The Maker Movement. Implications of new digital gadgets, fabrication tools and spaces for creative learning and teaching

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The "Maker Movement" deals with innovative forms of production and do-it-yourself work. It is not only a way for new business models and developments, e.g. using 3D print or other new digital tools and gizmos, but also influencing education. This paper introduces several diverse terms (from FabLabs to Hackerspaces) and gives insights into background, practice and existing experiences from Maker Movement in educational settings amongst all age groups. As a conclusion, the authors present reasons why practitioners and researcher should consider its educational potential. Besides its creative and technological impacts, learning by making is an important component of problem-solving and relating educational content to the real world. Besides this, digital tools for making are not expensive, for example apps for mobile devices or rents for 3D printer (compared with desktops in 1:1 settings). The Maker Movement is seen as an inspiring and creative way to deal with our world, it is aware of ecological challenges and of course, and it is able to develop technological interest and competences casually. Finally, the authors give recommendation for reading for all who got interested in making.

1. Exploring new trends in education: The Maker Movement

As innovative educators and researchers, it is important to be up-to-date on current trends and developments and how they might impact education. In higher education, a popular resource for e-learning trends and future developments is the New Media Consortium's (NMC) Horizon report (e.g. Johnson et al., 2012) that is released yearly. Based on data collected from professionals in the field, the report focuses on the potential wide-range adoption of technologies currently used for learning within the next few years. Another popular resource, The Innovating Pedagogy report (Sharples et al., 2013) from the Open University in the UK views trends and future developments more broadly to include new trends and future (un-invented) technologies. Grounded in new educational terms, theories and practices, it proposes ten innovations that "have not yet had a profound influence on education," but "have the potential to provoke major shifts in educational practice, particularly in post-school education" (Sharples, et al., 2013, p. 3). One of the innovations listed in the 2013 Innovative Pedagogy report is "maker culture" with the subtitle "learning by making" that "encourages novel applications of technologies, and the exploration of intersections between traditionally separate domains and ways of work" (Sharples et al., 2013, p. 33). The Maker Movement was already named a top ed-tech (educational technology) trend in 2012 by hackeducation.com (posting from November; see Watters, 2012). Its potential for education has been avidly discussed on several websites and discussion forums, where some see it as the next revolution in education, using statements such as "The next revolution in education will be made, not televised."[1] This article attempts to answer the question: What is the "Maker Movement" and what are its influences and its (potential) impact on learning and education? Given the possible impact of this trend on education, the aim of this contribution is to provide a broad introduction to the issue and discuss its likely influence on education as a first step to initiate discussion of this (potential future) trend.

Within this article we will a) introduce the Maker Movement and its elements b) describe how it relates to other developments in the history of education c) provide examples of how it has been adapted and has influenced learning spaces or educational settings d) review existing literature on this new phenomenon, and e) discuss the implications for learning and teaching with respect to why educators, learning organisations as well as researchers should be aware of these new developments. A scientific in-depth analysis of the status quo is not possible in this article as we were not able to find any existing comprehensive work that brings together these related strands, stories and existing work within the new field. Due to the newness of this phenomenon, we also reviewed sources such as Wikipedia, other Web sources and reports on current developments, whose validity might be a point of contention. It is also possible that despite our efforts, we have missed some existing literature or part of the puzzle. Nevertheless, we hope this contribution is a helpful step forward to provide a robust overview of these new developments and their significance for educators.

2. The Maker Movement: Internet of Things, its adoption trough makers and their key ideas

The idea behind the Maker Movement is to create and develop new things (concrete or digital) using new tools such as 3D printer in open spaces, work shops or labs (Anderson, 2012). It combines innovative forms of productions and do-it-yourself work. Even if not everything and every action amongst makers is digitally driven, making deeply builds on the development of the "Internet of Things" (IoT). Small computers or digital devices and tools, which are connected via the Internet, are built and used to create or produce new products. Some examples for this are: to sew fancy interactive clothes, to develop new user interactions with the Internet using RFID chips (for example to send an e-mail if a key is hung up at home), or to construct a robot which is able to clean one's own flat. Making in this context does not just focus on IoT and uses a fusion of the digital and physical world as well as traditional tools.

In the "Maker Movement Manifesto", Mark Hatch (2013) identifies the following nine principles for the Maker Movement:

- "MAKE – Making is fundamental to what it means to be a human. We must make, create, and express ourselves to feel whole. [...]
- SHARE – Sharing what you have made and what you know about making with others is the method by which a maker's feeling of wholeness is achieved. [...]
- GIVE – There are a few things more selfless and satisfying than giving away something you have made.[...]
- LEARN – You must learn to make. You must always seek to learn about your making [...]
- TOOL UP – You must have access to the right tools for the project at hand. Invest in and develop local access to the tools you need to do the making you want to do.[...]
- PLAY – Be playful with what you are making, and you will be surprised, excited, and proud of what you discover.
- PARTICPATE – Join the Maker Movement and reach out to those around you who are discovering the joy of making. [...]
- SUPPORT – This is a movement, and it requires emotional, intellectual, financial, political, and institutional support. The best hope for improving the world is us, and we are responsible for making a better future.
- CHANGE – Embrace the change that will naturally occur as you go through the maker journey. [...]" (pp. 1 ff).

