Participatory design for sustainable social change

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Tendencies in contemporary participatory design suggest a move away from engagement of limited stakeholders in preconfigured design processes and predefined technology outcomes, towards more complex and long-term engagement with heterogeneous communities and larger ecologies of social and technological transformation. Building on core values of participatory design, we introduce three dimensions of engagement of scoping, developing and scaling that we argue can be essential in developing a holistic approach to participatory design as a sustainable practice of social change. The dimensions foreground central aspects of participatory design research that are discussed in relation to a long-term project exploring design and digital fabrication technologies in Danish primary and secondary education.

Keywords: participatory design, design process, user participation, design practice, educational technology

Current tendencies in participatory design suggest a move away from developments of technological artefacts or applications, or empowerment of limited groups of stakeholders, towards more complex and long-term community-driven involvements, in which researchers scaffold and prime the development of new skills, practices and conceptions of design and technology. Such processes are not only about co-designing a mutual outcome of the process, but also about a different type of scoping and scaling of multiple and possible directions for sustainable change within larger ecologies of social transformation. The challenge of contemporary participatory design research is that while the use of participatory practices and methods is increasingly spread across domains and general discourses of design and everyday life, the values and meaning of ‘participation’ itself are losing their significance. Smith, Bossen, and Kanstrup (2017) address the challenge of ‘participatory design in an era of participation’, arguing that core values from participatory design are still mostly found in smaller research projects working with dedicated concerns in situated contexts. They are highly dependent on the researcher(s) engagement and facilitation and therefore often difficult to sustain or scale into long-term change (Iversen & Dindler, 2014); or in the words of Carroll and Rossen: “The challenge of participatory...
design in contemporary community informatics is chiefly one of creating a self-directed and sustainable process of continuous learning” (2007: 258).

In much participatory design research, core values and political aspects of empowerment, democracy and voice become backgrounded in favour of methods and techniques for pragmatic design solutions. In doing so, there is a risk of jeopardising the potential qualities of depth, sustainability and scale. These qualities are fundamental aspects of empowering stakeholders and communities to participate in the development of and decisions concerning their own futures (Bjerknes, Ehn, Kyng, & Nygaard, 1987; Kensing, 2003), and changing people’s conceptions of technology to realise their own role in creating critical alternatives for the future (Bødker, 2003), together with the long-term commitment to changing the practices of communities and institutions for the better (Marsden, Maunder, & Parker, 2008). In this perspective, one important question might be whether ‘participation’ is the right place to look for the answer; or whether we need to develop more holistic approaches for moving beyond user participation and technology design, towards ways of engaging people in the complex acts and networks involved in contemporary social and technological transformations.

In this paper, we articulate how a strong commitment to values, practices and contexts in participatory design research projects might be scoped and scaled in ways that make them academically valuable while also creating impact at a societal scale. Our focus is not only to accentuate core values of participation, but also to broaden their relation to the cultural practices and future imaginaries that they become part of through our engagements (Smith, Iversen, & Veerasawmy, 2016; Smith, Vangkilde, et al., 2016). Based on experiences from the long-term research project FabLab@School (2013–2017), aimed at introducing emerging digital technologies in Danish primary and secondary education, we introduce the three dimensions of engagement of scoping, developing and scaling, which we argue can be essential for participatory design as a sustainable practice of social change. The dimensions serve as a lens to foreground central strands of a contemporary participatory design approach that have been important in our work (see Figure 4.). Moreover, they address a more general transition that we see in design research towards larger-scale and longer-term commitments to quality of life and societal impact, an inclusive focus on social practices, and the development of complex socio-technical systems and networks of actors (Stappers and Giaccardi, 2017; Bødker & Kyng, 2018).

The first of the three dimensions of engagement in participatory design for sustainable change that we suggest is *Scoping: From user involvement to protagonist communities*. Here the focus is on creating a space of mutuality in which diverse participants are able to explore and rehearse potential futures together and develop directions to suit (evolving) goals and aspirations, while
maintaining agency and building networks. The second dimension, Developing: From technological artefacts to digital practices and conceptions of technology, emphasises the processual dimensions of developing tangible and intangible outcomes, not predefined as technological artefacts, but attuned to critical conceptions of technology and the production of new digital cultures in specific contexts. The third dimension, Scaling: From tangible outcomes to sustainable social change, focuses on creating multiple opportunities for sustaining and scaling projects, beyond the agency of individual actors, within larger communities and across domains and stakeholders at various levels of authority (see also Figure 7).

