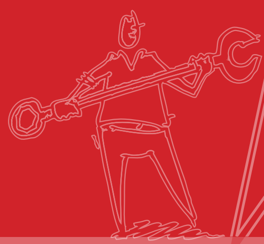
PLATFORM
MAKER EDUCATION



Maker Education
Theory and Practice in the Netherlands

White paper for
Platform Maker Education Netherlands

Maker Education
– Theory and Practice in the Netherlands

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Introduction

Maker education is a new educational movement that sees potential in the process of ‘making’ at school. Maker education hopes to achieve the development of ‘maker-skills’ such as developing creativity, imagination, engineering and problem solving trough making in school (Meij, 2014; WaagSociety, Petitie: maken moet weer terug in het onderwijs, 2014). The Dutch Platform Maker Education is a platform where Maker educators, people interested in Maker education and Makers themselves meet. The community shares ideas, and curriculum examples trough the digital platform as well as events organised by themselves (MakerEducation, 2016). Platform Maker Education has a strong belief that Maker education can help school children to gain 21st century skills (future oriented skills) and become more self-directed and confident citizens, prepared for our fast and rapid changing society.

The goal of this report is:
* to connect existing international research about Maker education to Dutch maker education in practice,
* to gain insight in how the creative make and learn processes of Maker education in the Netherlands are set-up
* to find out how the interest of students in technology is stimulated and what the role of using new technologies is.

For the writing of this report several Maker education experts with different backgrounds have been consulted. The experts participated by joining events organized by Platform Maker Education. Three evenings were organized by Platform Maker education to share knowledge and to be able to experience making in 2016. The topics were: Low-tech, Digital Fabrication and Programming. The evenings were held on different locations throughout the Netherlands and attracted people from different areas and provinces.

Furthermore, four Dutch (two primary and two secondary) schools have participated in observation sessions. Tow observations of 120 minutes each have been executed with 67 Dutch students in total in two secondary schools. Furthermore, 7 Maker Education (ME)-lessons have been executed with seven classes and approximately 175 students in total, this has been evaluated with six involved teachers on a primary school during an interview of 90 minutes. Additionally, two interviews of 30 minutes were executed with two teachers of primary education to evaluate two ME lessons that were given to 61 students.

In addition to this, this report presents a literature study on the origin of Maker education and shows connections with other learning approaches or theories. A model based on the input of several Maker educators and experts is presented as a method to compare theory to practice. The observations and interviews on four schools are embedded to verify elements of the model or pinpoint friction between theory, the vision of Platform maker education, and the practice of Maker education in current Dutch education situations. Finally, insights are presented on how the learning and the process of Dutch Maker education is set-up, what the trigger of making is and how technology plays a role in this process.

Moving the maker movement towards Maker Education

Maker education is inspired by the maker movement in America (WaagSociety, Platform Maker Education, 2015). The Maker movement has been growing fast since the launch of ''Make magazine'' in 2005 and can be defined as follows:

> *''The maker movement, as we know, is the umbrella term for independent inventors, designers and tinkerers. A convergence of computer hackers and traditional artisans, the niche is established enough to have its own magazine, Make, as well as hands-on Maker Faires that are catnip for DIYers who used to toil in solitude. Makers . . . combine with open-source learning, contemporary design and powerful personal technology like 3-D printers. The creations, born in cluttered local workshops and bedroom offices, stir the imaginations of consumers numbed by generic, mass-produced, made-in–China merchandise.'' - (Voight, 2014)*

There are many different terms often associated with the maker movement, including ''Hackerspaces'', ''Fab Labs'', "Tinkering space", "Maker Lab" or "Workshop". For example, the number of registered Hackerspaces is over 2000 spaces around the globe (Wiki, List of Hacker Spaces, 2014). Davee et al. reported 41 different descriptions and names that indicate a location or activity for making. These activities or locations both focus on a form of making that include digital technology, digital fabrication and prototyping tools (Davee, Regalla, & Chang, 2015). There are many spaces, tools, demographics and types of places that encourage, guide and promote making. 'Makerspaces' can be seen as a more general and inclusive term for these. The current trend is to bring making into education, to stimulate learning trough making. The international Maker Education Initiative empowers communities to transform their education systems by integrating making into all facets of their work (MakerEd, 2016). The international Maker Education Initiative, situated in America was founded in 2012 and has the mission to create 'more opportunities for all young people to develop confidence, creativity, and interest in science, technology, engineering, math, art, and learning as a whole through making' (MakerEd, 2016).
Making activities are also growing under the name of the Fabfoundation, an international non-profit organization formed in 2009 to facilitate and support the growth of the international FabLab network (Fabfoundation, 2016).

The grassroots Fablab Education community presented on the grassroots knowledge sharing conference Fabuse the outcome of collaboration. A collaboration between Fablab Groningen, Maakschappij, Cabfablab Den Haag, Fablab Zuid Limburg, Kiz Zwolle, Fablab Truck Amsterdam, Protospace Utrecht and FablabAmersfoort. The main question they asked themselves was how to bridge the gap between Fab Labs and education. This initiative is continued by the Fablab at de Waag in Amsterdam and Fablabbenelux, Rotslab, Frysklab and de Populier, who wrote a manifest on behalf of 34 supporters. The manifest was signed online by 330 people and presented as a petition to the Dutch chamber committee on the 4th of November 2014 (WaagSociety, Petitie: maken moet weer terug in het onderwijs, 2014).

Inspired by Maker Education Initiative, the Fabfoundation and the related Fablab events (a Dutch collaborative for making) was set-up. The foundation of Platform Maker Education started on 11 February 2016, with the launch of an online platform (WaagSociety, 2015), set up by inspired 'maker supporters' from the Waag Society, secondary school 'de Populier' and the Frysklab. A lot of schools (students and teachers) participated in different workshops (on digital fabrication and open design) at different Fablabs. During this time some Fablabs changed their names to 'Maker space' and new people and organisations started their own Maker Spaces. With the start of Platform Maker Education a voucher system was introduced which supported 51 Dutch schools in implementing maker activities (MakerEducation, 2016). The vouchers were mostly set-up as workshops, given to teachers (40%) and students (60%). Locations were situated in nine different provinces of the Netherlands, 50% of the schools were primary education, 45% secondary education and 5% was MBO.

At present, the amount of registered Hackerspaces in the Netherlands is 25 (Wiki, Netherlands, 2014), the amount of Fablabs in BeneLux is 61 (FabLabBenelux, 2016) at which diverse educational activities are provided. They also participate or inspire others to participate in Maker events/festivals and Maker activities at schools.