According to Hatch (2013), his manifesto is only an initial sketch. He writes, "In the spirit of making, I strongly suggest that you take this manifesto, make changes to it, and make it your own. That is the point of making" (p. 2).

Social movements do not normally originate from one point or one man's idea, but take place as multiple sub-developments in different ways. This is also true of the Maker Movement that has evolved in multiple forms such as public studios and laboratories where people are able to make something (sometimes for a small fee) and these forms have received different names. Specific terms and hubs for the Maker Movement such as the FabLab initiative in MIT, hackerspaces and makerspaces are explained later in this section. On the one hand, these terms are sometimes used synonymously with each other, and on the other, fundamental differences between their concepts (concerning business model; non-profit vs. commercial) and

[1] http://www.techlearning.com/features/0039/meet-the-makers/54261#sthash.XT9Z5nj5.dpuf (2014-04-04)

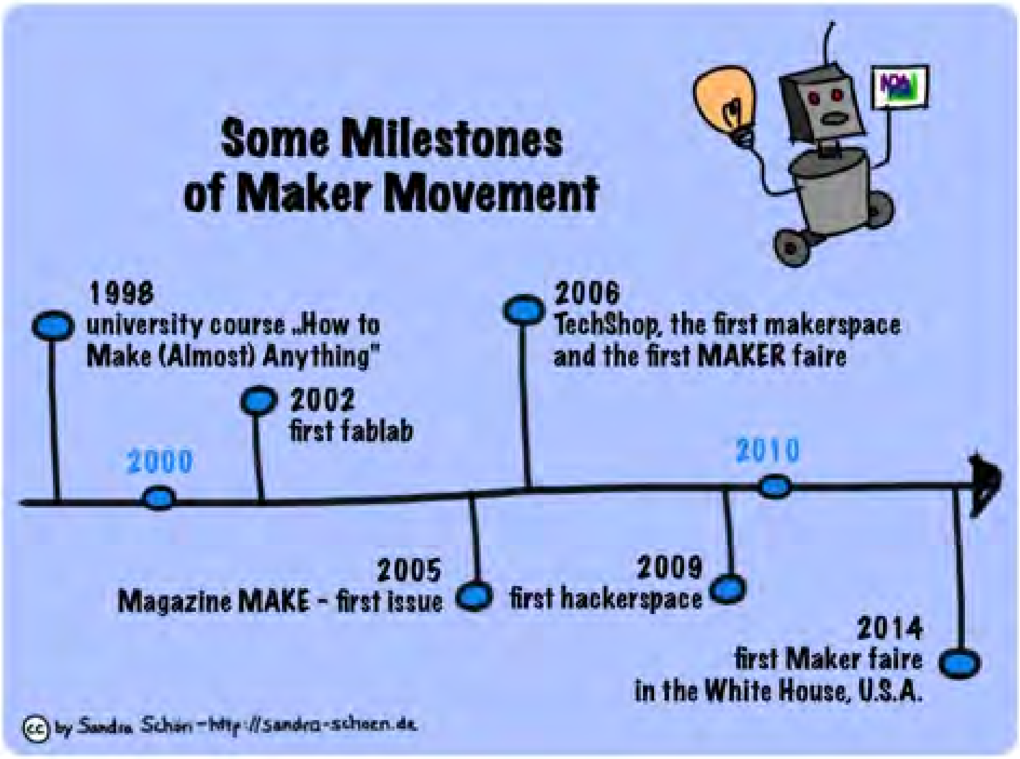

Figure 1: Some Milestones of Maker Movement

main activities (fabrication, programming, and the role of digital tools) have been highlighted. Some readers may hesitate to accept the term "Maker Movement" because they might consider it an exaggeration for a recent development to be equated to a social movement. Using existing definitions and theories, Walter-Herrmann (2013) confirmed that the FabLab movement is a social movement, and we consider the FabLab as a part of the Maker Movement. Although all the different terms and definitions that fall under the Maker Movement do not have a "corporate identity" and are not always viewed as belonging together, and some might not regard the Maker Movement as a social movement, it is used as a heuristic term in this paper. The following paragraphs describe some of the different terms, movements and hubs that make up the Maker Movement (Figure 1).