We argue that these dimensions concern central aspects of participatory infra-structuring (Bødker, Dindler, & Iversen, 2017) that address both horizontal local aspects of social, technical and organisational engagement, and the vertical aspects of engagement with multiple, local and (inter)national levels of authority, that need to be addressed to enable long-term impacts for larger communities of stakeholders. Developing such a holistic approach to scoping and scaling projects based on core participatory values of democracy and empowerment have potentials to translate into sustainable forms of social change. In the following sections, we describe the contemporary challenges of participatory design before dealing with the three dimensions in more detail. Finally, we briefly discuss the challenges and potentials of this approach and how it might further contemporary participatory design research towards social change.

1 Contemporary challenges of participation
The core values of democracy and empowerment were clearly articulated in the early history of Scandinavian participatory design. The political attention on workers’ rights to participate in the development of technology at the workplace was strongly rooted in the early participatory research projects (Bjerknes et al., 1987; Ehn, 1988), stating that those affected by new technology have a legitimate reason to be involved in its design (Kensing & Blomberg, 1998). This political attention has remained a characteristic of participatory design, though in various forms and sometimes with much weaker intensity, and complemented by pragmatic and ethical arguments for involving users in design. The paradox is that the more acceptance participatory design has gained in the general design discourse, the more diluted the meaning of ‘participation’ has become. In early participatory design projects, involving users in technology design was new, provoking and challenging because establishing a space in which researchers, software enterprises, managers and end-users could meet, exchange ideas and learn from one another required the development of new techniques and methods for scaffolding participatory processes and interactions. In the last decade, the focus and diversity of participatory research has continued to spread from the workplace to industry, public spheres and
everyday life (Smith et al., 2017). What participation is for whom and in which contexts is hence an ongoing concern. A concern which should not merely focus on securing the ‘quality and gain of participation’ in the design process, but also its relevance to the longer-term impact of engagement in various environments. How, for example, are the core ideals and values of participatory design taking on new forms and meanings — not merely on an overall level of innovation and participatory cultures in contemporary society, but as critical, mundane and contextualised approaches to meaning- and decision-making across contentious private and public contexts (Andersen, Danholt, Halskov, Hansen, & Lauritsen, 2015; Iversen, Halskov, & Leong, 2012)?

Vines et al. (2013) point to the missing focus on central questions and values in the design process and call for a ‘reconfiguration of participation’ in Human Computer Interaction research which is more aligned with participatory design rather than merely user participation. Following, Vines, Clarke, Light, and Wright (2015) again suggest a focus on configuring participation, addressing the habitual gap between the claimed values and the actual practice of user involvement, by concentrating on questions of who initiates, directs and benefits from participation in design, in what forms user participation takes place, and how control is shared with the users in design. Along the same lines, Read et al. (2016) criticise much participatory design focussing on interaction design and children for lacking a theoretical foundation, as children rarely influence the final outcome and little emphasis is put on design as a mutual learning process. This concern is further scrutinised by Frauenberger et al. (2015), who introduce a methodological framework for critically reflecting on participatory design projects according to their alignment of values, outcomes, epistemology and stakeholder participation. The authors point out that such projects need to be evaluated, not only in relation to tangible outcomes, but also in relation to the participants’ learning gains, the values of the projects and their grounded epistemological perspectives. Such voices echo earlier concerns by, for example, Bodker and Iversen (2002) regarding the initial fascination of user involvement, and the need for a professional participatory design practice in order to yield its full potential within the growing landscapes of user involvement. Also, Sanoff (2007) established links with the core political conceptions of democratisation and mutual decision-making in participatory design, and its potential to reach from local and private organisations to national levels.