Learning & Making

Learning by doing has played an important role in society since the Middle Ages, where people learned practices, skills and crafts by doing. Like for example, the apprentices of guild masters, who learned by working for a guild master.

Although making and doing has never fully vanished from education, the focus in secondary education in the Netherlands has been mostly on theoretical learning goals as can be seen in learning goals defined by the (Dutch) government (SLO, 2006). However, society is changing and there is a growing need for employees with so-called ‘21st century skills’ (SLO, 2014). With the most recent revision of the Dutch learning goals in 2007 and the current technological advancements of computer technology/rapid manufacturing, learning by making in classrooms is on the rise, often with the goal to stimulate 21st century skills. Twenty-first century skills are domain-crossing skills and competencies such as creativity, the ability to research, innovative thinking (entrepreneurship), critical thinking, problem solving, communication, creativity and reflection (SLO, 2014). The Waag Society highlights creativity as an important principle in Maker education, next to collaborative problem solving skills, innovative thinking and digital literacy. The Waag Society believes that the physical creation of artefacts enables students to explore, to develop and experience their talents in broad sense (WaagSociety, 2014).
In 2016 “platform education 2032” (an independent think-tank which directed a national brainstorm with educational, business and science experts) published advice for OCW (Dutch ministry for Education, Culture and Education) that suggests that education needs to be more future-oriented and focus on skills such as personal development, knowledge acquisition and social development (Onderwijs2032, 2016).

Theories about Learning

Some of the most commonly known theories about learning are behaviourism, cognitive and social constructivism, and connectivism (Huitt, 2013). Behaviourism is a movement that states learning can be observed and shaped by analysing and reinforcing behaviour (Skinner, 1976). With behaviourist teaching and learning, the correct behaviour is often reinforced trough repetition and by providing feedback. In cognitive constructivism (e.g. work by Bruner and Piaget) learning is the result of the construction of meaning by the individual learner. In constructivism, the learner takes an active role in constructing his own understanding. The learner applies self–regulation and builds conceptual structures through reflection and abstraction. In social constructivism learning is assumed to also be a result of influences of the social environment on thinking. For example, in the work by Vygotsky, it is assumed that people learn through help by others.

The theory of constructionism is a way of learning described by Seymourt Paper (Papert, 1991). In his work Papert describes the learning theory as actively ‘’building knowledge structures” and learning to learn. Furthermore, he puts more emphasis on the importance of learning through making (Ackerman, 2001). Maker education is relatively new and can be seen as a form of constructionism (Katterfeldt, 2015).

‘’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.’’ – Seymour Papert 2008

While Papert argues constructionism isn't just ''learning by making'', Maker education as a way to learn seems closely connected to constructionism. This is confirmed by Katterfield and her team who regard ''make results'' as ''external representations of mental concepts'' - (Katterfeldt, 2015), describing a link between making and constructing knowledge structures.

Approach to learning

The following educational approaches have similar characteristics as constructionist learning theory: *Design based learning, Inquiry/Problem based learning and Experiential learning.*
Design based learning and inquiry/problem based learning received a large amount of attention and originated in relatively the same time span, being 1960-1980, while Maker education originated in the beginning of the 20th century. One way to describe **experiential learning** is that the learner discovers and experiments with knowledge first-hand, instead of relying on experience of someone else. Learning can occur by engaging in doing or making, but also by observing (Kolb, 2014).
Problem/inquiry based learning builds on experimental learning and introduces questions and problems as learning initiator (Savery, 1995). Problem based learning is more structured and often used in higher (medical) education. Learners work together in teams to solve problems closely related to course material.
Design based learning (DBL) adds a ''design process'' and ''designing phase'' to problem based learning, in which students design solutions or artefacts for problems or opportunities concerning a target group ((Kolodner, 2003); (Scheltenaar, van der Poel, & Bekker, 2015)) . DBL combines a wide range of characteristics such as a design process, collaboration and reflections, assessment, project characteristics, descriptions of teacher and child roles & learning environment (described in the Reflective Design-Based Learning framework (M. Bekker et al., 2015)).

Maker education has different possible manifestations, some borrowing more from experiential learning, some more from problem- or design-based learning. An important element in Maker education is the high emphasis on making of physical artefacts, often assisted by digital fabrication. Digital fabrication is an umbrella term for rapid fabrication technologies that are used with computer-aided design software suites. As opposed to design based learning, making is not always necessarily focused on a problem or user group, it can start from personal motivation, fascination and personal interest.
These forms of experiential learning are based on learning through experiencing and doing. According to Hummels et al. (2008) reflection is an important aspect of a creative process that students need to incorporate in a learning process. Therefore, it is important to have a balance between thinking and doing to stimulate learning (Stables & Kimbell, 2007). This thinking, or even better, reflecting can take on different forms, reflection-in-action and reflection-on-action. Reflection-in-action can be described as a '*conversation'* between the designer and the construction materials while making, in which the creator makes and reflects almost simultaneously. Reflection-on-action is a learning mechanism where the creator is reviewing what s/he has done, after the phase of the actual making and or manipulating the materials at that moment (Schön, 1983).

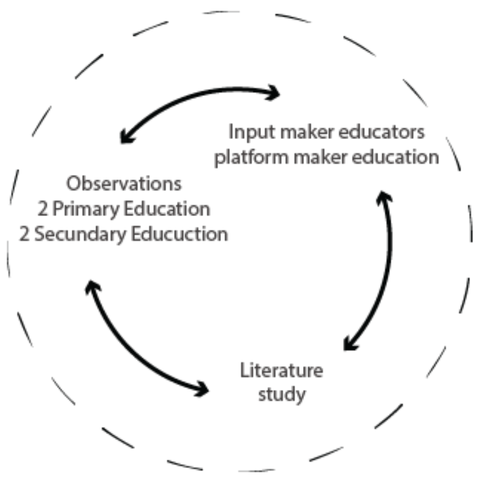
Martinez et al. describe in 'Invent to learn'; a learning model for designing and making; Think; Make and Improve (Martinez, 2013). Thinking may include activities like: brainstorming; predicting; gathering materials; setting goals; sketching; deciding whom to work with; researching; planning. The most action occurs in the 'Make' part of the process, in which students may: play; build; tinker; create; program; experiment; (de)construct; observe others; share and borrow code; document their process; ask questions and repair their creation. At some point in the process, the maker (or the team of makers) might get stuck and be willing to improve their creation. 'Improving' may include activities like; conduct research; talk it out; discuss with peers; use different materials and play with it. Improving is essential when learning. Papert mentions in relation to constructionist theory that making and iterating to make things better, leads to understanding (Martinez, 2013). To actually learn and understand, a balance between thinking, making and improving reinforced by reflecting (in and on action) is required.
Students learn through making, experiencing and applying construction materials and fabrication tools during an iterative make process. Mitchell Resnick, discussing his work on construction kits, explains that construction kits are systems that engage kids in designing and creating things. Construction kits have the potential to be easy to start with (low floor), while still having the ability to reach an expert level (high ceiling) and can be general enough so that they can be used for multiple projects (wide walls) (Resnick, 2005).'

