CHAPTER 3

A Participatory Design Approach to Sustaining Makerspace Initiatives

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Abstract

This chapter proposes a framework consisting of six steps for sustaining makerspace initiatives by use of infrastructures developed through a participatory process.

Our framework derives from eleven cases in which we have supported the initial stage of a makerspace initiative for eleven Danish municipalities and a private foundation. The aim of this work was to create sustainable infrastructures around the initiatives and to provide the makerspace initiatives with a shared vision for development in accordance with the individual ambitions and circumstances of the municipality.

In this chapter we condense our experience into a six-step framework to inspire future makerspace initiatives globally. The six-step framework is based on current research in Participatory Design (PD) and draws on principles of stakeholder involvement, infrastructuring and vertical and horizontal alignment. Here we exemplify how this work may lead to more sustainable and robust makerspace initiatives.

Keywords

MakeEd – participatory design – sustainability

1 Introduction

As makerspaces are gaining acceptance globally as laboratories for digital creativity and learning, many existing makerspaces are struggling to extend their funding and to maintain their relevance after the first years' attention as a new and politically potent learning environment.

Makerspace initiatives are undoubtedly expensive to establish but perhaps even more costly to maintain, develop and run as vigorous and open hubs for digital creativity, innovation and learning. Whereas many guides and tutorials

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provide good starting points for purchasing equipment and hiring staff to a makerspace initiative, only few research-based initiatives address the importance of establishing infrastructure around the makerspace initiative that secures a sustainable and robust structure for developing the makerspace beyond the initial project phase and into a long-lasting resource for learning and creativity. In this chapter we provide a framework for developing local and robust infrastructures based on a PD process. By infrastructure we refer not only to technical structures but to the organisational, political and personal structures that are needed for long-term success of makerspaces. The framework is distilled from 11 cases in which we have developed local makerspace initiatives for a private foundation. All of the eleven makerspace initiatives were located in formal educational settings in relation to K9 teaching. Our work draws on PD principles emphasising how social and technical initiatives can be sustained. In the following sections we briefly introduce these principles before presenting the framework and demonstrating how the framework was put into practice with stakeholders from schools, municipalities, libraries and educational institutions during the past two years.

2 Participatory Design

In this section we provide a brief introduction to PD as an approach to makerspace development. PD is a design tradition that grew out of Scandinavia emphasising the direct and continuous involvement of future users and stakeholders in the process of design (Simonsen & Robertson, 2012). For PD, the reason for involving people directly in design is not only that their knowledge is valuable in terms of creating the best design results. It also reflects a democratic ideal of giving voice to those that will be affected by the results and making sure that they benefit from design. As such, PD embodies a commitment to ensuring that participants enjoy lasting gains from their participation and that the things that are developed through design are sustained after the project ends. Historically, PD has primarily been associated with the design and introduction of digital technology although it has also been applied in other areas such as organisational development and within education.

We suggest that PD is a fruitful approach to makerspace development because it integrates concerns for designing physical and digital spaces, educating and creating organizational commitment. Furthermore, PD explicitly addresses the challenge of how new initiatives will be sustained over time within an organisation. These concerns are of pivotal importance for successful makerspace development and hence PD is a potential good match. Moreover, PD has already been applied within the area of digital fabrication and

the broader challenge of supporting digital design literacy in education (e.g., Smith & Iversen, 2018; Iversen et al., 2018).

To provide a conceptual scaffolding for the framework proposed in this chapter, we now dive into some of the central PD principles derived from Bødker et al. (2017) that we will use to articulate how and why PD works as an approach to makerspace initiatives.

Principle 1: Collaborative Hands-on Activities Involving Stakeholders

As noted, a central tenet in PD is the direct involvement of stakeholders in design activities. Not only do future users and stakeholders take part in making overarching design decisions and setting project goals; they take part in very concrete hands-on activities exploring future practices, design ideas or ways of organising work. Collaborative hands-on activities serve several purposes in PD.

Getting first-hand experience with what you are designing, whether it be technology or teaching environments, provides a strong platform for understanding the problem and the possible solutions. Abstract and perhaps intangible concepts become very real and tangible in hands-on activities as participants engage their bodies and minds. Also, hands-on activities are particularly useful as a way of facilitating shared understanding between stakeholders and as such they are important when working with diverse participants.