In contemporary research practices, the core political values of participatory design continue to thrive largely in smaller-scale experimental practices of innovation in which researchers engage stakeholders in (short- or long-term) technology design, social innovation and future-making practices (Binder et al., 2011; Björvinsson, Ehn, & Hillgren, 2012; Ehn, Nilsson and Topgaard 2014). Such projects demand dedicated attention to scaffolding open-ended explorations, in which outcomes are not predefined in terms of the design process.
and technological artefacts, but are negotiated and rehearsed among diverse stakeholders as potential future practices. These modes of engagement are theoretically bound to the history of participatory design, and incorporate methodological flexibility and sensibility towards involving marginalised voices and diverse stakeholders. Such commitments relate to design anthropological developments in our own work that emphasise situated, critical and richly contextualised approaches to co-designing possible futures (Smith, 2013; Smith et al., 2016; Smith, Vangkilde, et al., 2016).

A challenge, however, is that most participatory design projects remain isolated and experimental and are not easily sustained or scaled into organisational and socio-technical change. Examples of successful large-scale and long-term involvement do exist, mainly within the health sector (Simonsen & Hertzum, 2012; Simonsen & Robertsen, 2013). However, in most cases, sustaining and scaling of participatory interventions is left to the stakeholders, communities and organisations after the end of the research project (Iversen & Dindler, 2014). In this perspective, we see a need to develop holistic approaches for moving beyond user participation and technology design to mutual engagements in the complex practices and networks of social change. In order to create impact, we should be concerned both about the qualities and configurations of participation in the project and the design process and about developing contextual approaches that allow for scoping and scaling sustainable transformation. Such an approach, we claim, cannot merely be oriented towards generating research results, but needs to define goals and concerns with(in) situated contexts and communities. In the next section, we examine a project that addresses these concerns.

2 Digital fabrication in education: the FabLab@School research project

The FabLab@School project was developed in autumn 2013 and spring 2014 by a small interdisciplinary research team as part of the research Centre for Participatory Information Technology at Aarhus University. The research project was set up as a collaboration with three municipalities in Eastern Denmark, and based on the global FabLab@School concept developed by the Transformative Technologies Learning Lab at Stanford University. The organisation of the Danish project was unique in terms of its participatory research foundation and the partnership between municipalities and academic research, which allowed for the creation of an extended living lab involving diverse stakeholders of students, teaching staff, local politicians and international researchers. While digital fabrication in education was novel in a Danish context, for both research and educational practice (Smith, Iversen, & Hjorth, 2015), the set up created the basis for defining a common direction and offered flexibility to develop the research agenda in appropriate ways, as our insights evolved throughout the project.
The project was established in conjunction with the introduction of a cross-curricular focus on innovation, entrepreneurship and digital technology in the Danish school system in 2014. Teachers were expected to integrate these aspects across all subjects with little or no experience in facilitating learning and design processes in relation to digital technology. New Crafts and Design subjects, or specific FabLab courses, were introduced with special focus on creative work with design and maker technologies. This gave rise to urgent concerns among the teachers and municipalities in the project about how to implement fabrication technologies such as Arduino, 3D printers, laser cutters and electronic kits into existing subjects, and about the physical and material requirements for creating lab environments in the schools etc. Although such issues were relevant to the project, it was important continuously to define our role as researchers, rather than consultants, who were co-investigating an emerging field together with the stakeholders within the broader objective of creating a sustainable educational initiative.

The academic field of digital fabrication in education emerged from a strong STEM and engineering-oriented focus, integrating the rise of the constructivist maker movement into the classroom (Blikstein, 2013; Schelhowe, 2013). In the Danish research project, we added a strong Scandinavian participatory approach to design processes and technology development (see e.g. Iversen, Smith, Blikstein, Katterfeldt, & Read, 2016; Smith et al., 2015). The objective of the research project became to explore the concept of digital design literacy — a bridging concept linking the technological aspects of digital fabrication and literacy with design thinking in the educational domain. The target group was upper primary and lower secondary school students aged 11–15 years, mainly within FabLab and Craft and Design, but also in interdisciplinary teaching contexts. The research explored the central qualities and dynamics of design literacy for students, and how this core competence could be scaffolded through constructive and critical digital design processes.