Differentiating
One could say the four educational methods/learning mechanisms are related but still have their own unique characteristics. Experiential learning being very broad, inquiry/problem based learning being structured and focused on solving problems, design based learning adding creativity and empathy into the learning process. Maker education introduces the restriction of making something physical using technology while stimulating projects that emerge from personal interests.

> *"Bringing the maker movement into the education conversation has the potential to transform how we understand 'what counts' as learning, as a learner, and as a learning environment. An expanded sense of what counts may legitimate a broader range of identities, practices, and environments—a bold step toward equity in education" (Halverson and Sheridan - 2014).*

Maker Education has potential, because it connects to different perspectives on learning. In *Invent to Learn*, Martinez and Stager highlight the importance of making within the next generation of Science Standards. Especially in the field of child centred approaches and "real engineering that is playful and creative." With the aim to honour the imaginary world of children (Martinez, 2013).
In addition to this, the physical aspect of making has some notable advantages regarding learning as research shows children learn better while playing and exploring in the physical world (Piaget, 1953). We do not only learn using our eyes and ears, using our other senses like touch, taste and smell as well during learning assumingly reinforces the learning effect (Shams, 2008). Furthermore, ''tangible learning'' makes children less likely to consider something as a traditional learning tool, increasing their engagement (Terrenghi, 2006).

Maker Education in the Netherlands
From theory to practice
Method
As Maker education is a loose educational format, it can have a multitude of different forms. To find out how maker education in (Dutch) practice looks and connects to the theory about learning & making two different approaches were taken.
Firstly, Maker education lessons at four different schools in total were observed or evaluated. Two primary education, two concerning secondary education, doing both general and specific observations. Secondly two meetings were attended of the Platform Maker education'' in the Netherlands. Input was gathered to conceptualise and discuss the model: **'describing the maker education values'**.



Platform Maker Education

Differences between the vision of Platform Maker education and practice have been presented in a plenary session at the final Maker Education Platform evening in Eindhoven. The reaction of Maker educators at Platform ME, our analysis of the observations and the connection of (new) literature helped us formulate opportunities and changes for Maker Education in the future.

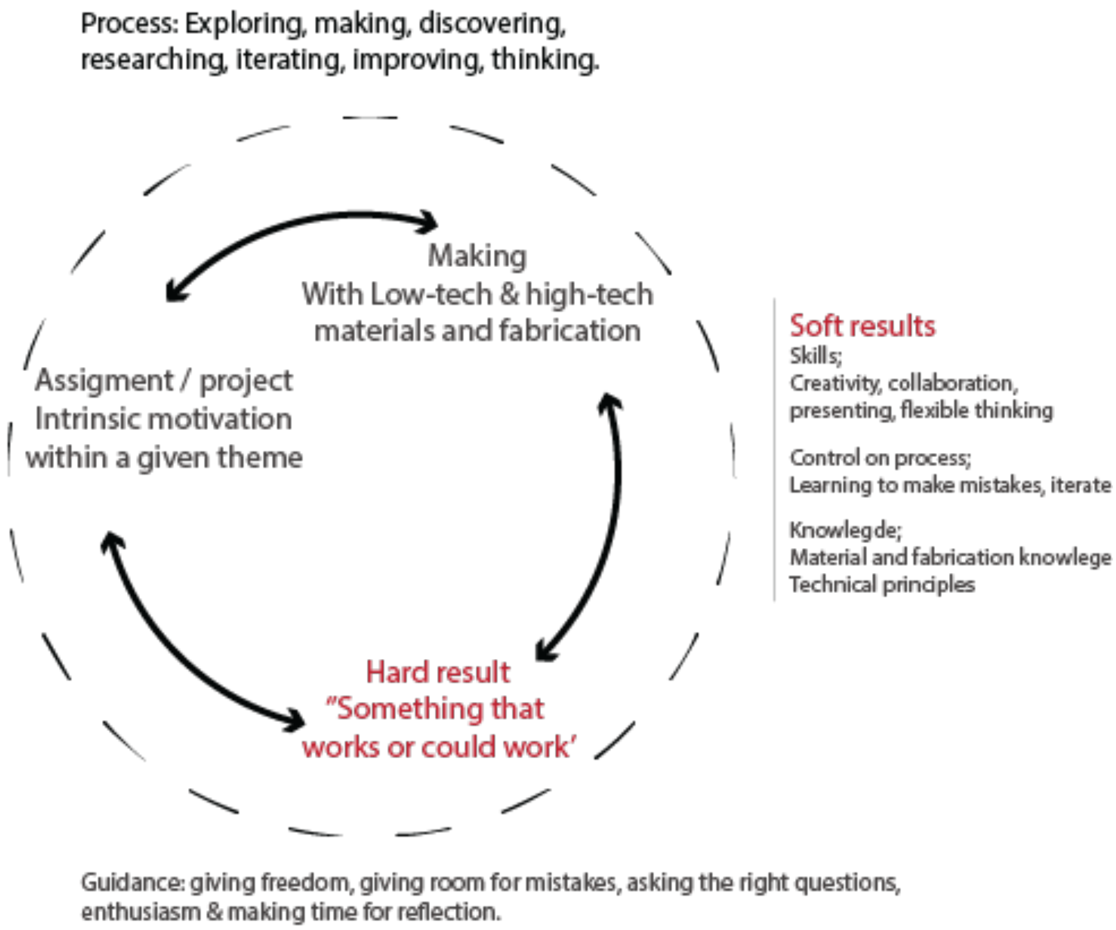
Observations, ME in (Dutch) practice

Observations and interviews with teachers have been conducted to map Maker education lessens in the Netherlands (two secondary schools and two primary schools). Observation points and interview questions have been formulated into a format beforehand, using literature review outcome and the created model of Dutch Maker education. The Maker education model was included in the observations in order to pinpoint friction between vision and practice, to crystalize unclear statements and to verify statements of the ME-model ('**describing the MEvalues**').
The detailed description of the four contexts that were observed and interviewed can be found in Appendix A.