The Fablab

The motto of the MIT Fab Lab (short for "fabrication laboratory") project is "Give ordinary people the right tools, and they will design and build the most extraordinary things."[2]. The project originated in 2001 at the Center for Bits and Atoms at the Media Center of the Massachusetts Institute of Technology under Neil Gershenfeld, the author of the book "Fab, The Coming Revolution on Your Desktop - From Personal Computers to Personal Fabrication" (Gershenfeld, 2005). Fablabs "provide access to prototype tools for personal fabrication" such as a 3D printer or laser cutter[3]. Following the opening of the first FabLab in MIT in 2002[4], Fablabs have spread across the world from Boston to Africa and Europe. They have found application in areas such as agriculture, health or housing, and are (normally) supported by non-profit organisations or funded by communal sponsors. Examples from Europe are the OTELO initiative ("Offenes Technologielabor", in English open technology lab, Austria non-profit organisation, http://www.otelo.or.at/otelo/idee/), the HappyLab (Vienna, Austria, co-financed by the Ministry and others, http://happylab.at) or the FabLab Munich (Germany, non-profit organisation, http://www.fablab-muenchen.de/). The Fab Lab foundation describes four essential features of registered FabLabs: Public access (free, at least for some time), a common set of tools, participation in the FabLab network, and they have to sign the FabLab Charta[5][6]. Currently about 280 FabLabs can be found at the foundation's Website[7].

[2] http://www.fablabdc.org/about/history/ (2014-04-07)

[3] http://www.fablabdc.org/about/history/ (2014-04-07)

[4] As mentioned by Walter-Herrmann & Büching (2013, p. 12), there are several other sources and also similar development elsewhere.

[5] http://www.fabfoundation.org/fab-labs/ (2014-04-07)

[6] http://fab.cba.mit.edu/about/charter/ (2014-04-08)

[7] http://www.fabfoundation.org/fab-labs/ (2014-04-07)

Maker faires

In 2005, the same year of the publication of Gershenfeld's book, a new magazine called "MAKE" was published in the U.S. MAKE is issued every two weeks and focuses on do-it-yourself projects involving computers, robotics, electronics, and other product areas. The magazine established the first Maker faire in 2006, a public and now annual event, in San Mateo Fairgrounds with over 100 exhibiting makers. "Maker faire" is a trademark, thus all events are registered and supervised by the Maker magazine. The special nature of these events has been emphasized by Watters (2012), who states, "There were plenty of other science fairs this year — including ones at the White House and at Google — but Maker Faire is fairly unique, I'd argue, in its culture, creativity, and community." By now, several Maker faires have also been hosted in Europe, for example the "European Maker Faire 2013" in Rome[8] or the Maker Faire 2013 in Hannover (Germany)[9]. Last, but not least, the White House in the U.S. plans a "maker faire" in 2014[10].

Do-it-yourself (DIY)

The new technological possibilities, grassroot-driven activities and FabLabs comes include the do-it-yourself (DIY) as a new business model. In a book titled "Makers," Anderson (2012) termed the "Maker Movement" a business development that can be likened to a new industrial revolution. The possibility of fabrication using new tools such as 3D printers by nearly everyone is a foundational part of this development. It allows inventors not only to develop a smart idea, but also to produce it. Invention, design and business go hand-in-hand, providing a lot of options for enterprising people, such as the possibility of very small businesses and low risks. According to Anderson, makers are combining do-it-yourself and manufacturing with new digital tools that he terms "digital DIY". Additionally the sharing of ideas and plans amongst the community is a unique cultural dimension of the movement that, along with fabrication, is supported by the usage of uniform standards.

Makerspaces

Another part of the Maker Movement is the development of "makerspaces". Makerspaces are (commercial) studios equipped with digital fabrications tools such as 3D printers or laser cutters, vinyl plotter and AutoCAD software that anyone can use for a relatively small fee. The mindset of people organising and visiting such makerspaces and its workshops is described as open, friendly, supporting and creative. The CEO of the first commercial makerspace, the "TechShop" founded in 2006 in Silicon Valley, Mark Hatch describes makerspaces as "a center or workspace where like-minded people get together to make things" (2013, p. 13). Success stories from the makerspace TechShop are contained in the Maker Manifesto (2013). Making is therefore an inspiring and creative way to use modern technologies and communication tools to support the potential development of innovation with a business impact (Anderson, 2012).

Hackerspaces

Besides "FabLabs" and "makerspaces", there are also "hackerspaces" (or "hacklab", "hackspace"). Whereas the first two terms are tend to be used synonymously and are used for public areas with digital production tools, hackerspaces have a slightly different focus. The idea of "hackerspaces" originated in Germany as an idea of the Chaos Computer Club in 2009[11]: Physical public meeting rooms for hackers (software developers and experts) are seen as inspiring places for open software development – and other technical applications. The first "hackerspace" was at the "c-base space station" in Berlin, Germany "a culture carbonite and a hackerspace [that] is the focal point of Berlin's thriving tech scene"[12]. Other popular hackerspaces are the "NYC Resistor" in New York City, USA).