The project grew considerably in the three years of its existence. From involving 12–15 so-called FabLab schools across three municipalities in 2014, the number rose to 46 by 2016, with more than 1100 teachers and 11,000 students being included in the project. Central labs have been established in four municipalities, with numerous unique labs being set up in local schools. The project has held a yearly conference on technology and design in educational practice, involving international researchers and practitioners as well as local politicians, teachers and educational specialists. It has produced a research-based master’s programme for teachers and consultants, which is scaled into Scandinavian and European training networks, and academic networks have been established across Europe, the US and the global FabLab@School network. In a Danish context, the project network now extends to all levels of authority, from schools to governmental advisory boards, giving input to national policy making with respect to future technology subjects in schools. The project has been
highlighted in several contexts as an ideal collaborative model of academic research for societal benefit (see Bødker & Kyng, 2018). The academic founders of FabLab@School regard the Danish project as the largest of its kind globally, serving as a working model and living lab for other FabLab-oriented projects internationally. The key questions are: How was a small research project able to produce sustainable impact through a long-term participatory approach? How was the research structured to connect results at various levels of engagement and across academic and public domains?

3 Research design: social research and design experiments

Our research has been driven by an interdisciplinary approach to social research and research-through-design, in which we combined qualitative research with design experiments, and a survey (Fallman, 2008; Smith et al., 2015; Zimmerman, Forlizzi, & Evenson, 2007). Based on a design anthropological approach, we initially studied students’ creative processes when engaged in small digital fabrication experiments in the schools. Insights from these studies fed into the development of a series of design experiments with students and teachers in two schools (see Smith et al., 2015). At the same time, we conducted a baseline survey (1150 students) assessing students’ level of digital literacy and design competence across age and schools in the region. See Figure 1 (below) for an overview of the research activities.

The aim of the research study and design experiment that followed was to examine how elements of design thinking and digital fabrication could provide students with new learning possibilities, based on an integrated approach to technology, design and societal challenges. The design experiments were conducted in two schools, in which we as researchers facilitated a design and digital fabrication course in four seventh-grade classes over an eight-week period (autumn 2014). Based on our results, a second participatory research experiment was carried out focusing specifically on teacher experiences and challenges when teaching digital fabrication and design processes. Eight teachers with different backgrounds, and teaching different subjects, from six schools participated in an eleven-week research experiment (spring 2015), in which they carried out the course (appropriated from design experiment 1) in their individual classes (grades 4–9) (Smith, Iversen, & Veeresawmy, 2015).

The design experiments with students and teachers generated various kinds of data: video recordings and field notes from following groups of students throughout the course, follow-up interviews focusing on the student’s experiences and learning outcomes from the process, video recordings of the teachers’ discussions and work, design materials created through workshop activities, online diary and field notes, as well as follow-up interviews with the teachers about their experiences and challenges during the process. Video
Data and interviews with the students from design experiment 1 were logged and transcribed with a focus on the students’ experiences with the design challenge, process and technologies, as well as the knowledge and competences they have gained. From design experiment 2, the qualitative data, the interviews and the video recordings of the classes and workshops were transcribed, coded and analysed, with a focus on the obstacles encountered by the teachers.

Our approach of integrating participatory design with anthropological research allows us to validate our insights by triangulating between different types of qualitative and quantitative data as well as design experiments and interventions (Hammersley & Atkinson, 2007; Smith & Otto, 2016). Especially when researching and designing potential futures with children and various stakeholders in complex networks and organisations, we find such a hybrid approach useful for generating knowledge from multiple positions. The

