Makerspace in School- Considerations from a Large-Scale National Testbed

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Abstract

Digital fabrication and making has received a growing interest in formal and informal learning environments. However, many of these initiatives often start from a grassroots perspective, with little coordination on a national level. This paper illustrates and discusses a study from an ongoing large-scale national testbed in Sweden named Makerspace in schools (Makerskola). The project embodies a series of considerations that arise when a maker approach is applied to a geographically widespread national education context. The results of this study are based on an analysis of the extensive project documentation and first-hand experiences from initiating and running a large-scale national testbed in Sweden, involving more than 30 formal actors and more than one thousand active partners in a national educational setting. The main contribution of this paper is the identification and discussion of five different considerations that have emerged during the project, and include *Procurement practices, The teacher and leader perspective, Informing national policy making, Creating equal opportunities*, and *Progression in digital fabrication*.

Author Keywords

Digital fabrication; Making; Education.

1. Introduction

As the digitalization of society evolves, knowledge of how computers, programming, computational thinking and digital fabrication affect society is of rapidly growing importance. Today, education should provide all children with the opportunity to not only use digital technologies and computer programs, but also provide them with opportunities to design and develop them. Without these competencies, it is hard to fully understand the nature of today's digital society, and these competencies will be even more important in the future. ICT mediates many of our everyday social interactions, and it has become a central part of our entire societal construction, our industrial and working life, our production of knowledge and a tool for creativity and innovation. Therefore, we need to foster a technological literacy that differs from computer classes aiming to prepare for future office work (Blikstein, 2013b). Knowledge about ICT as a material is important to understand what ICT is (Hallnäs & Redström, 2007; Löwgren & Stolterman, 2004), what qualities it has, what code and programming is, and how ICT can be combined with design thinking in education (Smith et al, 2015). According to Blikstein, digital fabrication and making inherit the potential to be a new chapter in the process of bringing powerful ideas, literacies, and expressive tools to children (Blikstein 2013a; Blikstein 2013b).

The maker movement emerges from the do-it-yourself (DIY) tradition, with activities organized from a bottom-up perspective, and led by grassroots innovation. The physical representation of making, or maker culture, is the makerspace - traditionally a community-operated physical space where people with common interests create DIY projects together, using technology, digital art, science, computers, etc. (Rivas, 2014). The ideas of digital fabrication and spaces for creativity and innovation have been adopted in many contexts and are now a recurring phenomenon all over the world. The typical makerspace is equipped with the necessary tools for every aspect of the technology development process, or digital fabrication, and documentation for a wide range of applications in formal and informal education (Gershenfeld, 2007).

However, there are several critical elements that need to be in focus for digital fabrication to be successful in education, e.g. digital tools, community infrastructure, and the maker mindset (Martin, 2015). One further element that needs to be present is a curriculum and digital strategy in education that provides a framework for teachers and schools to connect to. The Swedish government has recently proposed new national curriculums and new digital strategies for education in Sweden, from preschool to vocational education. Within the new curricula, that will become mandatory in 2018, programming will be introduced from primary school for all students, along with a range of other activities and content (Sveriges regering, 2017). Furthermore, descriptions on how to implement these strategies point towards applied practices and maker-oriented approaches as important aspects.

This paper broadens and expands on the above-mentioned elements by discussing initial findings from running a national large-scale test bed for digital fabrication and making in Swedish education. These findings are based on a single case study of the national Makerspace in School project, though informed by experiences from multiple sites around in Sweden. The paper is structured as follows: The next section introduces our research method. This is followed by an introduction to our case and the background necessary for understanding the context of the large-scale national maker initiative in question. The case study itself is structured around the authors' and project leaders' analysis of the project documentation and first hand experiences with the project. The final section, draws out considerations from our study and discusses these considering literature on digital fabrication in education.