Principle 2: Working Frontstage and Backstage

Since PD engages directly with future users and stakeholders a significant part of the design work taking place in PD involves activities where designers and users collaborate. This may include developing new ideas or concepts through workshops, evaluating existing working procedures or learning from each other's expertise. These kinds of activities are referred to as the frontstage of PD. But this is obviously not all of the work going on in PD. Much work takes place backstage. This is where participants have informal dialogues, plan activities, reach out to stakeholders and manage the ongoing process. Frontstage and backstage are a metaphor for describing how and where PD work is arranged and also provides a way of understanding how a PD process progresses.

Principle 3: Infrastructuring

In order for initiatives to last when the project ends, PD is particularly concerned with creating the tangible and intangible structures that support this. Infrastructures in general refer to the facility needed to make something operational (a city, a household, a school, etc.). Infrastructures can be physical

structures such as the facilities needed for makerspaces but, importantly, it can also be more intangible such as a professional networks or arrangements between teachers that will eventually be important for a makerspace to function. Infrastructuring refers to the work where these structures are created. It is well-documented in PD research, that these infrastructures are crucial in terms of ensuring that initiatives, such as makerspaces, are sustainable.

Principle 4: Working Horizontally and Vertically

For initiatives to gain momentum and eventually be sustainable it will most often be beneficial to consider how participation and engagement with different stakeholders has horizontal and vertical aspects. Working horizontally entails engaging with stakeholders in similar positions or with similar challenges. In terms of makerspaces, this might mean reaching out to other teachers to engage a wider audience in maker activities or to create professional technical forums around fabrication technologies. Working vertically entails looking at other levels of managerial or political power. For most initiatives striving to grow or for sustained existence it will most often be necessary to gain managerial support of several levels.

3 Participatory Strategies for Sustainable Makerspaces in Denmark

The participatory approach for sustaining makerspace initiatives derives from our current research within a Danish context from 2019 to 2021. A private Danish foundation has supported 11 municipalities with donations ranging from 0.7 to 1.2 Mill € to establish, operate and sustain local makerspace initiatives with the general aim of increasing children's interest in creating digital technologies and understanding how emerging technologies affects our everyday lives. Funding for makerspace initiative was provided from the private foundation for a period of three to five years based on three main criteria:

Ownership: To what extend the municipality took ownership at all organisational levels and beyond the funding period.

Spread: How many pupils, schools, and percentage of total teachers the municipality involved in the makerspace initiative.

Depth: To what extent the municipality invested their own time and resources in teacher training in STEM related matters in relation to digital fabrication.

Our research team was engaged by the foundation to conduct a start-up workshop for each of the eleven municipalities based on their individual makerspace set-ups, existing organisational structures and political objectives. The main objective with the start-up workshop was to ensure that the sustainability of the makerspace initiative was considered in the initial phase of the project designs. The eleven makerspace initiatives were fundamentally different from each other. This was partly due to the size of the municipalities ranging from 3.860 to 22.857 pupils and including from 7 to 52 primary and secondary public schools in their makerspace initiative. Moreover, the initiatives funded were very different in relation to strategies for makerspace location(s), outreach, scaling, competence development, prior knowledge of makerspaces, and partnering with local libraries and other existing networks.

Each of the workshops involved 12–30 participants from the municipality on various levels in the existing organisation ranging from the director of the school departments, project leads, 3–5 school principals, teacher trainers, teachers with expertise in digital technologies and to some extent other external partners from industry, museums or libraries. A total of 198 participants took part in the eleven workshops.

The 11 municipalities have individual setups in regards to the chain of command within education and school management. We have identified eight archetypal roles in the municipalities and around the task of sustaining makerspace initiatives. These categories are crucial to understand when identifying how sustainable makerspace initiatives are primed in collaboration between these different levels of authority.

Director of education: the highest level of authority in the municipality with regards to K-12 education who develops strategies and allocates budgets in close collaboration with elected politicians.

Project lead: assists the director of education and is responsible for the makerspace initiative, which includes acquiring funding and purchasing more expensive equipment at the municipal level.