<table>
<thead>
<tr>
<th>Study</th>
<th>Object of study</th>
<th>Research method &amp; data</th>
<th>Participants</th>
<th>Duration</th>
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<tbody>
<tr>
<td>Pilot workshops (&amp; conference)</td>
<td>Visions and knowledge of digital fabrication and design thinking among school and municipality stakeholders</td>
<td>Co-design &amp; community building - Video observations - Recorded talks - Field notes - Sketches &amp; design materials</td>
<td>115+ teachers, lab leaders &amp; school directors 15+ local &amp; international researchers</td>
<td>3 full-day workshops, 2013</td>
</tr>
<tr>
<td>Fundraising &amp; conference</td>
<td>Proposal &amp; fundraising, and organisation of first European conference on fabrication technologies in education.</td>
<td>1st European FabLearn - workshops, presentations etc. across academic and public domains</td>
<td>255+ teachers, managers, politicians &amp; researchers</td>
<td>3 months, –1 day conference, 2014</td>
</tr>
<tr>
<td>Ethnographic field studies</td>
<td>Digital fabrication processes in education created and run by teachers in school</td>
<td>Qualitative research - Video observations - Field notes - Interviews 6 teachers &amp; students</td>
<td>5 classes 5th-9th grade 5 teachers 3 schools</td>
<td>7 weeks, 2014</td>
</tr>
<tr>
<td>Baseline survey</td>
<td>Students’ experience with &amp; competences in ICT &amp; design</td>
<td>Quantitative research: - Survey data - Observations</td>
<td>1,150 students 50 schools</td>
<td>4 weeks, 2014</td>
</tr>
<tr>
<td>Design Experiment 1</td>
<td>Students competences in digital fabrication and design processes created and run by researchers in school</td>
<td>Research through design: - Video observations - Field notes - Interviews, 12 students</td>
<td>4 classes 7th-grade students 2 teachers 2 schools</td>
<td>8 weeks, 2014</td>
</tr>
<tr>
<td>Design Experiment 2</td>
<td>Teachers’ experiences with and challenges in digital fabrication and design processes created by researchers and facilitated by teachers</td>
<td>Design experiment &amp; qualitative research: - Online diaries - Video observations - Field notes - Interviews, 8 teachers</td>
<td>8 teachers 6 schools</td>
<td>8 weeks, 2015</td>
</tr>
<tr>
<td>Teacher training</td>
<td>Teachers’ competences in design and digital fabrication facilitated by researchers and developed in practice by teachers</td>
<td>Mixed methods: Pre- &amp; post survey Observations &amp; discussions Portfolio &amp; exams</td>
<td>45 teachers 6 lab leaders 7 consultants</td>
<td>14 weeks x 2, 2016</td>
</tr>
<tr>
<td>Endline survey</td>
<td>Students’ experience with &amp; competences in ICT &amp; design</td>
<td>Quantitative &amp; qualitative research: - Survey data - Interviews, 22 students</td>
<td>449 students 17 schools</td>
<td>4 weeks, 2016</td>
</tr>
<tr>
<td>Development of national curriculum</td>
<td>Research input to national-level policy making for technology and design in education</td>
<td>Development of research agendas into national curriculum</td>
<td>Research and government organisations</td>
<td>2017-</td>
</tr>
<tr>
<td>International outreach &amp; development</td>
<td>Development and expansion of project and approach in national, Scandinavian and European context</td>
<td>Development of educational approaches to technology and design in international context</td>
<td>Research and educational institutions, and policymakers</td>
<td>2017-</td>
</tr>
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Figure 1 Overview of the main research activities for the FabLab@School project (2013–2017 and beyond)
different approaches have allowed flexibility in terms of our research priorities. For example, the strong focus on teachers followed our initial research on the students. The baseline survey together with the ethnographic studies provided us with insights into the students’ level of experience and competence, which helped us make ongoing adjustments to the design experiments. The endline survey and interviews with students provided insights into the shifts in competence at FabLab schools compared with control schools, and facilitated the development of a framework of archetypical students and schools when working with design and digital fabrication (see Figure 3 below).

In the following, we turn to the three dimensions of engagement that we consider central for a participatory approach aimed at creating sustainable social change. The dimensions can be seen as embedded in and complementary to the research design and activities presented above. In practice, the dimensions are not progressive, exclusive to one phase of the project, or limited to technology-oriented projects, but together they provide a lens to entwine decisions made prior to and throughout a participatory process. Insights from each dimension are presented before discussing their implications for participatory design in the final section.

4 Scoping: from user involvement to protagonist communities

Important concerns of participation are raised by Vines et al. (2015) who frames participatory design research as beginnings, middles and endings. Beginnings are related to how researchers establish relationships with participants and reflect on who determines the research agenda, and how certain groups or communities are involved rather than others (2015: 78). In Vines, Clarke, Wright, McCarthy, and Olivier (2013), the authors suggest moving from a focus on user participation and participatory design to engaging in acts of configuring participation. They critique the emphasis in HCI research towards ‘user design’ focussing on the experiences and use after design (Redström, 2006). This lean towards ‘designing the users’ draws attention away from participation in the process itself, and how design and use are mutually constituted in a dialectic relationship throughout the process (both before, during and after). Hence, as Vines et al. (2013: p 431) argue, there is a need to emphasise “the configuration of the experience of participation itself” and to critically articulate reflections on e.g. who initiates, directs and benefits from research where users participate in design.