Results

By combining the data gathered from the observations and the plenary discussions with Platform Maker education we distilled a model that describes Maker education in Dutch context.
Briefly put, a Maker Education lesson / activity starts with a ***project description / assignment***; through the assignment (open for their personal interpretation / to personally connect to) students will go through an iterative ***Maker process guided by maker educators***. The results of a Maker lesson can be divided in ***hard and soft results***; a hard result is the actual and tangible product or prototype; soft results are skills or knowledge that can be developed though its integration in a Maker education lesson.

Model



The elements of the model will be explained more elaborately in the next paragraphs; we also emphasize the insights of our observations at the Dutch schools to highlight a connection or show friction between the vision on ME and the practice of ME. In addition to this, some of the insights are illustrated with quotes from the participants in the research activities.

Maker education Project / assignment

Vision of Platform Maker education

At Platform Maker education different opinions were shared on how a Maker Education lessons starts or should start. Some Maker educators proclaimed that a lessons should start from students themselves, seeing, touching and imagining the possibilities you can do with the provided (digital) materials and to find a direction by experiencing, doing and exploring different things. Others explained their positive experience with a ''real world'' case provided by a company that enhanced great engagement and motivation of the students.

'When the assignment is 'real' from somebody outside school or a company, students tend to dare more.'
'Intrinsic motivation is important, the freedom to make something your own'
'It makes a difference how you structure your lesson, start with brainstorm to let children make it their own.'

Observations in practice

The observations at the Dutch secondary schools showed that students started from a formulated design brief. For example, 'hack your own school' and 'make a redesign of the Dom-toren' (see Appendix A for Maker education examples in Dutch practice). Interestingly, both assignments started to make sense to the students when they could find and formulate their own idea and direction within the given assignment.

In primary education, we saw some differences concerning the themes that were addressed. The themes that inspired students included more abstract challenges, for example themes about the concept 'light' or 'mobility'. The students explored these themes more into depth by actually making and experimenting after they created ideas during a brainstorm. They accidentally discovered new things by experiencing that some things did not work with the provided materials. The trigger for making seemed to be their formulation and idea generation for a problem, which was inspired by the provided theme the students are guided and triggered to find and think of a solution for their created problem. A few kids, though, have no ideas until they can play hands on with different materials. They get inspired by materials, forms, shapes, colours, digital and interactive aspects and working principles. Only afterwards they start thinking about what they can do with it.

Maker education process and guidance

Vision of Platform Maker education

The process of a ME-lesson is open, students iteratively go through different stages of; exploring, experiencing, sensing (sensing & making sense) researching and iterating, all done while making prototypes and products.

ME educators/teachers play an important role within this process, they trigger students with their attitude, their ability to give students enough room for personal interpretation and exploration and by asking the right questions to help students determine their next steps independently. They have to hand out the right materials & tools, but let students make their own mistakes too. Not all the knowledge has to be there, but enough needs to be present to get started. Many teachers at Platform Maker education however experienced the struggle of managing the process and incorporating improvements based on previous feedback due to time constrains at school.

'Give students freedom, dare to let them go on their own'
'Learning how to make mistakes is essential'
'Asking the right questions'

'I cannot support the learning process of students thoroughly, because I cannot guide all students at the same time while being in charge of the laser cutter. It is hard to monitor what they have learned and how they can improve this during the process.'

Observations in practice

The observed teachers in secondary education gave freedom to the students; sometimes only basic information was given at the start of a Maker education lesson. Another observation showed that some process steps were provided before each lesson. Teachers asked students questions to enable students to find a possible process step, which was mostly done before the start of the Maker education lesson. We experienced similarities in primary education, where teachers stimulated students to find the answers to questions themselves by stimulating them to figure out how the answers could be found. However, the process of generating ideas and exploring the context is more guided: a worksheet gives structure in directing some fundamental process and thinking steps.
Sometimes time was missing to discuss all the work of the students. This meant that there was often little time for improvements based on feedback and reflection. In one particular lesson, students were heading towards the end of the project and were working towards their presentations. However, when looking at the student's mind-maps and sketches, there were clear differences compared to previous concepts and the final end result. This seemed to show students worked iteratively. Analysing the sketchbooks confirmed that students repetitively went through process steps; they adjusted their design and enriched it based on feedback. Most students were aware of what they had done, could explain and show which steps they had made. During one observation students seemed to be proud of their design. Another observation showed the contradictory, students seemed to be insecure about their work and were afraid to make mistakes.

Maker education hard result

Vision of Platform Maker education

The Makers of Platform Maker education state that the result of a Maker Education lesson always ends in something what works or could work. From their viewpoint, exploring through making is different from exploring through for example a practicum. Students learn to understand the world and develop certain skills and knowledge to execute practicums. Making is creating something from your own identity, with your own hands and placing it in the physical world.

'Making something that works or could work'

'Maker Education enhances placing something in the world, with your own hands, something that works'.

Observations in practice

Observations in practise revealed Maker education lessons do not always end in something that works or could work. However, we saw that students did find it important not to end with empty hands, both in secondary and in primary education. In most lessons students get graded regarding their process and their results. They tended to make something tangible in order to be able to present something at the end of a project, whether this might be a sketch, a visualization of the product or prototype (explorations). Students also experienced that they had to adjust the initial ideas they sketched because the provided materials could not offer the right functionalities to build a construction, design or a technical circuit. Materials seem to inspire students to make things from their own imagination, to try different things than the students had in mind before and by accident materials help them make new and creative prototypes.

Students working with 'real material' seem to be working more 'lively, active and engaged' on their projects, their whole body and mind seems to be more actively engaged during learning.