2. Method

To study the initial experiences from the ongoing Makerspace in school project, we adopted a single case study approach (Yin, 1994). The study of this project has so far generated large amounts of qualitative data of different formats (interviews, first hand experiences, field notes, written documents, video conferences, web documentation, web resource bank, photo and video documentaries and summaries of events) as well as some quantitative data (data on numbers of participants and geographical location). Interviews were supplemented by observations of participants performed by the authors during several key workshops and meetings during the project. Observations were documented in photos and notes and later written up for analysis. Project documentation such as e.g. number of hours invested in the project and type of activities was acquired from the project leaders and project partners. All the project data and material was thematically analyzed to condensate meaning by the project leaders and the authors. The analysis gave insights to the state of the project, but also identified possible themes, hindrances and enablers that were then discussed among the authors. After all possible themes were listed, all critical elements were gathered to determine higher-order categories, possible overlaps, and refinements. After defining the higher-order categories; *Procurement practices, The teacher and leader perspective, Informing national policy making, Creating equal opportunities*, and *Progression in digital fabrication*, the next step was to determine whether the most important lessons-learned were captured or whether additional categories were needed. From the analysis, key findings were extracted, discussed and written up. This finally led to the structure presented in this paper. All three of the authors' organizations are official project partners, and one of the authors is a main project leader.

3. The Case - Makerspace in School

The national Makerspace in School project started in 2015 and continues until 2018. Geographically distributed all over Sweden, approximately 30 local education authorities (e.g. municipalities), businesses, science centres and academic partners are involved in the project, and more than 1350 individual participants (teachers, school leaders, researchers, etc). The Makerspace in School is funded by the Swedish innovation agency working under the Ministry of Enterprise, Energy and Communications.

The aim of the project is to contribute to the development of new subject matter specific methodology based on the creative use of new as well as existing technologies, but also to develop an understanding of how these technologies affect and mediate the ways we live and how our societies work on a more fundamental level. Challenging young people to explore the boundary between analogue and digital resources also means combining theoretical and practical work, in line with what happens in for example crafts, but in an even broader context. The project provides opportunities to develop and disseminate best practices in the field of maker culture between teachers, schools and local education authorities, who over time have the intention to improve our schools' educational activities in general and has so far been referenced and provide input for future national curriculum development.

There are around 120 members responsible for the projects more formal processes, e.g. leaders from schools and municipalities. The project is coordinated by two project leaders, but the main activities are taking place in the hundreds of schools from the participating partner municipalities and organizations, all over Sweden. The project coordination is foremost about ensuring communication channels, organizing some common events, and acting as support for materials, activities, knowledge exchange, inspiration, technology expertise, etc. Central to the implementation in the project is to establish several local test beds where the methods, equipment and logistics can be evaluated. More specifically, this means that individual teachers or teacher teams in a school work with students to:

- Explore the idea to recast a school's craft environment to a makerspace.
- Introduce programming, coding and computational thinking.
- Work creatively with Internet of Things and electronics.
- Explore and reflect on how new technologies are affecting and mediating society, work, play and life in general, including how it affects the basis for democracy.

To be able to work with a large-scale testbed, with a nationally distributed project group, much of the project's processes and resources are digital. The project has three main channels of communication; a website for more static information (Makerskola, 2017a), the digital archive (Makerskola, 2017b) and two separate Facebook groups. The digital archive website serve as a web-based knowledge bank that will cater for the project's results survival after completing the project (Makerskola, 2017b). The archive is divided into activities for school subject specific matters, such as chemistry, music, mathematics, etc., but also into school forms; pre-school, elementary school, after school, high school, special education, and informal learning. The archive also includes information about products, suppliers, project members, instructional videos, a library, information about the project and about maker culture, etc. There are about 370 articles published in the archive so far, and 37 instruction videos on Micro:bit in both English and Swedish.