Makerspace manager: runs and maintains the makerspace and purchases most of the equipment; provides training and guides teachers in how to use the makerspace and integrate 'making' in their teaching practice; can be someone at the municipal level, school level or both.

School principal: responsible for a particular school that participates in the makerspace initiative; not every school might

	aspire to an in-house makerspace but instead rely on the yet to be established municipal makerspace.
Teachers:	provide education to pupils but do not necessarily have an understanding of makerspaces and how to integrate making in their teaching practice.
Project partners:	has a strategic interest in co-developing makerspace initiatives together with the municipality and one or more schools (e.g., library, youth club).
Funding agency:	private or governmental institution that provides funding to develop and realise a makerspace initiative within the municipality, typically for the first 3 to 5 years.
University researcher:	responsible for the workshop program (i.e. the six steps) and some of its content.

Each of the workshops were ideally conducted during two or three-days – the first day one month before the next. The workshops took place in an existing well-established public makerspace engaging the local makerspace personnel in the workshop as inspiration for the participating municipalities. Due to the pandemic restrictions in 2020–2021 six of our makerspace workshops were transformed into virtual environments with all six municipalities together.

Based on the eleven unique cases of makerspace workshops, we identify six general steps that were present in all cases to support the sustainability of makerspace initiatives. The six steps were implemented differently in the 11 cases depending on local circumstances. In the following section, we will present the six steps with the aim of providing other projects with guidelines and inspiration for conducting their own participatory process for sustaining public makerspace initiatives. For each of the six steps we provide a general description of the activities, how they reflect PD principles and details in terms of how the individual step played out in our 11 cases.

4 The Six Steps towards Sustaining Makerspace Initiatives

In this section we provide a description of the six-step framework that led to more sustainable makerspace initiatives in the eleven Danish municipalities. We will go through the six steps highlighting the main objectives of the different steps, the participants and activities conducted to reach the suggested outcome. We have provided an overview of six steps in Table 3.1.

Step 1: Understanding the Complexity of a Makerspace Initiative

The overall objective of the first step is for project leads and school principals to develop a thorough understanding of the complexity of makerspaces, and related to this, of the role of the makerspace manager. A common misconception is that providing access to state-of-the-art digital fabrication and maker technologies will in itself lead to valuable educational practices with these technologies, which is rarely the case (Van Mechelen et al., 2021).

A vibrant makerspace requires not only technical but also strong organisational infrastructures to sustain the initiative. One such infrastructure revolves around professional and competence development enabling managers to run and maintain the makerspace and teachers to use the facilities for educational purposes. It further requires infrastructures for knowledge sharing within and between makerspaces and different organisational levels in the municipality and participating schools. As for the role of the makerspace manager, apart from technical skills and assuring safety, they need diversity and interpersonal skills, the ability to train and give feedback to teachers with diverse backgrounds and engage students in maker education. Project leads and principals need to be aware of this extensive function description when hiring a makerspace manager on the municipal and/or school level. In sum, a vibrant makerspace initiative needs substantial infrastructuring to establish strong communities of practice involving a wide range of local stakeholders, including a skilled makerspace manager.

The activities in our cases took about 5 hours and started with a short pitch by the project leads, explaining their vision and objectives for establishing a new makerspace in their respective municipality. This activity was followed by a short discussion and ensured that all participants understood the ongoing initiatives in their own and other municipalities. Afterwards, participants were invited for a guided tour in an existing makerspace where they could interact with teachers and pupils who were using the facility. Meanwhile, the makerspace manager explained how he enables and inspires teachers to set up meaningful activities with their pupils, and he talked about the technical and organisational requirements for running a makerspace more broadly. Finally, after the tour, participants developed plans for community-based training and knowledge sharing within and across schools that could be sustained in the long run.