In summary, the term "Maker Movement" has probably been coined based on all the above terms such as "MAKE", the MAKER faires, Anderson's (2012) book "Makers", Hatch's "Maker Movement Manifesto" and several others. It is used in several references in the educational literature. However, the term "Maker Movement" is not widely used or used by all those who describe these activities and who might prefer to still use other terms with slight differences and meanings for the activities we heuristically describe as part of the "Maker Movement" in this article. Perhaps the current phase of the Maker Movement and its bunch of terms (and definitions) is comparable with the early years of the OER (Open Educational Resource) movement, where several terms such as free open educational content, open learning resources, were used to describe the similar resources. Before people in the field came together, shared terms and resources, and the phenomenon was

[8] http://www.makerfairerome.eu/check-out-the-program/ (2014-04-04)
[9] http://makerfairehannover.com/ (2014-04-04)
[10] http://www.youtube.com/watch?v=e53UPiFDH0k (2014-04-04)

[11] See Wikipedia, http://de.wikipedia.org/wiki/Hackerspace#cite_note-1 (2014-04-04)
[12] http://bergie.iki.fi/blog/ingress-table/ (2014-04-14)

more widely acknowledged, several terms were used by people in different parts of the world or the field. This also means that a term other than "Maker Movement" could get more popular in the future, but understandably, we are unable to foresee it. Before we describe how the Maker Movement and its tools are influencing educational and learning environments, we would like to explore the history of this movement in education.

3. Roots and references of the development in education: Constructionism

The construction of knowledge using physical artefacts and the usage of technologies to invent or engineer is not new in education. In this section we trace the roots of the Maker Movement to other developments in the history of education (see figure 2). Reformist and progressive educators from the first half of the 20th century such as Maria Montessori, Friedrich Fröbel, Johann Heinrich Pestalozzi, Célestin Freinet and John Dewey promoted the usage of physical artefacts and tools in education. All of them viewed "the prospect of child development in the fact that he/she constructs knowledge by him/herself through physically manipulating his/her environment" (Schelhowe, 2013, p. 95). Montessori emphasized the use of all the senses in learning, while John Dewey was a strong proponent of learning by doing, who emphasized two-way learning interactions between learners and their environments, stating that learning should entail "participation in something inherently worthwhile" and a perception of the "relation of means to consequences" (1926, in Archambault, 1964, p. 150).

Building on Jean Piaget's view of learners constructing knowledge by interacting with their environment, Seymour Papert proposed constructionism or "learning-by-making" (Papert & Harel, 1991, p. 1) where learners would use tools to make things in order to construct knowledge. Providing the example of children creating soap sculptures in art class, that "allowed time to think, to dream, to gaze, to get a new idea and try it and drop it or persist, time to talk, to see other people's work and their reaction," (Papert & Harel, 1991, p. 1) Papert describes constructionism as a means to learn "in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe" (Papert & Harel, 1991, p. 1). According to Papert, Logo, a language he developed in 1960 enabled students to use "this high-tech and actively computational material as an expressive medium; the content came from their imaginations as freely as what the others expressed in soap" (Papert & Harel, p.2). Papert's seminal work "Mindstorms" that describes