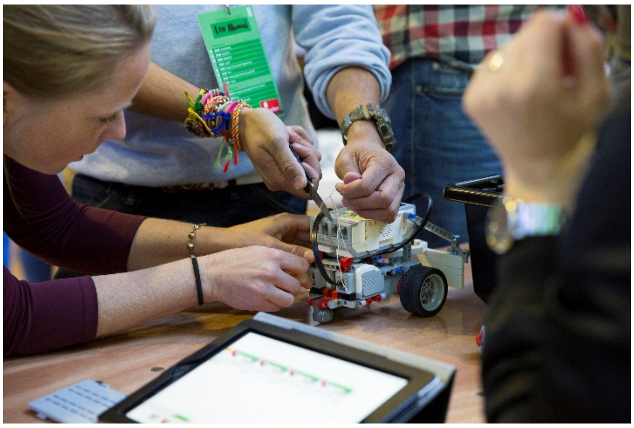

Figure 1: Teachers programming and constructing in a workshop at MakerDays 2016

Figure 2. Teachers participating in a workshop focusing on prototyping with Strawbees at MakerDays 2016

The project places great emphasis on human resource development. Every year, a *MakerDays* conference for knowledge sharing between teachers and school leaders is organized with over 400 participants, in which also stakeholders outside the partner group are welcome to participate (MakerDays, 2017). See figure 1 & 2.

The project has currently conducted maker culture and programming workshops as regular activities in 13 municipalities. The establishment of the makerspace as a physical environment has begun on a limited scale in a small number of municipalities. There are seven established environments around the country, with expertise in makerspaces, maker culture and programming, and with the ability to disseminate and share their expertise. Today there are environments in preschools in four municipalities. The project has about 15 elementary schools committed to different extents. In some places, it is a teacher team, in others the entire management of the municipality involved. Special education schools are creating a test environment between three school municipalities. High schools have started, but to a limited extent, in three places. This list is of course not complete for all of Sweden, there are many more organizations that focus on maker culture in education, and those listed here are only the formal partners in the project.

4. Considerations for Digital Fabrication in Education

Based on the first-hand experiences from the Makerspace in School project, and complemented by an analysis of the project documentation, several considerations for initiating and running a large-scale national project on establishing digital fabrication in education have been found. This paper focusses on five of them: *Procurement practices, The teacher and leader perspective, Informing national policy making, Creating equal opportunities*, and *Progression in digital fabrication*.

4.1 Procurement Practices

Today there are limited quantities and types of technology, materials and methods available concerning makerspace and programming with established technology and software vendors and distributors. Almost all the participating school principal's report on procurement and contract difficulties, which prohibit them from acquiring the required tools and materials. The project has therefore initiated a documentation process to address this problem to support the project partners. This information is published in the project's web based archives. Also, a test bed where methods, materials and models can be explored for development of the makerspace in schools is under development.

Most of the schools and municipalities involved are bound to strict rules and processes for procurement. As much of the tools and materials of digital fabrication are new to these schools, there is a threshold for carrying out proper procurement. During workshops, several suggestions for more easy access to materials have come up, such as e.g. new recycling policies for municipalities when handling electronic waste, develop standard models for procurement, and continuous updating of laws on procurement practices. Another suggestion has been for municipalities to partner up with companies that are involved in procurement and develop educational materials when creating pedagogical scenarios.

Despite the problems with procurement in the project, several prototype setups of makerspaces have been tested over time in different contexts from the beginning of the project, and several more are planned.

Procurement practices when investing in technology for education can have a major effect on how a field develops (Grönlund et al, 2014). To speed up the process of providing future makerspaces with tools and materials within a shorter time frame, while keeping the level of administration at a minimum, it may be beneficial to identify the common tools and materials needed to design and develop a makerspace for an educational context. This list can be iterated together with the businesses who have won procurement bids for providing technology to these contexts. By addressing the business stakeholders, and providing them with the same lists of tools and materials, there is an opening to create a market with actors already within the system.

