyone else seemed happy. Teachers, parents, friends were all congratulating me for my hard work and success in these exams. I felt that in order to achieve something that should have made me happy, I had to loose something that actually did make me happy.

But I still had hope. Surely, now that I was in the School of Electrical and Computer Engineering, I would be able to rekindle my old childhood passion. Just like in those days, years ago, I expected to be able to start making things again. But that just didn’t happen. My experience at University, like that for so many of us, was that it was a continuation of school. I was also surprised to find that many of my colleagues did not share a passion for engineering, for electronics, or for making. They spent years of their lives studying to gain entry to the School of Engineering, because of the excellent job prospects that such degree brought along. Engineers are always in demand. Then again, maybe I am wrong; maybe they did have a passion for making and engineering, but it was taken out of them in school.

During my university years at the School of Engineering, the opportunities for tinkering were rare. The first few years, when minds are fresh and excited, were consumed in learning various academic subjects. I took every lab I could just to experience the feeling of doing something practical again, the feeling of making something. However the vast majority of my time was spent in the library or working on assignments at home. Learning was a series of lectures, study and exam cycles. Very conventional.

The years of drought in university culminated in my final semester, where for perhaps the first time in years I had been given a choice: what would I like to work on for my graduate project! I was finally able to get a taste of the freedom that I had craved for since childhood, to spend hours, days and weeks exploring a technology of my choice, making things that don't work, learning from them, showing others my work. The fact that eventually I presented this work to my professors and received a grade does not matter. These last six months in my career as an undergraduate engineering student were the best because I was finally making something that excited me.

Isn't this the experience, in varying degrees, that most of us had of their schooling days (2)? Albert Einstein famously said that "creativity is simply intelligence having fun". Are you having fun? Are your children having fun? Are your students having fun? Are the learners under your care and jurisdiction having fun? Are they creative? Or has their creativity been killed by their school, as Sir Ken Robinson has suggested?

The eleven thousand hours, once you add other school-related, forced activities, easily become fifteen thousand. Add higher secondary and then university education, and we are looking at almost thirty thousand hours spent in traditional education for the average person in a western developed country.

And we have to ask ourselves: What are the dividends that we as people and collectively as a society have received for all this work by students, teachers, parents and everyone involved? How much of that time should really be devoted to learning basic literacy, like language and arithmetic, and how much should be devoted to developing children as individuals so that they have the best chance of growing into active, confident and creative individuals, capable of contributing their minds and skills to creating a better world?

Years after my graduation from the School of Engineering it occurred to me that perhaps I should have dropped out as soon as I realise that my learner where not being met. Or perhaps I could have searched for alternatives. But I can only say that now, with the benefit of hind sight, and decades worth of experience as an educator and life long learner. Without this knowledge, making decisions like that contain too much risk for most young people to even consider. Like so many other young people, I did not have the mindset, the maturity or the self-confidence to do so. Perhaps more important, I had the social pressure to get through it, get my degree and move on with life. I know now that I should have looked for a way to better align my drive for learning and making, of learning through making and how I spend my time, day to day.

I can imagine this conversation: "How can you even contemplate dropping out, how can you do this to your parents? To your teachers? All their sacrifice, all the things they have done for you will be for nothing".

But then, what about the children? Is our system, our mindset, our way of education asking our children to sacrifice their passions, or their search for their passions, in exchange for compliance with a system designed in the 18th century with mass production factories and urbanisation in mind?

Children are naturally wired to be learners; they learn through play, through doing. When the system created to help them learn takes away the most important pathways of learning, play, experimentation, curiosity and their ability to pursuit them, we are removing a large part of their capacity to learn and be creative. Is there any wonder then why children that are having learning difficulties at school feel disconnected, disappointed, unfulfilled? Is there any wonder why so many children get in trouble and stay in trouble for long periods of their lives, maybe forever, with the severe consequences to themselves, their families and friends, and society?

Can you imagine how our lives could be better, and our societies, and world be a better place if the bulk of our schooling was influenced by the principles of Maker-style education? How can we, as educators, parents, and policy makers, respond better to the knowns and unknowns of life in the 21st century?

What would life be like if the joy of making and the sense of achievement and fulfilment that it brings was at the core of our schooling years?