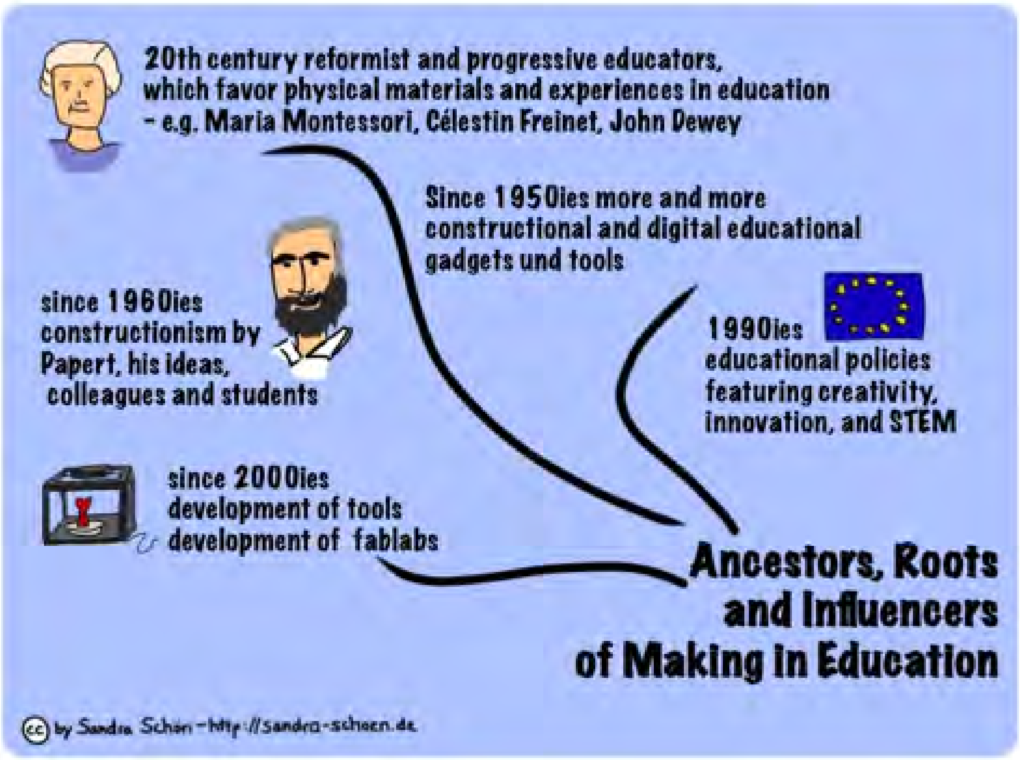

Figure 2: Ancestors, roots and influences of making in education

a microcosmos for children as a computer based learning environment (Papert, 1980) and innovative projects at MIT such as the Constructionist Learning Lab (Stager, 2006) have greatly influenced present learning environments for makers. Papert describes eight main ideas of his Constructionist Learning Lab as: “learning by doing”, “technology as building material”, “big idea is hard fun”, “learning to learn”, “taking time – the proper time for the job”, “you can’t get it right without getting it wrong”, “do not unto ourselves what we do unto our students”, and “we are entering a digital world where knowing about technologies is as important as reading and writing” (Martinez & Stager, 2013, p. 73f).

Interestingly, the idea of “engineering for children” was often focussed on boys in the 1940ies to 60ies, whereas the education focus of “making” for girls was on cooking, tinkering and household. Small wooden blocks are probably the first developed materials for children to build, construct and engineer a small new world. The development of small plastic blocks by the Swedish enterprise LEGO (1949/1958) are the modern popular plastic variant of such educational engineering materials. Probably the first construction kit for radio technology was offered in 1950 by KOSMOS. Other examples of development toys for children are the construction toy “Fischertechnik” available since 1965 that enables the building of small machines in children’s rooms or classrooms. Digital technologies have also played a role in educational toys for engineering since the introduction of the LEGO Mindstorms series at the end of the 1990ies. This construction kit allows children to built robots and machines with a programmable brick computer, sensors and motors. It is available since 1998 and builds on prototypes developed by the MIT Media Lab.

While several of educational tools were developed in conjunction with the educational theories discussed above, not all educational tools and learning spaces related to the Maker Movement might be directly derived from them. Besides the Maker Movement and constructionist traditions, technologies have been used as digital tools for creating or learning in several other settings that are influenced by other reasons, aims and theoretical backgrounds, which are too diverse to review in this article that is focused on the Maker Movement. For example, science fares are similar to maker faires, but focus on fostering interest in science and sciences activities. Another example are science museums or universities that have labs or workshops for children to arouse interest and provide interactions in science. Other activities, such as programming sessions for kids, aim to foster well-defined competences, for example software developing skills. Further reasons to use technologies and digital tools in learning are the development of media skills, communication skills, creativity and civic participation.

4. Exemplars of Educational Application from the Maker Movement

Within our paper we use the term “making” as related to new forms of relative simple ways to fabricate real or digital things with digital tools, including fabrication, physical computing and programming (see Martinez & Stager, 2013). Building on how “making” is a result of several developments and theories in the history of education, in this section we review some exemplary educational tools, learning spaces and educational settings that we consider representative of the Maker Movement. We start with short introductions to tools that are explicitly built

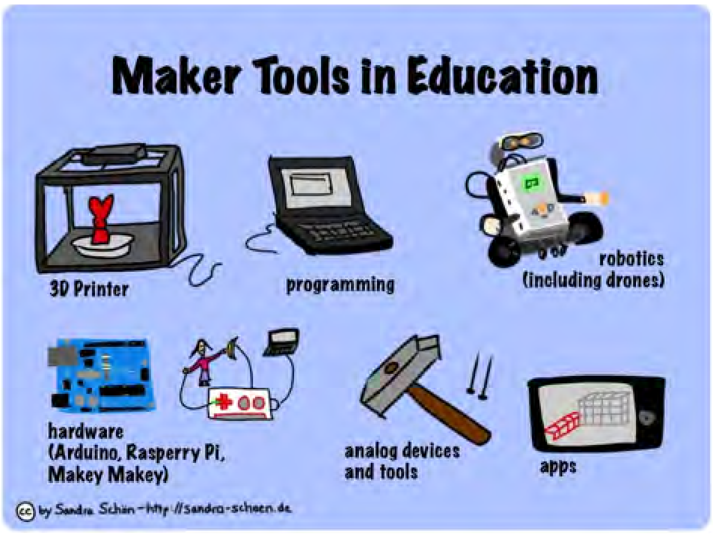

Figure 3: Digital Tools for Making in Education

to initiate and foster creative engineering and application in children and adults (see figure 3).