Making with high-tech and low-tech materials

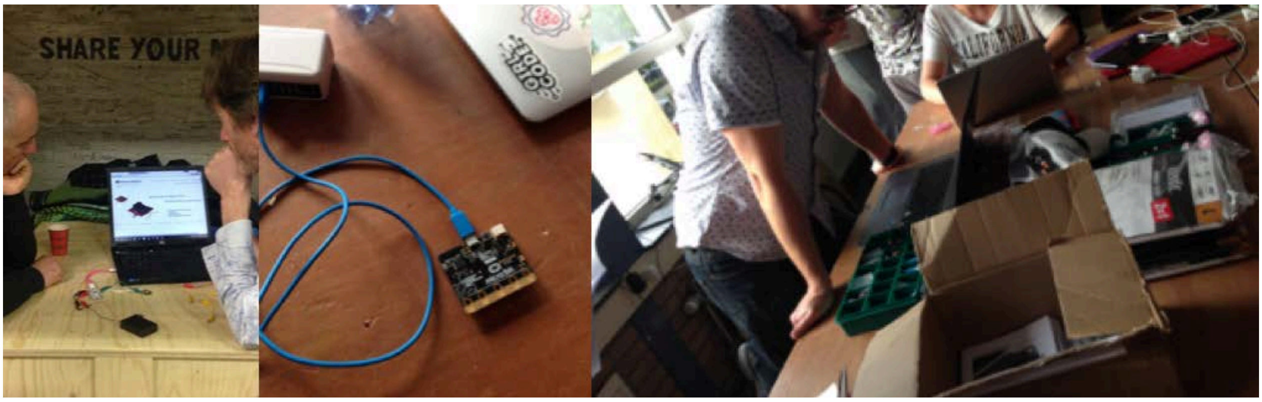
Vision of Platform Maker education

During the different Platform evenings, there was a discussion concerning the role of using of technology in Maker Education. Teachers seem to highly value teaching students about new technology. New technologies and work of students is shared during the meetings of Platform Maker education (see images).

The question of Platform ME concerning the role of programming in ME was difficult to answer. It seemed that programming itself is not a learning goal but can be easily integrated in Maker education. The focus was more on the process of making and technology served as a supportive attribute in learning. This would lead to the focus of technology in Maker education not on programming but on teaching digital literacy and computational thinking.

Teachers explained that they are looking for a balance between Maker education project and course-based goals. Understanding the law of Ohm for example is something different then trying different resistors when soldering an electronic circuit. Especially interesting about making is that it seems easier for students to connect what they learn to practice. By making something students find out if they miss certain knowledge. If this is the case they need to do research and are more open to learn for example about the law of Ohm. This is different from gathering knowledge without a clear feeling of relevance. Maker education teachers have the idea that by making student will remember better, have a richer learning experience (working together, being creative, generate concepts and constructing). Less positive is that Maker educations teachers regard it difficult to verify what is learned and that the learning process takes more time. Although not entirely in fashion of Maker education, some teachers saw more potential in simply illustrating a concept with a prototype using some technology.

Sharing digital technologies for making in the classroom like papercutting, sewing with conductive thread, paper electronics using copper tape, LED's and batteries & digital pattern design.



Sharing digital technologies like Arduino Lillypads for making wearable's, looking for educational options with the new Microbit (microcomputers given to British schoolchildren) and Makers showing their self-made 'easy to program with electronic kits' they teach digital literacy with at schools.

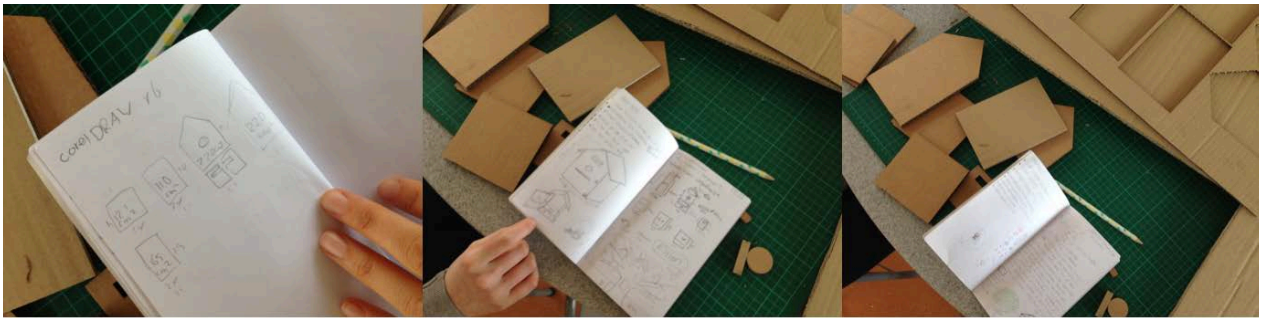
Observations in practice

A diversity of materials and tools were used during the observed ME lessons; **digital oriented materials and tools** like computers for word-press blogs, programming in notepad, thinkercad for 3D drawing, 3D printers, a lasercutter, LittleBits., LED's, batteries, motors and propellers. In addition to this more **construction oriented materials** such as plywood, cardboard and recycled packaging were also used. Primary schools also used 'Techniek Torens' (a collection of different materials to explore technical and physical principles (CreativeKidsConcepts, 2015)). and for the youngest plastic and wooden building blocks. Other digital tools were also available and present for different ME lessons such as Makey Makey, digital cameras, iPads, Lego-Mindstorm/robotics and Scratch software. During primary educations lessons, students worked more with modular and tangible building blocks. They could select electronic parts like motors, batteries and LittleBits and combine these with cardboard and recycled materials. Students learned about electricity (how it can turn on a LED or motor) and constructing prototypes.

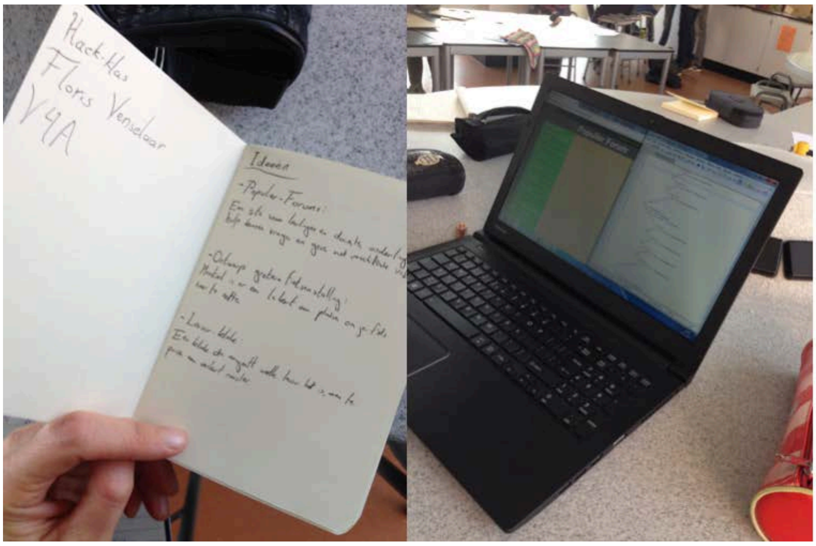
Combining batteries, LED’s and building blocks / construction kits exploring light

Combining electronic parts and recycled materials to make light and mobility designs