References

1. OECD Education at a Glance 2013.
2. How the education system is making kids stressed and sick

Interesting readings

- Making Education Work: A report from an Independent Advisory Group chaired by Professor Sir Roy Anderson
- How the Maker Movement Is Moving Into Classrooms
- Makerspaces Lead to School and Community Successes
- Engaging Students in the STEM Classroom Through "Making"
- How the education system is making kids stressed and sick
- Time in school: How does the U.S. compare?
- School Years around the World

The new role of the school

There is almost no way to achieve any level of success in any field without the ability to solve problems, and computational thinking provides a methodology for developing such skills.

Initiatives such as Mathematics by Inquiry and the Coding Across The Curriculum program emphasise practical learning methodologies aimed at assisting young learners in developing fundamental making, critical thinking, and problem-solving skills.

Maker education revolution

Conventional education is struggling to provide the learning environment necessary to help raise the future innovators, problem solvers, and entrepreneurs that advanced societies need. Maker Education offers a model for education in the 21st century.

“In school, you’re taught a lesson and then given a test. In life, you’re given a test that teaches you a lesson.” — Tom Bodett

What is the role of the conventional school in this Maker Revolution as I have outlined it in this book?

It is critical. The bulk of our children attend conventional schools, and this will not change any time soon. And I don’t think that should change. Our societies will find it hard to function at all without schools. In particular the public schooling system is one of the core responsibilities of modern, organised states.

The conventional schooling system has to be our focus for bringing about a transformation. This is the transformation that I call "Education Revolution". A transformation that takes a system designed in the 18th century and modernises it for the 21st century. The system after which this transformation should be modelled is Maker Education.

A study done by Deloitte, found that (1):

- Over 70 Kickstarter-funded makers, who collectively received 23 million dollars in pledges from over 138,000 individuals, were present at the 2014 Bay Area Maker Faire
- Shapeways announced over 13,500 online storefronts selling 3D designs in 2013
- ETSY reported $1.35B in total merchandise sales in 2013 from over a million active shops
- Rethink Robotics launched a safe, capable, intelligent and affordable industrial robot – Baxter – for $25,000
- Foxconn deployed 20,000 robots as part of its plan to have over a million robots in its factories over the next few years

The growth in the size of the markets for companies like Kickstarter, ETSY and Shapeways derive directly from individual maker activity. There is nothing fundamental stopping any school student, or any individual at all, from directly participating in this economic activity right now. You need an idea, a talent in communicating it, and you are ready to join global markets that have never existed before.

Rethink's new industrial robots means that sooner than what many think is the case, makers will be able to create an automated production line in your home or garage. At this level of automation, individuals and small companies can be competitive in terms of cost of doing business against businesses operating at much larger scales, at least for many niche products.

The way by which student performance is evaluated is also changing. The traditional exam and transcript system is being supplemented or even replaced by portfolios. MIT now evaluates students' portfolios as part of their evaluation and admission process (2). If you want to study engineering at MIT, you better start making! In Australia, Curtin University has also started to consider student portfolios with evidence of academic achievements, qualifications and ability for select courses instead of formal exams (3). It seems that this is just the beginning of a sustained trend to rethink how students may gain access to higher education. A coalition of 80 prestigious Universities and Colleges was set to do just that (4).

The recognition that Making is a fundamental component for the prosperity of a society is becoming more common. President Barack Obama, through his 2012 Maker Initiative, exemplified the importance of the Maker Movement, community and philosophy as a cornerstone for social growth and prosperity in the 21st century (5).

Schools play a fundamental role in all of this since that is where the majority of the Maker Education and making activity has to take place. Schools are already adjusting to this call with a lot of energy. The call for change has been received with enthusiasm. Teachers and policy makers show that they understand the importance of change through their actions. Where other areas of public discourse, like tax reform, climate change policies and the health system, seem to be caught up in endless debate for even agreeing about the problem, in Education there seems to be a constructive consensus.

In Australia, the Federal Department of Education and Training has restored a focus on STEM (Science, Technology, Engineering and Mathematics) in an effort to better prepare students for an uncertain economy and society of the future (6). Initiatives such as Mathematics by Inquiry and the Coding Across The Curriculum programme emphasise practical learning methodologies that are geared towards helping young learners acquire fundamental making and critical thinking and problem-solving skills.