To lower the entrance hurdle to start up digital fabrication initiatives in public educational contexts, the design of standardized maker kits for education would be preferable. These can be divided into different categories, depending on the level of complexity, e.g. one for starting up, one for extending, or subject specific. These kits should be designed based on national procurement bids and local conditions. Once a few standardized maker kits have been developed, partnerships with companies that can handle the distribution of the kits could be established. Through these partnerships the costs would lowered, accessibility to equipment would increase, and in the end, make the creation of makerspaces for educational institutions more feasible.

4.2 The Teacher and Leader Perspectives

According to Smith et al (2016), the most significant challenge for introducing ICT as a design material in schools is the teachers' lack of professional knowledge related to digital technology and design thinking, since these topics are not part of their basic teacher training. So, when introducing digital fabrication in the classroom, the teachers experience a lack of control and authority in the classroom (Smith et al. 2016), and they become more of facilitators. The Makerspace in School project is in dialogue with the formal teacher education to create new opportunities for teacher training through partnership, as teacher training is a prerequisite for good continuity.

Efforts to create a continuity around communication, dialogue and knowledge sharing in the project is ongoing. A virtual platform for networking and development of the Makerspace in School project is under development in the project website (Makerskola, 2017a), as well as the development of a web-based knowledge bank (Makerskola, 2017b). However, there is a reported need for different perspectives and forums in the project. For instance, the information and documented activities in the digital archive are structured into school subjects and school forms, as there is an outspoken need from teachers to share knowledge and experiences from within certain subjects or school forms. This is also shown in e.g. the increased engagement for more specific themed conference discussions rather than those of general nature. Throughout the project, a very specific need has also been raised by the participating organizations, namely the need for school leaders to have separate video conferences discussing issues related to strategies and management of maker activities.

In the Makerspace in School project, several participants have run into problems with insecurities not only from teachers, but also school leaders. The project participants have multiple times indicated a need for separate training of teachers and school leaders, for both to gain some confidence in this area.

The aim with digital fabrication and making in education is to better support learning and working in the area between the physical and digital world, which may raise awareness of and interest in science and technology among children and their teachers (Blikstein 2013a). However, the participants have experienced that digital fabrication and making are not prioritized by leaders and colleagues who do not have knowledge in this field themselves, because they do not think there is any support in the curriculum. The leaders thus ask for support in judging the teachers' knowledge in the area, while the teachers ask for competence development in making and digital fabrication, and in coordinating and developing interdisciplinary teaching. Teachers also, express a need for the schools to develop a transdisciplinary approach between subjects, to make use of the available knowledge and materials at hand. Therefore, there is a need in the project to support and run separate tracks for teachers and school leaders, in extension to organizing common activities. In the Makerspace in School project, this is supported by e.g. separate communication channels and video conferences for leaders, and during the MakerDays conference there are activities and workshops dedicated to the leader perspective and the management of digital fabrication education activities and resources. This is also reflected in the latest initiative from the government, where the Swedish national agency for education have launched an online course for all school leaders in Sweden aiming to further develop competences in managing digitalization in schools. One of the project leaders from the Makerspace at School project will be responsible for parts of this education, and experiences from the project will be directly applied in the teaching material.

4.3 Informing National Policy Making

There is a need for policy, law and regulation of education to adapt and develop in accordance to the societal changes about digitalization and automatization (Brynjolfsson & McAfee, 2014). Policy makers need to understand and be demonstrated the power of digital fabrication and making in educational settings with children. There is a need to invite and develop methods for involving policy makers into the actual activities, for instance by planning dissemination activities.

The Swedish government's ongoing mission to the National Agency for Education in ICT strategies for both pre- and primary schools as secondary and adult education is under development and in referral. The ongoing process indicates that the project Makerspace in School can support the more operational implementation of parts of these strategies. The project has directly contributed to the design of the digitalization strategy, and we see that the project is a knowledge resource for many far outside the project when it comes to the introduction of programming and creation of ICT as material in schools.