Step 2: Hands-on Introduction to Makerspace Education

During the second step, teachers with different disciplinary backgrounds from the participating schools who did not participate in the first step are invited

TABLE 3.1 An overview of the six-step framework in relation to objectives, activities, actors and relevance

Step	Objectives	Activities	Actors
1	Understanding the function description of a makerspace manager at the municipal and/or school level; Understanding the need for long-term competence development for managers operating the makerspace and teachers using it with their pupils; Understanding the need for knowledge- sharing within and across schools and municipalities	Short pitch by project leads, explaining their vision and objectives for establishing a new makerspace in their municipality; Guided tour in an existing makerspace; manager explains technical and organisational infrastructure and daily practice of running a makerspace; Opportunity for participants to talk to pupils present in the makerspace about their experiences	Main participants: municipal project leads; school principals; aspiring makerspace managers Lead organiser: university researchers and makerspace manager
2	Hands-on experience with digital fabrication and making; Understanding the learning potential of maker education beyond operational skills; Developing teachers' ability and confidence to integrate digital fabrication and making in their teaching practice; Shared understanding about the challenges teachers may face and the type of competence training this requires	Introduction to design brief followed by group work in a makerspace under guidance of a more capable peer; Discussion on the role of the teacher in maker education and how to deal with recurring challenges	Main participants: teachers with various disciplinary backgrounds Lead organiser: municipal project leads
3	Situate maker education within the broader political landscape and digitization of society; Develop a shared understanding of makerspaces not only as places for collaboration, creativity and design, but also for critical reflection on how digital technology transforms society (macro-level); Providing research-based arguments to achieve buy-in from policy makers and other stakeholders	Presentation of international research on maker education and its societal relevance by a knowledgeable researcher followed by discussion; Participants write down main takeaways and ideas for the next step	Main participants: director of education, school principals, teachers, municipal project leads Lead organiser: university researchers

(*cont.*)

TABLE 3.1 An overview of the six-step framework in relation to objectives, activities, actors and relevance (*cont.*)

Step	Objectives	Activities	Actors
4	Developing a vision and strategy for each makerspace within the larger organisational infrastructure (micro-level); Support participants' ability to communicate the initiative clearly to colleagues and other stakeholders; Creating enthusiasm and sense of ownership around the initiative	Participants reflect individually on ideal learning environment for a makerspace; Participants break out in small groups to develop a makerspace canvas including a shared vision for and the resources needed to realise that vision; Each group prepares a presentation of their makerspace canvas	Main participants: school principals, teachers, municipal project leads Lead organiser: university researchers and makerspace manager
5	Commitment from management on the municipal and school level to sustain the initiative beyond the initial funding; Securing financial stability	Each group presents their makerspace canvas to the other groups and the director of education; Director of education links the initiatives to the strategic vision of the municipality; Researchers elaborate on how to bridge the strategic vision of the municipality and the school; Representative of the funding agency explains criteria for evaluating makerspace initiatives; Participants write down main takeaways and ideas for later use	Main participants: director of education, school principals, teachers, funding agency Lead organiser: project leads
6	Understanding of the different types of technologies that can be purchased; Awareness about safety risks, maintenance requirements and other criteria that can be used to make a selection of technologies	Guided tour in another makerspace; the manager explains the different technologies in the makerspace, their purpose and use, etc.; University researcher presents a framework that maps digital fabrication and making technologies onto learning objectives; Participants decide on what technologies to purchase for their makerspace initiative	Main participants: school principals, aspiring makerspace managers, municipal project leads Lead organiser: university researchers

for a workshop to get hands-on experience with design and digital fabrication technologies by addressing real-world challenges in small groups. This activity is facilitated by a more capable peer such as a makerspace manager who introduces the design brief and helps participants with navigating the design process and using the equipment. The activity culminates in one or more tangible artifacts and, through continuous reflection, in arguments for why these artifacts address the challenge introduced in the design brief.

The main objective of this step is for teachers to become familiar with the types of activities that take place in makerspaces and develop a shared understanding of the learning potential of maker education. Since these teachers will be the ones introducing pupils to design and digital fabrication, a related objective is for teachers to develop the ability and confidence to integrate maker education in their teaching practice. Teachers tend to think that the goal of maker education is for pupils to learn how to operate digital technologies and produce tangible artifacts, but the design process and collaborative learning that takes place along the way are far more important. The value of maker education lies, arguably, in the potential for learning and knowledge production, which far exceeds the particularities of a single design brief.

For other participants such as project leads and school principals, this step provides insight into the challenges experienced by teachers, and the type of competence training they might benefit from most. More so, it helps participants to understand that collaboration and 'horizontal work' are vital to realise makerspaces' educational potential.