‘User design’ occurs when we configure the process of participation. That is to say, decisions made before and during user participation impact heavily on the quality of their involvement in design (Vines et al., 2013: 432). The problem we see in many reports on participatory design is that the ‘beginnings’ are often
what is reported after the formal launch of a project, and not what preceded it, or indeed went beyond its completion to sustain the gains and impacts (Iversen & Dindler, 2014). We focus instead on what we call Stage 0. That is, what happens in the (often long) process of figuring out how to configure participation in the research project. At Stage 0, we not only configure participation, but we also engage in designing particular types of users based on our knowledge and assumptions of the context and domain of research. There are no users per se in this phase of the project, even if the most important decisions are taken at this stage. Rather, users, and even researchers and designers, are invented through acts of creating and defining the project itself — relating to concerns, values and biases as well as pragmatic constraints of resources and timing.

An important aspect is hence to reflect on how users and stakeholders are ‘invented’ for and in the project. Another is to question the degree to which we define participants’ roles to allow flexibility and agency during the process. Aligned with the values of political participatory design, the result of a project has to be determined not merely by the technological objects it produces, but also by the learning outcomes it produces for the involved stakeholders (Nygaard, 1979; Kensing, 2003). The learning outcome of a project, however, is not easily predictable, but often only realised or assessed towards the end of a project. Moreover, in long-term projects, different types of participants are engaged at various levels and on various occasions throughout a project, and unexpected outcomes and forms of engagement are often the most interesting. The dual challenge then is to define participants in ways that allow for the flexible engagement and agency of diverse stakeholders over time, as well as configuring participation in ways that enable people, practices and networks to (co)evolve as a consequence of their dynamic involvement.

We provide two examples of how we worked towards what we name staging protagonist communities, by inviting various stakeholders into a shared and extended space of exploration. In Iversen, Smith, and Dindler (2017), we define a protagonist role for children in a commitment to political participatory practice. Our objective is to transcend the goal of giving children a voice in design, and to address more broadly how children can be empowered to shape technological developments and critically reflect on the role of technology in their own practices. This deepens our understanding of how children may be empowered through the design process, while contributing to building competences and skills for young generations in the twenty-first century. Extending this approach to acknowledge the importance of networks of people within and across organisations and levels of authority, provides a strong basis for the building of protagonist communities. Dindler and Iversen (2014) suggest that designers should focus on developing and nurturing personal and professional relationships among participants in the design process, as these can play a critical role in terms of sustainability. The authors describe the design
process from a relational perspective as constant dynamics between people temporarily coming together in flexible knotworks and the establishment of more permanent networks of people and organisations. Here, knotworks refers to fluid assemblies that allow collaborative constellations among heterogeneous participants, that are less rigid than networks but potentially can develop into more permanent networks. Bødker et al. (2017) extend common notions of participatory infrastructuring as horizontal co-design of mutual learning to emphasise the vertical levels of authority in which different political and practical arenas come into play. Using the FabLab@School project, they also point to the reach and sustainability of a project, which are often highly dependent upon the tying of knotworks and networks, both horizontally and vertically. Hence, even if the primary research objective of the FabLab@School project was defined in terms of the students, the tying of knotworks within a larger community of stakeholders at various levels of authority played a crucial role for us in creating a sustainable foundation for the project. At Stage 0, configuring participation meant inventing and staging participants and communities for the project and continuously attuning to the outcomes of creating this shared space.