Physical Computing

Physical computing[13] encompasses several digital tools such as sensors or micro controllers that are used to control systems, regulate motors and other hardware or to make analog signals available for computer software. In recent years, the “MakeyMakey kit”[14] developed by students of the Media Lab

[13] See http://de.wikipedia.org/wiki/Physical_Computing (2014-04-04)
[14] http://www.makeymakey.com/ (2014-04-04)

at the MIT has gained a lot of attention. The kit was developed to create and invent new forms of inputs for a computer. The very simple usage makes it possible to use bananas as input keys of a laptop or putty as a joystick (at least as input device for the arrows). Additionally, Arduino[15] and Rasperry[16] Pi hardware kits are comparatively simple hardware devices that are programmable with relatively simple developer knowledge. "Lillypads" is a special hardware kit used for clothes, for example, it is now possible to design a dress that blinks according to the bass within a dance hall. Robotics kits such as Lego Mindstorms[17] that enable the creation of robots, which can perform different activities, also belong in this category.

Programming Tools

Several educational programming tools are available that have been specially developed for children. Etoys, directly influenced by constructionism and Logo, enables the programming of virtual entities and their behaviours. It was followed by the development of programming language Scratch[18], a multimedia authoring tool popular in educational settings for both children and adults, by the MIT Media Lab's Lifelong Kindergarten group. Over 400,000 Scratch projects have been created in the last decade and are shared in a Web-based community platform using a Creative Commons license that allows users to re-mix parts of projects to new products. A further example of an educational Java-based programming tool that enables community sharing is GreenFoot, which older students can use to build interactive games and simulations. As hackerspaces focus on software development and open source software, an open movement for coding by children has emerged, called „Coder Dojo" and driven by the idea „We want every child to have the opportunity to learn how to code which is why the movement is Open Source"[19].

Fabrication Tools

Although fabrication tools are used and adapted for educational settings, it appears that that special educational adaptations of these tools are not yet available. Special 3D printers for children as toys are currently a future vision that might be a possibility according to reports about a partnership of Hasbro and 3D systems[20]. Although it seems to be possible to construct a 3D printer with Lego Mindstorms[21], a special 3D printer for educational purposes is not yet available.

North American experiences with making with kids

Martinez and Stager offer four possibilities of using materials for making in educational settings: "1. Specific concept. Use the materials to teach a specific concept, such as gears, friction, or multiplication of fractions. 2. Thematic project. Visit a local factory, amusement park, airport, construction site, etc. and construct a model of it. Design a set for our medieval carnival. 3. Curricular theme. Identify a problem in Sub-Saharan Africa and build a machine to solve this problem. 4. Freestyle. The materials become part of your toolbox and may be used when you see it. This choice of media or medium requires student to develop technological fluency (p. 65)."

In the USA, makerspaces for kids exist in various learning environments, namely, in-school, after school, home-based, homeschooling and museum-based (Young Makers, 2012). An example of a makerspace within schools is the MENTOR program in 2012 that piloted ten low-cost makerspaces in California high schools. By 2016, MENTOR aims to have more than thousand makerspaces installed in high schools (Watters, 2012). A special makerspace for kids located in Toronto (CA) that is described by Jennifer Turliuk, Co-executive and "Chief Happiness Officer" as follows:

"The first element is a dedicated space where kids know that they can be safe, be creative, and have autonomy, and we've seen that they really take ownership and do things like tell other kids to clean up after themselves or to act more safely with tools, which I haven't seen elsewhere. Secondly, we have real tools — we give kids the ability to use soldering irons, saws, glue guns, things that are quite dangerous. If kids ask us if we can do something for them because they're too scared or they're not sure how, we generally say no and help them learn to do it safely and become more comfortable with it, or find another way to achieve their goals. Thirdly, process over product — we emphasize that it's okay to fail, and we value experiential learning (learning by doing), so instead of telling them step-by-step instructions, we advise them to try and figure out how to do it themselves, ask other kids, or research it online."[22]

[15] http://scratch.mit.edu/ (2014-04-04)
[16] http://www.raspberrypi.org/ (2014-04-04)
[17] http://www.lego.com/en-us/mindstorms/?domainredir=mindstorms.lego.com (2014-04-04)
[18] http://www.lego.com/en-us/mindstorms/?domainredir=mindstorms.lego.com (2014-04-04)
[19] from http://coderdojo.com/#zoom=3&lat=48.9225&lon=-35.15625&layers=00B0T (2014-04-04)
[20] http://www.theguardian.com/technology/2014/feb/17/hasbro-3d-printing-children-kids (2014-04-04)
[21] A tutorial: http://www.instructables.com/id/LEGO-bot-3d-printer/ (2014-04-0
[22] http://makezine.com/magazine/how-to-remake-the-world-by-making-with-kids/ (2014-04-04)

Developments specific to Europe

Two main forms of maker-like learning spaces and the usage of such tools in learning settings in Europe are workshops in and outside of schools. These workshops are driven by the need to foster STEM knowledge and skills at an early age. For several years now, workshops focusing on robotics, electronics or similar areas use technologies to increase interest and skills in technologies, development, and engineering. Typically, such workshops are offered as "research centers for pupils". For example, such workshops for children were held in Bremen in 2008[23]: "Sports and technologies" (for children between 9 and 13 years), "mobile robots" (for children from 11 to 15 years) and "humanoid robots" (for children between 13 and 17 years). Workshops for children (and adults) within the FabLabs and makerspaces in different parts of Europe, mentioned earlier in this paper, also serve as excellent learning spaces that focus on showcasing certain techniques and encouraging the creation of creative and innovative products. For example the Austrian FabLab "happylab" in Vienna offers special programs, workshops and times for children[24].