The activities in our cases took about 1.5 to 3 hours. The makerspace manager, a local teacher, introduced assignments she had previously done with her pupils (e.g., using 3D modelling to design a sign for the school library). She explained how she integrated learning goals and framed the design assignment in a way that avoids pupils from choosing the easiest way to a solution and often results in poor argumentation. The participants then started working on the assignment in small groups with the help of the makerspace manager. After each group had presented their design concept and argumentation, she facilitated a discussion on the role of the teacher in maker education and how to deal with challenges such as pupils being more tech savvy than you are, faltering collaboration, and student groups that value quick and 'shiny' results over process.

Step 3: Establishing the Grand Narrative of a Makerspace Initiative

In the third step, all participants from the municipalities (incl. the director of education), schools and external project partners are invited for a state-of-the-art overview of international research on maker education. This overview is

provided by an acknowledged researcher in the field and followed by a discussion. The main objective is to situate maker education within the broader political landscape and digitization of society and, for participants, to develop a shared understanding of makerspaces not only as places for collaboration, creativity and design, but also for critical reflection on how digital technology is currently transforming society. This rapid transformation requires different types of education and learning, equipping pupils with a thorough understanding of digital technology and its ethical and societal impacts. Makerspaces could fill this gap and help pupils on their journey towards becoming active and critical citizens who keep the advancing digitization in check.

Introducing participants to this macro-perspective is important as it increases the likelihood that those involved in establishing a new makerspace, ranging from the director of education to teachers, embark on the same journey. The state-of-the-art overview furthermore provides participants with input for creating a vision for their local makerspace initiative (see Step 4), and equips them with research-based arguments to achieve buy-in from policy makers, parental school committees, other local schools that are currently not involved in the initiative, and so forth. In short, Step 3 focuses on research-based alignment between all participants involved in the makerspace initiative and reflects the PD principle of working vertically to ensure support and shared understanding among stakeholders at different levels of authority.

In the cases with Danish municipalities, this step took about 1.5 hours. The talk was provided by a distinguished professor who had been collaborating with the ministry of education to establish a curriculum on technology comprehension, the objectives of which are closely aligned with those of maker education. During the talk and discussion, participants were encouraged to write down ideas on sticky notes, which they used in the next step to further develop their local makerspace initiative.

Step 4: Developing the Makerspace Initiative within the Existing Municipality Landscape

The fourth step involves all participants from the municipalities, schools and external partners, except for the director of education. Whereas the previous step presented participants with a research-based perspective on maker education and its societal relevance, this step is all about the micro level and further developing the makerspace initiative. Participants first reflect individually on their 'dream' for an ideal makerspace learning environment and then break out in small groups to map existing resources and develop a 'makerspace canvas', that is, an overall strategy for their initiative within the context of their local

municipality and school. This is achieved through a series of exercises in which participants take a human-centered perspective to discuss and describe (1) the envisioned users of their makerspace, (2) the channels through which these users can be reached, (3) their motives for visiting, using and returning to the makerspace, (4) the activities and practices they might engage in, and (5) the human and material resources this might require, both existing and new ones. Each group visualises the outcome of these exercises on a big canvas, which they present to the other groups and the director of education in the next step.

The main objective of this step is for participants to recognise that there is no standardised method or approach to realise their vision, and to situate the makerspace within the existing organisational infrastructure. Participants furthermore learn to communicate the initiative in a convincing manner, thereby focusing on both high-level values and operational requirements. This step reflects the PD principle of infrastructuring and, again, uses hands-on activities to foster participant engagement.

In our cases, this step took 3 hours and was facilitated by a professional with extensive experience in change management within organisations. To inspire participants at the start of the session, a vision statement was read out loud by a makerspace manager who had been successfully running a makerspace in a school. The vision statement was co-created by teachers and pupils and did not only serve as an objective to strive towards, but also as a means to create ownership of and enthusiasm about the makerspace initiative. After this introduction, the participants broke out in their municipal groups and started working on their makerspace canvas with the help of the professional facilitator.

Step 5: Confirmation and Articulation of Management Support for the Makerspace Initiative

In the fifth step, each municipal group presents their makerspace canvas, which they developed in the previous step, to the other participants and director of education of the participating municipalities. The director, in turn, explains how the initiatives fit the strategic vision of the municipality, expressing their interest and support on a political level.