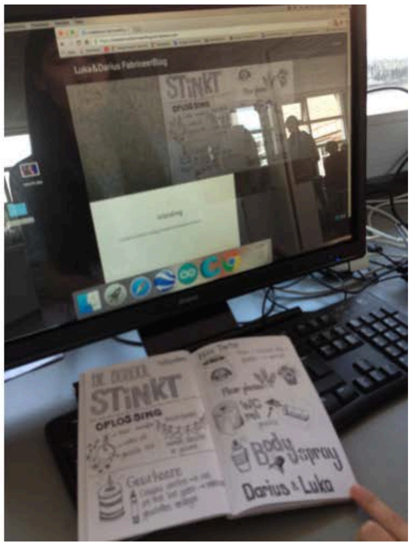
During secondary education classes, students had the freedom to choose between different materials to start making; most of the MBO students choose to work in the software program Tinkercad (on which they had have classes the year before) a few groups choose cardboard and paint, and only one group choose Lego Mindstorms. There were a few students who wanted to incorporate more electronics in their cardboard design but they did not know how and they seemed to be buzzier keeping the group working together then enabling themselves to make their design more complex. In the VWO class students choose more diverse materials and tools for their prototypes; laser cutters with wood or cardboard, programming, cardboard and paint, WordPress and paper and pencils. Students seemed to be eager to make stuff with programs they have never seen or used before, like for example making a Wordpress blog, they made and learned in one lesson to build such blog. Students applied their knowledge while making their ideas, for example using the laser cutter in a very structured way by measuring and making detailed notes to cut the materials in the right size.



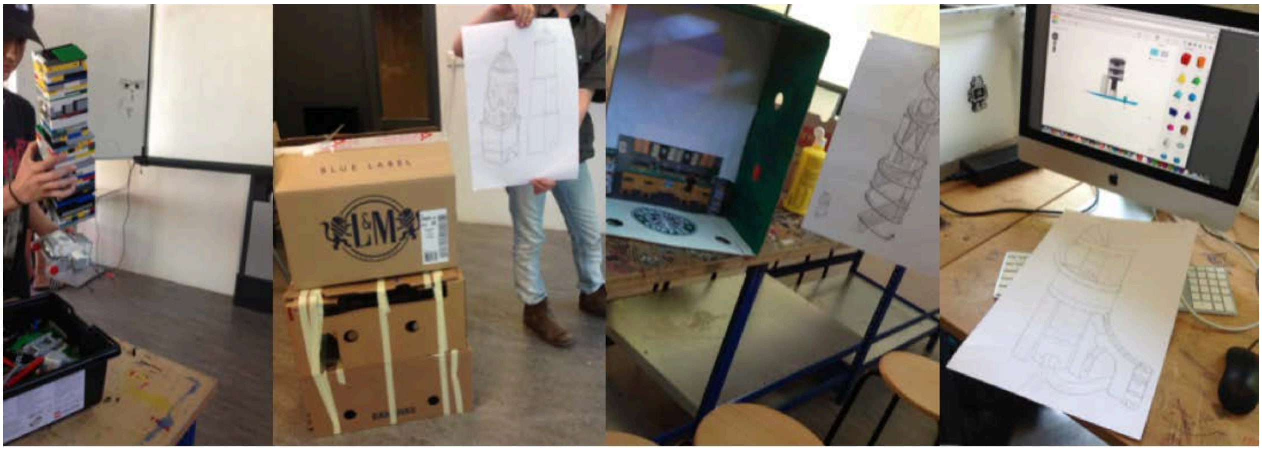
In search for a concept this student made an idea box measuring everything for the laser cutter to fit together nice and tight



Programming a forum to teach and learn from peers



Weblog for bringing across the concept of different designs on smells at school



Freedom to choose their own material (Lego, raw cardboard, painted cardboard, 3D drawing) but the end result had to be handed in digital (movie, animation or photo)

Maker education Soft Result

Vision of Platform Maker education

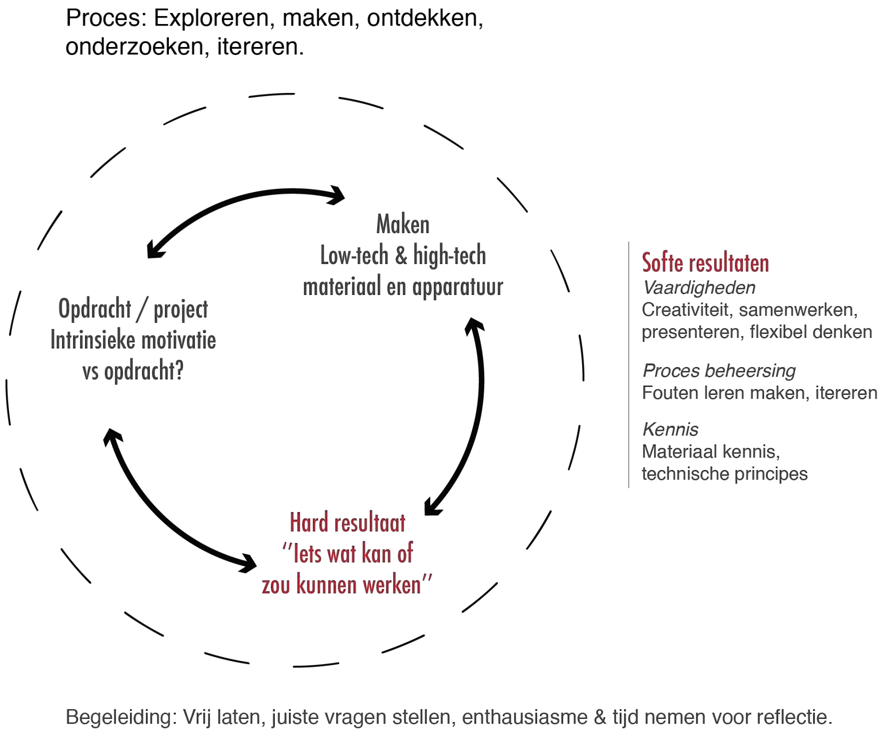
The Makers see a clear potential in what Making can offer; a lot of skills are used and stimulated, intertwined within the making process. You can develop specific skills, knowledge and experience about the process of making and knowledge about the materials you are working with. Skills may vary from presenting, collaborating, creativity and a flexible mind-set. Through reflecting on the process while making and after making, students get aware on how they manage the process and what they learn. The Maker educators at Platform Maker education concluded students and teachers still need some improvements on how to incorporate reflection into the process, as it must not take over the actual making.