5. The Maker Movement and education – considering its educational potential

As a conclusion of our introduction of Maker Movement and its educational adaptations, we want to summarize reasons for its educational potential. While we acknowledge that there are other forms of learning activities and educational strategies that also include relevance to the environment, creativity, and problem-solving, such as problem-based learning or project-based learning, there are several reasons why we consider the Maker Movement to be a trend relevant to educators. There are potentially diverse approaches to structure reasons for making in education. We choose the traditional didactic triangle of teacher, student and content, which is in our case a set of tools for our following description (see figure 4).

[23] http://www.innovationscamp.de/workshops.php (2014-04-05)
[24] http://happylab.at (2014-04-05)

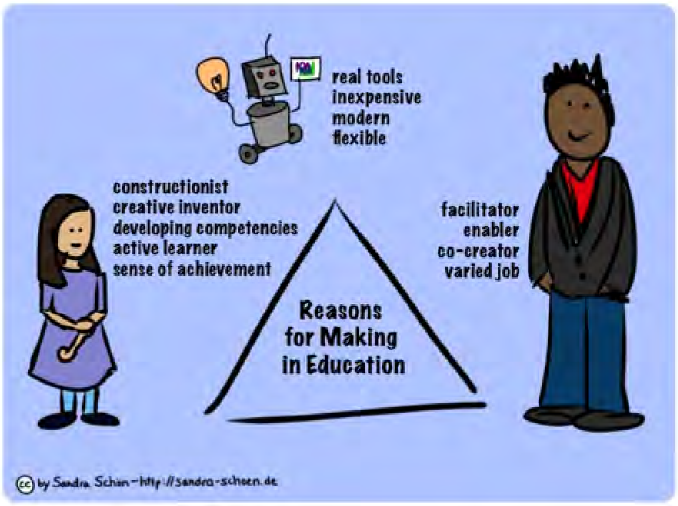

Figure 4: Reasons for Making in Education

Maker students

We start our collection of reasons for making in education with a look at the student. Children today grow up with digital technologies (Ebner et al., 2013). Using modern digital tools is in general a way to meet their expectations and prior knowledge. Educators can exploit this familiarity with technology, students' tendency to play with technology, and the easily availability of technology to help students create or construct products that relate to their environment. Especially maker tools and maker movement will challenge and develop their ability to construct something, and potentially to construct something new, creative and innovative. Making in education may address specific learning content, for example electronic circuits. Nevertheless, it can address a wide range of teaching goals for students. Besides STEM and technology interest, knowledge and competencies, this includes creative, innovation development, and problem solving. Maker students are active learners, with a high need to explore, to discuss and to share experiences and ideas. Also social and personal competences are to be included in our potential learning goals. In general, the skills of creating and innovating can have a broad impact on students' lifelong learning and ultimately for education and society.

Besides this, making as constructionist activity of students is a theoretically and historically funded principle for successful learning, coined as "learning by making (doing)" (see above; Papert & Harel, 1991). With respect to learning, it helps young and old experiment with innovation, develop an open mind, be creative, compute, and problem-solve, while considering the impact of their creations on society, ecology, and the environment.

The construction within making leads to several products and concrete results: Students fabricate "real things" (such as a machine) or products (such as a stop motion animation). Compared with typical learning results for students in form of ranked test results and marks, this can be seen as valuable source for senses of achievement. This can be important, but is not restricted to, school underachievers. And sense of achievement might be the best, when making comes up to solve problems of the real world, and/or when teachers and parents are surprised by students' ideas, solutions and constructions. Last, but not least, the openness of the maker movement and its Internet affinity additionally have the potential of idea sharing and co-operation in excess of classroom boarders.

Maker teachers

Looking at the teacher in a maker setting, it is obvious that traditional teacher-centred teaching does not fit. Typically, teachers in maker settings change their role to facilitators and enablers. Making means that students themselves are active. This automatically shift teachers' role from leading to support and tutoring. In contrast to problem solving and project tasks, where teachers are experts or at least the most experienced in the classroom, maker settings may also dangle such clear competence gaps. On the one side, students may be better or more experienced in one of diverse tools, for example the sewing machine or the mobile phone. But even more important, the openness of the setting and the creative results within this approach may lead to a situations, where the students may be better as the teachers. Co-creation, and also learning by teaching, than will not only be a (wished) mind-set, but teaching reality. This can be challenging as well as motivating and surprising for teachers. For students, it is the chance to see teachers as inspirational partners as well as models for their own learning, while watching their (better) learning and problem solving abilities.