During the life of the Makerspace in School project, the Swedish National Agency for Education have developed drafts of possible changes to policy documents regarding the national ICT-strategies for the school system (Skolverket, 2016). The changes mainly aim to enhance and clarify digital competence in the policy documents, that will impact changes to the curriculum as well as the syllabus. The proposal is based on the EUs and The Digitalization Commission description of digital competence. Secondly, the government has decided to change national curricula and introduce programming in schools as an integrated part in several subjects. The new changes around digitization will apply to almost all subjects. One consequence of this is that the National Agency for Education is now working to create training materials for teachers and educators, and have turned to the Makerspace in School project for advice.

There is a growing need for the ability to understand digital systems and services as well as its impact on individual level and modern day society, and will be integrated in primary and secondary school education (Skolverket, 2016). Hopes are this will strengthen students' way of relating to media and information in a more critical and responsible way. The usage of digital technology also aims to inspire to creative ways of problem solving and putting ideas to life. Beginning slowly by adding programming to mathematics and engineering as part of the teaching to start educating digital competence.

One question that the project raise is what the government's choice of programming languages, platforms, and so on will be. When initiating and developing national training services and materials, it becomes a clear "nudge" or indicator on which programming languages and platforms that the government prefers. Even if the government does not have an intention with the selection, it will greatly affect the outcome. If they choose to support a physical platform, so it automatically means a draw towards the more maker oriented activities, while if the direction is more towards programming that only has some digital gestalt it will drive the development of more traditional computer science 101. The project strives to partake in discussions with the government about the alternatives.

4.4 Creating Equal Opportunities

To create more equal opportunities for all children to understand and learn about digital fabrication, we need to make sure that activities are attractive and relevant to many, both boys and girls. This holds for both formal and informal education. In the project activities, it has been seen that both the topic of a workshop and who is invited can greatly influence girls' participation. It is therefore important to pay attention to how activities are organized, described and presented. A recent BBC Learning and discovery research report show that 23% of 147 girls consider studying ICT and computer science in the future before trying basic coding with the Micro:bit platform, while 39% of another group of 208 girls answered yes to the same question asked afterwards trying out coding with the same platform (Education Business, 2016).

One important question is if gender specific activities, i.e. where only girls are welcome should be organized or not. Based on several activities organized close to the project it can be conclude that there is a higher interest from girls to attend if boys are not invited, i.e. gender specific activities make a difference on if girls are interested in attending or not.

Several initiatives have focused on organizing both small and large events targeted towards just girls. For instance, once per year MakerGirl (MakerTjej) Luleå is organized, where girls age 9-15 are invited for a full day workshop style event, see figure 4. The participants get to try 3D-modelling and 3D-printing, graphical programming of quadcopters and robots, programming mathematical patterns for embroidering on clothing, creating virtual reality environment using game development tools, soldering, and programming electronics using among other things a LED-brooch or light-up unicorn horn, see examples in Figure 3. Everything they produced during the workshops, they could take home with them and continue to experiment with. The events are full day activities without parents present. The participants were divided into several groups that rotated between different specific workshops and the energy level was very high the entire day. The available seats filled up within the first few days without any other advertisement than just posts on Facebook. The number of available seats have varied between 75 and 90 and almost everybody that had signed up showed up as well. This was arranged as part of a national effort called MakerGirl with the goal of getting more girls interested in computing through making and digital fabrication in Sweden.

Figure 3: MakerGirl Luleå participants with examples of LED-brooch or light-up unicorn horn

Figure 4: Participants in MakerGirl Luleå

Regarding the content of the workshops, experience from organizing many events show that specific programming events attract fewer girls, while events for digital fabrication attract more girls even if they include programming elements. Specific technologies that attract girls is fabrication using light up elements, e.g. personal decorations using LEDs in various forms, both in whimsical examples like creating a light-up unicorn horn or in slightly more serious examples where bags and clothing are decorated with light elements.

During the activities for children, it was identified that adult women including mothers compared to men and fathers can be a bit shy of testing new technologies and thus *MakeHer* was initiated in 2015 to address this. The group, where only adult women, age 20+ are welcome has meet around 15 times and have had around 10-25 participants at each meeting where women learn from each other about 3D-modelling and 3D-printing, game creation, programming, electronics, etc. The overall goal is to create female role models that do not shy away from modern technology and can help girls with technical problems.