At Stage 0 (autumn 2013), we staged a series of activities, engaging various participants from schools and municipalities in dialogues about future hybrid learning spaces. Through a design game format (Brandt, Binder and Sanders 2013), each municipality worked to envision their FabLab@School initiative based on divergent motivations, visions and resources. Using a 5 × 2-metre paper tablecloth, the groups developed an illustration of how the initiative could be conceptualised in relation to the existing school infrastructure in each municipality. Some groups developed a blueprint of the physical FabLab in their schools by reinventing the common (US) FabLab, while others created a shared vision of innovation across schools and public spaces. Teaching children to innovate, they argued, would require entirely new ways of learning that stretched beyond the physical and contextual boundaries of current educational facilities. The second part of the workshop targeted the actors, roles and networks of people that would carry and secure the establishment of a technology-enhanced learning space. The dilemma was who would secure knowledge transfer, technical expertise and pedagogical skills, and how collaborations between central lab leaders, local teachers and/or potential technical staff could be established.

The design game format was well suited to initiate discussions within and across the municipalities, unpacking the complexity of the diverse perspectives and resources towards a common vision. The design game was also used in the third workshop, where participants developed formats for integrating digital fabrication across subjects and didactic goals through explorative ways of learning and making. Here focus was on concrete learning activities for children, and how they could be imagined and conceptualised. Based on their

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own expertise in mathematics, music, language etc. educators developed a Seven Days design process, while creating relations across schools in the three municipalities. Using mock-up materials, props and game- or storyboard templates, participants were encouraged to rethink elements of their professional practice in the light of the digital fabrication technologies they had encountered in the second workshop, where 70 participants explored the learning potentials of an array of maker technologies (see Figures 2 and 3). Through presentations and hands-on workshops ranging from smart textiles with Arduino and LilyPads and mash-ups of creative interfaces to sketching and 3D printers, the participants gained inspiration for their future work and more nuanced understandings of digital technology, not merely as hardware and software, but as flexible materials and props for action and transformative learning. Together, the workshops functioned both to initiate a community of stakeholders and as an emergent process for co-designing the project’s research agenda.

Figure 2 Participants working with Arduino, Makey Makey, Scratch and electronic kits during the workshops

Figure 3 Participants working with Arduino, Makey Makey, Scratch and electronic kits during the workshops

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The activities at Stage 0 demanded many resources to establish what was still not formally a funded research project. However, they allowed us to create an emergent space to explore practices and assumptions, conflicts and opportunities within a limited timeframe and setting (Smith & Otto, 2016). In this way, they were instrumental in defining and scoping the project towards a wider protagonist community, generating knotworks and research agendas that embraced the real-life complexities and unpredictable potentials for longer-term change.

Identifying the students as the subjects of our research project was a second crucial point in our approach. The community networks and vertical levels of authority were important for the development and sustainability of the project. However, the ultimate focus was on the students and the quality of their future learning environments. Based on insights from Stage 0 and qualitative research into the schools, we developed an eight-week design experiment involving students and teachers in two schools (see Figure 1, design experiment 1). Through an extended design process, we created a framework that allowed students to be the main actors in driving their own process, and to improve their skills to design and reflect on technology and its role in their everyday life. This protagonist role for the students was articulated throughout the process activities, and explicit in the design brief.

The semi-authentic design brief challenged the students to redesign a public park for Aarhus city council, who wanted a more recreational urban space for everyday leisure and social activities. The challenge was structured to scaffold the development of relevant concepts for a specific real-life context, and contained three important components to engage the children as protagonists in the design process, namely authenticity, closeness and complexity. Aarhus had been elected European Capital of Culture in 2017, providing an opportunity for redesigning the park. The authenticity of the design brief allowed the students to engage in creating local change. The municipality’s involvement as project sponsor included the students in a broader network of professionals exploring future urban environments. The challenge was also situated in the students’ own neighbourhood, creating identification while retaining openness to develop their ideas freely. The students were thus faced with the complex challenge of (potentially) being engaged in a public decision-making process and, importantly, improving their own physical surroundings. Three requirements of integrating social, technological and novel aspects into the developed concepts were built into the design brief and revisited throughout the students’ work. Introducing the design brief and urban context as well as the planned field studies, the students worked to frame and reframe the challenge and plan the execution of their process. Our roles were to structure and support the collaborative activities in the groups and to scaffold the students’ sense of ownership and legitimacy in the process.