'Maker Education changes the vision on learning, it's value lies in: giving lessons by open assignments, collaborating and creativity'

'Traditional education is really directed, ME offers students the development of other skills.'

Observations in practice
In practice, softs results seem to be present in Maker education lessons. Students integrate their own creativity and imagination in their maker education lessons. It seems that their trust (stimulated by teachers to learn from making mistakes) enables them to be flexible throughout the process, making iterations due to this developed flexible mind-set, asking questions and taking initiative.
One teacher emphasized during an interview the importance of creating space for students to make mistakes. The teacher felt students learn the most from their own mistakes. Trough Maker education they will also learn that making mistakes is part of the process and they do not need to restrict themselves. They will discover their talents, know what they are doing and get confident in managing their processes. When students can explain why something failed and can reflect well, they learn and gain control over their processes.

Discussion and conclusion: the potential of maker education, challenges & opportunities



In this report, we describe the creative 'make-and-learn' processes of Maker education in the Netherlands and describe how the interest of students in technology is stimulated and what the role of using new technologies is.

A literature study on different learning mechanisms and how they connect to Maker education helped us define the background and form of Maker education. We developed a model that explains the values of the Platform (ME) on Maker education. The model has been set-up through interactive and plenary research sessions with leading Maker educators of Platform Maker education. The research sessions were deliberately fed by questions originating from our literature study. The elements of the model have been examined in practice.

Maker Education in the Netherlands

In 2005 the Maker Movement started to grow in America, this movement focused on promoting and stimulating youngsters to start making and exploring (digital) materials (MakerEd, 2016). The Maker Education Initiative and the Fablab foundation are both non-profit organizations that inspired Maker educators in the Netherlands (Fabfoundation, 2016) (MakerEd, 2016). The Dutch Platform Maker education, inspired by the Maker Movement and the Fablab foundation, emphasizes on bringing making into education. Several Fablabs, which focused already on making, were in 2013 struggling with bridging the gap between FabLabs and education. Since the launch of the online platform in 2016, several Maker initiatives, events and locations have registered on the Platform (MakerEducation, 2016): including maker initiatives, festivals, events, school labs or extracurricular maker spaces.

In practice, we see that Maker education has many different forms and is still in development. For example, there is a thin line between design-based learning and maker-lessons. In practice, sometimes, the end result of Maker education lessons can be a sketch or a proposal on paper, not something that works or could work, as defined in the vision of Platform Maker education. Platform Maker education recognizes the difference between their vision and actual practice and they acknowledge the importance to work towards their definition of Maker Education: to make something that works or could work' in practice as much as possible. Schools are balancing between applying course-specific knowledge and Maker activities were students develop more soft skills (mentioned as soft results in the ME model). Platform Maker education has the strong vision that students learn differently though discovering by making prototypes and/or explorations. Literature confirms that this 'tangible learning' not only stimulates engagement and imagination but also shows that students learn better while playing and exploring in the physical world (Piaget, 1953) and (Davee, Regalla, & Chang, 2015). The Platform ME does admit that freedom must be given to schools and that they need to be encouraged them to implement Maker Education, or at least an element of making in their traditional curriculum. The same is found by the platform 2032 they advise more freedom to make choices, personal development, attention for (global) society and collaboration (Onderwijs2032, 2016).

Maker education is relatively new and can be seen as incorporating elements of constructionism (Katterfeldt, 2015). Papert described the theory of constructionism as a way of learning in 1991 (Papert, 1991). The learning theory envisioned learning as actively ''building knowledge structures''. Maker education can be seen as a way to learn with a close connection to constructionism. Resnick confirms also the importance of constructing with materials and state that students become better learners while they explore concepts through their expressive activities (Resnick, 2005).

By exploring, discovering, iterating, thinking, reflecting, wondering, prototyping and making, students are iteratively going through different Maker Education process steps. Through these kinds of lessons students get more familiar, learn from making mistakes and accept that they have the freedom to make mistakes. Martinez and Stager describe this as a compact learning model for designing and making; Think; Make and Improve (Martinez, 2013). Papert mentions that making and making things better leads to a more complete understanding (Martinez, 2013). A balance between thinking, making and improving reinforced by different moments of reflection is required to reach this complete understanding.

The trigger of making in education

Within our study we discovered that students were triggered to start making when they found their own path within a given assignment or theme, fostered by trust in their own (developed) competences and trust given by teachers. The chance that students find this engagement and eagerness to make a project their own is strengthened when the theme of a Maker lesson fits the experiential world of students (sometimes conceptual while ideating - sometimes more technical during hands on with materials). Platform Maker education agreed, and mentioned the different applicable themes for primary and secondary education.

- Primary: more broad on sustainability issues and animals
- Secondary: more related to course specific content and theme more on things with impactions on their own social relations and culture

Papert also states that the best learning experiences (for most people) come when they are actively engaged in designing and creating things, especially things that are close and meaningful to them or others around them.

The role of and learning goals related to new technology in Dutch Maker education

In the Maker education lessons, we observed, the trigger to start making was mostly caused by some form of intrinsic motivation within the given challenge like: 'I want to make this idea', or 'I want to solve this problem'. The provided materials and (digital) fabrication tools acted as constructive means to iterate and build generated ideas or to make artefacts while using digital oriented technology. The **digital oriented** tools and materials were for example computers for word-press blogging, programming in notepad, Thinkercad for 3D drawing, 3D printers, a laser cutter, LittleBits. LED's, batteries, motors and propellers. **Construction oriented** materials such as plywood, cardboard and recycled packaging but also plastic and wooden building blocks.

The materials triggered the students to explore, discover and iterate. Sometimes because things did not work out as they expected or the provided materials did not support what they intended to make. For example, students wanted to make a Frisbee that generates electricity for lights when throwing it but had to adapt their idea since they couldn't construct their idea with the provided materials.

A variety of (digital)materials and fabrication tools are required to suit different needs for different students. Materials or systems should provide a low floor but also a high ceiling: easy enough for beginners from different ages and levels to get started (low floor) and possible to reach a desired level for experts (high ceiling) (Resnick, 2005)'. The observations showed that some students were able to design a whole blog on Wordpress, something which they had never done before, but also that some students remained with their familiar software program Tinkercad and did not dare (yet) to explore new tools or techniques.