Almost every time gender specific events for girls are organized, parents to boys ask when the corresponding events for just boys will be organized and the typical answer is that events for only boys will be arranged when there are more women than men working in the technical work sector.

The non-profit organization Luleå Makerspace, founded by one of the authors has worked targeted towards getting more girls interested in technology in general through digital fabrication and four years after the club was created, 48% of the members are female, a number very much higher than the average in makerspaces in Sweden.

When the girls have become interested in technology through among other things the above-mentioned gender specific events, it is important to give them an opportunity to continue working with technology and to support their knowledge progression to help them keep this newfound interest.

4.5 Progression in Digital Fabrication

Around the world, many activities and workshops are organized around getting youngsters interested in technology in general by letting them try out specific technologies and tools. Some examples include programming games in Scratch, programming robots, doing 3D-modelling and 3D-printing, using laser cutters, etc. but many of these activities focus on the tools or a specific technology itself.

Instead, it is important to support the progression of knowledge where the child can start with something simple and move on to something more advanced. It is important that the child gets the chance to show that they can apply their knowledge around digital fabrication in new ways. This can be done by starting with something simple like programing a brooch using a Micro:bit, then moving on to creating a LED-tiara following pre-defined instructions followed by them creating a more advanced project where they have to do much of the design (both technical and aesthetically) such as a “living” butterfly on a tiara followed by a much more advanced project such as creating a skirt with hundreds of LEDs including programming patterns, solving mobile power supply problems and making it a stable solution for public consumption.

During 2016, in an experiment called *Young Makers*, 15 children (6 female) got the chance to work on their own project by going from an idea to a prototype and during the project they got to learn the technologies and tools they needed to fabricate their personal creation. The group met over five 2h workshops where each participant got to initially identify what they wanted to create and then experiment their way towards a working solution. The experiment was very successful even though it required a lot of technical skill from the experiment leaders. Interviews after the final presentation showed that the participating girls had an increased interest in creation using modern technologies while it was at the same level for the boys.

Interviews also showed that the girls already knew what they wanted to create next while the boys were more uncertain. The boys also had a harder time initially finding what they wanted to create while the girls selected their project idea immediately after the initial inspiration session. Out of the 6 participating girls, 5 had attended earlier MakerGirl-events.

It has often been mentioned in the Makerspace in School project that available teaching examples are often either too trivial or too difficult. Thus, finding examples that opens for experiential learning, with good interaction between the digital and the analogue world, and that supports progression is key, and this is something that the project addresses by developing teaching materials and descriptive maker movies.

5. Discussion

This paper is based on an analysis of data gathered on several sites in Sweden. This means that all aspects might not be relevant to all countries and all situations. For example, projects falling under externally or privately funded project procurement practices might not experience the same challenges with procurement as listed here. Still, we believe that several of the considerations listed in this paper are valid and can be applied to some degree in many different types of contexts. A short summary of the considerations is listed in Table 1 below.

Procurement practices	**Teacher and leader perspectives**	**Informing national policy making**	**Creating equal opportunities**	**Progression in Digital Fabrication**
Identify common tools and materials with stakeholders.	Develop professional training for both leaders and teachers through partnership.	Involve and train policy makers.	Activities directed to both boys' and girls' interests.	Initiate interest with simple activities.

Design of standardized maker kits.	Support knowledge exchange both teachers and leaders.	Develop teaching materials.	Organize activities targeted towards girls only.	Stimulate progression of knowledge.
Partnerships in distributing kits.	Mutual understanding for leader and teacher perspectives.	Programming vs fabrication in the school curriculum.	Interest in Programming vs Fabrication.	Challenge the students.

Table 1. Summary of considerations deriving from the Makerspace in School project.