Maker tools and content

As a third strand we want to discuss the role of maker tools and "maker content" for education. As described, these are digital tools and facilities to fabricate and produce new products and also art work. Inherent, the do-it-yourself approach includes up-cycling and other environment friendly materials. What maker tools and materials make special from the perspective of learning and instruction is that they are real content, compared with typical learning materials as textbooks, virtual learning environments, blackboard and so on. Maker tools are not only "theoretical" content as concrete, real action is needed to deal with them. Making deals also with theories and concepts, but more important is practice and transfer. As we mentioned in our paragraph about educational roots and ancestors, the character of maker tools and content and the related work with it has be seen as important for learning at least for several centuries of educational theorists and practice, if not for all human times. Making own experiences, making something concrete, dealing with concrete (but also "digital") products can be seen as an elementary learning with the potential of deep learning adventures.

Although learning and education is seen as important in current times, financing issues plays a big role. Of course it might sound expensive to equip a maker space in a school for example with 3D printer, laser cutter or vinyl plotter, and several other tools and materials. Nevertheless, the making approach is neither a 1:1 setting for high-end tools, nor is it focusing only at very special disciplines and ages. Compared with other approaches for learning with technologies, especially the 1:1 desktop setting in computer classes or personal textbooks in every discipline, maker tools are inexpensive. Maker tools are of great flexibility, as they can be used for a diverse set of disciplines, learning settings, focus and learners' ages. While making might involve the use of physical materials, it is increasingly also possible to produce virtual artefacts while "making", as mentioned above (e.g. with Greenfoot). Digital software for making is also not very expensive, is increasingly available as open source, and can often be used on mobile devices that are becoming more usable and more popular lately. Similar to other maker tools, such maker apps on mobile devices enable children of any age to create and make and are not specialised for special ages, settings and disciplines.

Not necessarily, but an important driver to use and deal with maker tools is simple that they are modern and up-to-date. There are so many tools and application scenarios that it is simple to realise ideas that were not thinkable some years ago. This is attractive for students and makes it magic for educators: Maker tools bring the possibilities to use up-to-date technologies and innovative learning settings in classrooms. Compared with the effort to offer up-to-date learning software and hardware for computer and Internet based learning for a whole school, the usage of latest tools and developments know gets realistic.

From our perspective, these are several reasons why educators and policy makers should consider the Maker Movement and its potential in education. Of course, making in education has not only potentials, but also challenges. Inherently, several challenges might influences our sketched potentials negatively. Papert and Harel (1991) for example see a challenge in the prevalence of "instructionism" in mainstream education: The need of teachers to feel to be in control of learning environments and to lecture students, is opposed to students being able to experiment and create to learn. Besides such challenges, our list of reasons to consider making as a new form of learning and teaching for education hopefully inspires to take a deeper look into the field.

6. Learning from Experience: Further Resources about the Maker Movement

We would like to end this article with further resources for readers who might want to read more about the present the state of the art of literature, research and further education with respect to the Maker Movement.

There are a lot of collections for maker educators that concentrate on new tools and gizmos as well as potential products or exemplary developments. Wilkinson and Petrich (2014)'s book "The Art of Tinkering" presents the products and projects of more than 150 makers "working at the intersection of art, science and technology" These include example recipes for conductive dough or how to fuse plastic for up-cycling. The book's cover itself is printed with a special ink that conducts electricity ("open up this book and discover how to hack it").

The amount of research on selected maker issues, for example tinkering with computers, robotics in schools or programming with pupils is enormous. Selected books that make an initial contribution to the role played by "making" in education are:

- An open access book, "The Maker Club Playbook" is offered by Young Makers (2012). It is for everybody who wants to open a makerspace and includes several examples for education settings and approaches. Also for practitioners and free available is the "Makerspace Playbook" by Makerspace / Maker Media (2013). The PDF includes helpful lists from tools to funding ideas. A good help to design maker programs as activities for children, including also for example maker faires for kids, is offered with open access by New York Hall of Science (2013).
- Martinez and Stager (2013) 's "Invent to Learn" about "making, tinkering and engineering in the classroom" is meant for educators and gives insights into learning concepts, examples and the practice of making in schools. They describe the development of makerspaces in schools and also a didactical framework for its usage in the classroom.
- Honey and Kanter (2013)'s "Design. Make. Play. Growing the next generation of STEM innovators". is meant for practitioners, policymakers, researchers and program developers and is a collection of several chapters on making, but only on games, which potentially influence and foster the STEM competences of children.
- Diverse digital tools for education are also topic of a chapter within the German speaking L3T textbook that is available as open educational resource (Zorn et al., 2013).

European educators had already started to adopt, to adapt and to share their experiences. From our point of view, especially community building and research above the diverse strands of maker activities – for example of FabLabs, hackerspaces, or coder dojos – should brought together. As our research, especially in German speaking countries pointed out, terms and ideas of several shops and communities may potential (and actual) maker activities for children. We would love to inspire you, besides reading and discussing, and to initiate you to be an active part of the maker movement for educational purposes. Just make it!

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