The impetus for this is supported by the statistics. According to the Australian Bureau of Statistics, the demand for STEM related jobs is increasing at about 1.5 times the rate of other jobs in recent years (7). The initiatives of the Australian federal government are having a significant effect how policies are translated to educational initiatives in schools. In South Australia, for example, the STEM Works program was designed to provide 139 schools with modern facilities (8). Approximately 75,000 students that study in those schools now have access to these new facilities.

Students in Trinity Anglican College are now becoming familiar with modern robotics concepts by building and programming their own robots. They deal with technical problems on their own, create designs, keep notes, and prepare for taking part in RoboCup competitions (9). At Ravenswood School for Girls in Sydney, students learn programming by building their own robots and assigning various tasks to them, from following a black line on the floor to detecting obstacles and adjusting their course (10). At the Armidale School, children are using Scratch (11) and Snap (12) to learn computational thinking . In a complex world, computational thinking provides a useful approach to problem solving that draws on concepts from computer science . There is virtually no way to achieve any level of success in any field without a capability to problem solving, and computational thinking provides a methodology for training for such skills (13).

According to the Department of Education and Child Development of South Australia, 75% of jobs in the next 10 years will need STEM skills. I believe that this is true for virtually every modern society that is forward looking and progressive. If schools can't equip learners with these skills, what is at stake is the survival of that society as an entity. Without these skills, there will be stagnation, social disorder and eventual disintegration. In this sense, schools, and the education system, is as important as the military, the police, the medical system. Without one, a country cannot exist in an independent, cohesive entity over the long term.

So, what can schools do? In the absence of top-to-bottom guidance and support, schools have to embrace the principles of Maker Education to the limit of their ability and freedom to do so. Not every school can afford Lego Mindstorms, but every school can afford cardboard and masking tape.

As Adam Savage of the Mythbusters said in his MakerFair 2012 Keynote: “It doesn’t matter what you make, as long as you make something.”

Making is not so much about the the tools and the physical deliverables, but about the developing a scientific thinking process and a growth mindset. Schools must start with a change in the way they perceive themselves. From being places where education is delivered, to being places where makers meet. Teachers become facilitators in students’ learning journeys. Students learn from each other by making, and teachers provide mentorship and infrastructure. A history lesson, a geography lesson and a mathematics lesson can be turned into opportunities for making.

Instead of talking about the Parthenon, why not design one in Tinkercad and print it on a MakerBot? Maybe then, the students will begin to appreciate some of the challenges of Phidias, and become intimately familiar with this object of historical, cultural and artistic significance. Instead of talking about the Rise and Fall of the Roman Empire, why not create a timeline of its most important events, that includes dates, names of people, names of places, maps, photographs of artefacts, and anything else that the students think is important and display it on one of the walls of the school? Instead of describing geometry with a chalk and a blackboard, why not use it to program a robot to move in a circle or triangle, or play with geometry using Wolfram Alpha (14)?

Making in schools is possible immediately, with just the right mindset, and a few cheap and easy-to-find materials. The return on the investment will be beyond imagination!

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1. Impact of the Maker Movement report developed by Deloitte Center for the Edge and Maker Media from the Maker Impact Summit 2013.
2. MIT Portfolio entry
3. Curtin University Portfolio entry
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6. Restoring the focus on STEM in schools initiative.
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8. South Australia Department for Education and Child Development.
9. Welcome to a brave new world
10. Aussie kids learning computer coding at primary schools
11. Scratch, a visual drag-and-drop programming language
12. Snap!, a visual, drag-and-drop programming language
13. What is computational thinking?
14. Computational Knowledge Engine

Interesting readings

- How to make math class interesting?
- First Robotics Competition promotional video 2011 (Youtube)
- Making sense of mathematics through reasoning
- How the ‘Maker’ Movement Plans to Transform the U.S. Economy
- How Makerspaces Help Local Economies
- Maker movement makes waves in schools
- The Maker Movement – Retinkering Education
- How to start a STEAM program in your school
- Schools Shift from STEM to STEAM
- Scientists and Mathematicians in Schools
- South Australia investment in STEM

Maker Education Revolution