The envisioned outcome of this step is shared commitment from all participants, and the directors of education and school principals in particular, to further develop the makerspace initiative beyond the project duration, and ultimately, to secure financial stability. Compared to the third step that focuses on vertical alignment between participants regarding the societal impact of maker education based on international research, the fifth step is geared towards the local policy level and obtaining structural support. It reflects the

PD principle of working both backstage and frontstage to ensure that initiatives can be sustained over time. In our cases this step took about 1 hour.

Step 6: Choosing and Purchasing Technologies for the Makerspace

In the sixth and last step participants across schools and municipalities receive practical insights about buying, using and maintaining digital fabrication and making technologies. All too often, makerspace initiatives start by purchasing expensive equipment without first establishing a shared vision and strategies for sustaining the initiative in the long run, including educational objectives and community-driven competence development. Therefore, in this step, participants visit another makerspace (see also Step 1), but this time by focusing on the available technology. The makerspace manager takes the participants on a guided tour, and explains which equipment has been purchased over the years, how it has been used, which safety and maintenance regulations need to be considered, and any other challenges and opportunities related to these technologies.

After the makerspace tour, a researcher explains how to best choose technologies in support of educational objectives, thereby explaining core concepts (e.g., open-source, age-appropriate interfaces, interoperability) and elaborating on the pros and cons of commonly used makerspace technologies (e.g., Arduino, Little Bits, Makey Makey). This overview is followed by a few practical exercises for which participants use the outcomes of the previous steps to select equipment for their makerspace. In short, the sixth step is about the backstage work required to equip makerspaces with adequate technology.

In our cases, this step took about 3 hours. After the participants visited a makerspace, a university researcher presented a framework for selecting makerspace technologies and the participants broke up in small groups to apply the framework to their local initiative.

5 Concluding Remarks

In this chapter we have provided a six-step framework for sustaining makerspace initiatives through a PD process. The framework is generated by distilling knowledge and experiences from eleven cases in Denmark which provides a solid ground for introducing a participatory approach to sustaining makerspace initiative. Based on the experiences from the workshops in 2020 the funding agency decided that six new municipalities should follow the steps in 2021, and again based on experiences another six municipalities in 2022.

Several points are important to notice in relation to constructing a generalized process framework based solely on Danish makerspace initiatives. First, school systems are very different from country to country and so are the levels of authority within school systems. Second, funding agencies have different approaches and different requirements when supporting makerspace initiatives. Third, the willingness and culture of seamless collaboration between different levels of authority might differ significantly from culture to culture. Finally, the six-step framework requires substantial resources in relation to planning time, stakeholder participation, expert engagement, access to existing makerspace initiatives etc. These resources are not necessarily present when makerspace initiatives are initiated. These limitations to the proposed framework demand a high degree of contextualization and adaptation of the framework when applied in different circumstances and with different constraints.

As such, the framework is not a fixed recipe to ensure a sustainable makerspace initiative but a source of inspiration when planning the initial stages of a makerspace initiative based on collaboration and participation among teachers, management and makerspace experts.

References

Bødker, S., Dindler, C., & Iversen, O. S. (2017). Tying knots: Participatory infrastructuring at work. *Computer Supported Cooperative Work* (CSCW), *26*(1–2), 245–273.

Iversen, O. S., Smith, R. C., & Dindler, C. (2018). From computational thinking to computational empowerment: A 21st century PD agenda. In *Proceedings of the 15th participator design conference: Full papers-volume 1* (pp. 1–11).

Simonsen, J., & Robertson, T. (Eds.). (2012). *Routledge international handbook of participatory design.* Routledge.

Smith, R. C., & Iversen, O. S. (2018). Participatory design for sustainable social change. *Design Studies, 59*, 9–36.

Van Mechelen, M., Wagner, M. L., Baykal, G. E., Smith, R. C., & Iversen, O. S. (2021, June). Digital design literacy in K-9 education: Experiences from Pioneer teachers. In *Proceedings of the 20th annual ACM interaction design and children conference* (pp. 32–42). Association for Computing Machinery