The overarching goals of integrating and using new technology in education relate to Maker Education; 'to help kids become more fluent and expressive with new technologies (and old technologies too); to help them explore important concepts (often in the domains of mathematics, science and engineering) through their expressive activities; and most important to become better learners (Resnick, 2005).' We have seen that students applied domain-crossing knowledge in their design like making detailed measurements for a construction cut by a laser cutter, reflecting on their make process and writing project argumentation on a weblog. However, this is not always as easy as it looks, teachers find it difficult to implement course-based knowledge and reach for a complete understanding of for example physical principles. Understanding the law of Ohm and applying it in measurements is something different then randomly trying several resistors until the technical circuit works.
Therefore, more (design)research is recommended to support Maker teachers on implementing ME in such a way that it connects well to course material, while at the same time having a clear relevance for students and providing a possibility for students to express themselves.

Key papers

Connecting to the conclusion we present three key papers that provide means for further improving the form and position of maker education in the Netherlands and maker education lessons itself. The first paper is ''Design thinking for digital fabrication in education'' by Rachel Charlotte Smith, Ole Sejer Iversen and Mikkel Hjorth (Katterfeldt, 2015). This key paper is relevant as observations in practice shows educators have difficulties the making of something that works or can work in education. Rachel Charlotte Smith and here team present a way to consciously incorporate working and learning processes in maker educations lessons with digital fabrication.

The second key paper ''Designing digital fabrication learning environments for Bildung: Implications from ten years of physical computing workshops'' of authors Eva-Sophie Katterfeldt, Nadine Dittert, Heidi Schelhowe presents their experience with physical computing workshops for the past 10 years (Smith, 2015). In their paper they reflect on the value of making in education and present three core ideas that are essential for constructive maker education lessons.

The last key paper '' Some Reflections on Designing Construction Kits for Kids'' by well-known expert and visionary in his field Mitchel Resnick and his colleague Brian Silverman discusses ten guiding principles for designing construction kits for students (Resnick, 2005). These guiding principles can however be formulated in such a way that they could guide teachers in formulating and creating maker education lessons.

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Appendices

Appendix A: Four Examples of Maker Education lessons in Dutch practice

1. Secondary school ME-lessons
An open assignment
Theme: Hack your own school, students get the assignment to hack their own school. They get all the freedom, the end product can be something conceptual, digital, technical of a piece of art after 8 lessons.
Environment: Modern classroom, with four spaces and high tables. Materials are computers, 3D printer, laser cutter, a beamer, cardboard and tinker materials.
Who: 33 students of VWO 4 (fourth grade). +/- 15 years old (time; 2 lessons of 45 min.+20 min break), 2 teachers and one assistant.
The ME-lessons provided some direction in the activities students needed to do. The first two lessons had the goal to explore the process of developing ideas and execute them with a similar theme.
After this activity, students got introduced the world of creative hacking, what was the work of artists and others?
From this exploration, students started to create their own path within the project. Guided with an extra brainstorm activity to explore each an angle of their school and present this in Scratch. From this point, students had the freedom to challenge, motivate and help themselves and each other to build prototype and make something working.

2. Secondary school ME-lessons
A closed assignment
Theme: The Dom-toren is a big tower in the city of Utrecht, in these ME-lessons an assignment is created around this tower. In this set of several ME-lessons, students are asked to make 'their own' redesign of the Dom-toren, based on their own interest and imagination.
Environment: 'technique' classroom with high tables. Materials are computers, 3D printer and three closets. One closet if filled with digital technology: makeymakeys, digital cameras, Ipads, lego-mindstorm/robotics and LittleBits. Others are used for storage of student projects and materials suchs as scissors, paper, tape, pencils etc
Who: 2 classes of MBO students (second grade), 43 students in total of approximately 13 years old (time: 2x 120 min) and one teacher.

In the beginning, each lesson starts with a particular introduction and an assignment:

1. Summarize the history of the Dom-toren, the goal is to get an insight how the tower is build.
2. Make a mood board of images that express your view on the future and images that are important to you.
3. Combine your view on the future and your knowledge about the tower, it is time to generate some ideas!
4. You are going to start with making a new concept for the tower, students need to be aware of some pre-set requirements that needs to be integrated within the actual prototype/concept.

3. Primary education ME-lesson
Theme: Students are working on a 'light design' related to the question 'Can you design a more sustainable, healthier and interactive light?'. Learning goals within the subject 'Nature and technology' subject such as shadow, scattering of light and electricity are experienced using the toolkit. By creating their own idea and making a prototype students learn about technology by using it. They get familiar with the concept light by exploring LED-light and the present materials to design something with light.
Environment: Students work in the school workshop, with tables in groups, a Digi board for watching movies and visually explaining the process, ID-BOX with little bits (modular electronic blocks), extra LED's & batteries, construction materials and old packaging materials (for groups 1-3 only electronic parts like LED's & batteries were used and instead of construction materials plastic and wooden construction kits were used).
Who: +/- 25 students of 7 classes 1&2, 3, 4, 5, 6, 7 and 8, lessons evaluated during an interview with 6 teachers during their evaluation 90 min.

The ID-BOX contains an example of a modular design based learning activity for group 7&8 but was used as a ME activity in class 1-4; students get an introduction with movie explaining about LED. The teacher connects this introduction to existing themes they already addressed in school, like light in greenhouses, the environment and the increasing amount of light during spring. Making these links is done to make it easy for teachers to connect with the activity and it can replace another learning activity so it saves them time (which seemed to makes them more willing to integrate this during their regular classes).
The focus of this lesson is on building constructions with a LED, experimenting with materials and design something that gives light. The making is guided by a process of five steps.

1. Video introduction: discussion on the theme light after the movie
2. Brainstorm: generate first ideas and start in groups
3. Explore: experiment physical and digital materials
4. Make: develop an idea as a prototype and scenario
5. Present: reflect on the design and process by presenting insights.

4. Primary education ME-lesson (Designathon)
Theme: problems around mobility.
Environment: In their own classroom, using Digi board, materials to make with; cardboard, motors, propellers, batteries etc.
Who: interview with two teachers on their two lessons of 61 students in total, supported by three (classes 7&8) and two helping parents (classes 5&6).
A Maker-lesson developed by Emer Beamer, founder of Designathon workshops. A Designathon is a design-based project around a theme. The word 'designathon' is a combination of marathon and hackaton, where people create something in a longer period of time (Beamer, 2016).
This Maker-lesson three parts of each three hours. First students get introduced about the theme mobility by means of an informative movie. Students get inspired through the discussion after they have seen the movie. The process of making is guided as followed:

1. Generate and sketching an idea around the theme mobility.

2. Developing the idea further and making prototypes

3. Presenting the idea and giving feedback to each other

The teacher facilitates this process by walking around and asking questions. The students are quite free during the process, although worksheets guide students in their brainstorm by offering structure in thinking steps.