Digital fabrication and making for children continues to develop and reach out to the world, and brand new ways to engage children are constantly developed (Blikstein 2013a). As Martin (2015) argues, access to physical materials and digital tools is a prerequisite, in which procurement plays an important role.

However, for a successful integration into formal and informal education it is also necessary to underline the critical elements of pedagogy. In this paper, focus has not been put on pedagogy specifically as such, but rather on the different teacher and leader perspectives, and to support the development of teaching materials. The challenge is on how to design teaching materials, methods and activities that can easily be integrated into education and that are flexible enough to support many different styles, scales, contexts, time frames, diverse users, and not least of all progression. Young people need to acquire 21st century skills to become effective future workers and citizens in a knowledge society (Ananiadou and Claro 2009), and where both teachers and pupils reach a better understanding how they become empowered to act across projects, over horizontal and vertical scales (Bødker et al, 2017). Also, by informing and involving policy makers in a constant dialogue both on a local and national level and by paying attention to promotion of equality, digital fabrication might be on its way to reach its full potential in education.

The design of makerspaces and activities holds several political dimensions, and working with the project Makerspace in School created a discussion that is at the core of the current political debate of education. What is education for? How should the level of success in an educational system be measured? What knowledge should an educational system provide? Through engaging at a political level, both locally and nationally, the project Makerspace in School provide a common arena of political discussion, which is important, as political decision making most likely will have to occur on several system levels to fully implement change. With a national project as the one presented in this paper, much of the work does not include activities on a horizontal level only, but rather includes activities on a vertical scale, e.g. different levels of authority. This includes invisible or less practical fabrication work such as actively attending hearings, meetings, phone calls, expert meetings, or delivering keynote speeches, and may be important back stage work related to policy making for digital fabrication in education (Bødker et al, 2017). Several suggestions for changes in policy have been proposed during workshops and discussions in the project, with or without authorities. Politicians and decision makers need to grasp and become knowledgeable of the current changes in society, where digitalization and automatization drive change both regarding the market, as well as in society at large (Brynjolfsson & McAfee, 2014).

To maintain motivation and increase children's ability to construct mental models with previous knowledge and experience, it is important to involve children's own interests in educational activities (Papert, 1980). This of course applies to both girls and boys. Digital fabrication and making does not aim to appeal solely to talented children who might become innovators or entrepreneurs and have a special interest in computing and computational devices. Rather, digital fabrication is for everyone since all children growing up today will most likely be dependent on computation and computational devices for both professional and social life. However, by developing pedagogy where the diverse interests of the children are favoured instead of utility programs associated with work life, digital fabrication may foster a technological literacy that differs from computer classes aiming to prepare for future office work (Blikstein, 2013b). There is a parallel to the wood- and handcrafting concept in schools which also had the original goal of knowing the world by craft rather than fostering professional arts and crafts practitioners.

The authors of this paper have defined and focused on several considerations based on experiences from running a large-scale project on digital fabrication in education. This list is not exhaustive. However, it is the authors hope that the experiences presented in this paper may guide and support others who intend to engage in large-scale projects of this character.

6. Conclusion

This paper reports on a digital fabrication and maker approach to education with a large-scale national perspective. The authors have been involved in a series of digital fabrication and design thinking initiatives in education for more than a decade, where the Makerspace in School project is the largest of these initiatives, and is strongly grounded in a maker approach. From a research perspective, the understanding of what it takes to run a national large-scale testbed in this area has been studied. Given the emphasis that is often placed on the role of the grassroots initiatives to implement digital fabrication in formal education, taking on a coordinating perspective of a common national perspective is less common. The findings from the case study presented in this paper suggest that there is good reason to examine this perspective further. As is clear from the analysis and considerations raised during the project, the experiences point to some concerns that are seldom discussed in digital fabrication in education; Procurement practices, The teacher and leader perspectives, Informing national policy, Creating equal opportunities, and Progression in digital fabrication. Aware of that this list is not complete, it is the hope of the authors that other researchers, practitioners or decision makers may find inspiration in our findings.

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