Participatory design for sustainable social change
Through our framing of the design experiment, we invented and engaged the students as *protagonists* of the project. That is, we defined and framed the students as subjects in and of research, scaffolding a design process that encouraged exploration, agency and development of the students’ design competences. This focus on ‘users’ as ‘protagonists’ changed the design process, from merely focussing on points of user involvement to considering how engagement in the project could provide the participants with value and competences. In our design experiment, the objective was to provide the students with design competences for working with complex problem solving when designing with digital technology for real-life situations. For example, the design challenge — redesigning a public urban space in Aarhus for the municipality — was complex but in a familiar context outside the school that the students could identify with. The design process was structured to allow them to explore and develop individual solutions based on their own insights and motivations. The students were not asked to produce predefined outcomes or artefacts, but taught how to critically reflect upon technology and its role in shaping their own, and others’, futures (see also Smith, Iversen and Hjorth 2015). This focus on intangible outcomes of design, such as new skills, insights and a reflective stance towards technology, contributes to the understanding of how children and youth may be empowered through design, while preparing them for a future digitalised society. This point will be further elaborated on below.

In the initial phases of the project, the dual objective of developing sustainable infrastructures at the school and at political level, and a more narrowly defined research agenda targeting the students, allowed for an extended approach to participation. The particular scoping initiated the development of protagonist communities and contributed to developing flexible research agendas. Casting stakeholders at various levels of authority, as both objects and subjects in and of the project, our role as researchers was to stage and scaffold appropriate processes for developing complex networks and agendas within the project. This shifted the focus of participation from defining specific forms of user involvement to fit a set research agenda, to actively inventing and building protagonist communities among diverse and yet unknown stakeholders, while co-exploring an emergent research agenda. Configuring participation by inviting stakeholders into a shared space and allowing them to co-develop their roles and competences can be a crucial dimension of engagement. It enables us to continuously adjust and mature a project’s research agenda in correspondence to insights gained from both social science research and design experiments. Moreover, it allows us to continuously configure and reconfigure participation in ways that make research projects relevant and sustainable to the communities we engage with. Such a constructivist approach is aligned with the political tradition of participatory design and a design anthropological approach to the knowledge it generates. In the following section, we focus on how such a scoping can translate into further development of a participatory process.
5 Developing: from technological artefacts to digital practices and conceptions of technology

A challenge for HCI methods and techniques, as argued by Marsden et al. (2008), is that they rest on the assumption that users already have a good understanding of what digital technology can achieve, and basically facilitate work with already digitally literate users. Such assumptions convert into a common focus in participatory design projects on developing technological artefacts, rather than focussing on the processual development of new understandings and practices through engagements with digital technology. In the FabLab@School project, we found (lacking) conceptions of digital technology to be a central challenge in the Danish educational system. The baseline survey (see Figure 1) showed that students (aged 11–15), when self-assessing their digital competences, ranked high on experience with Microsoft Office (software) such as Word, Excel, PowerPoint and Google Docs, which was a focus area in the Danish government’s efforts to introduce digital technology into education. We named these skills “Office literacy”. Students also scored high on their self-assessed knowledge of (hardware) mobile phones, laptops and iPads, which they had learnt to use predominantly outside of school through social media use, gaming, communication, etc. Few students had knowledge of or experience with digital fabrication technologies and design. Some had been briefly introduced to fabrication technology such as 3D printing and Makey Makey in school, or to coding or robotics as part of out-of-school workshops. On questions of design and creativity connected to developing own ideas, in or out of school, the students received the lowest scores (see Christensen, Hjorth, Iversen, & Blikstein, 2016; Hjorth, Smith, Iversen, Loi, & Christensen, 2016).

The survey revealed that students conceived the technology as media for consumption and communication, as mobiles and computers for social media, games, etc. outside of school, and as simple tools (software applications) for math assignments etc. in school contexts. There was little understanding or critical awareness of technology beyond the screen or intended use. Taking off a mobile’s back cover by some was understood as opening the phone to see what was inside. Knowing the application features of a small handful of social media by heart was understood as the ability to teach others about mobile phones or tablets. Moreover, there were few indications of experiences or conceptions linking digital technology with creative acts of making or designing. Teachers’ experiences and conceptions were more advanced but akin in their approach to the digital fabrication technologies, which were regarded as contained tools that could be applied to ad hoc ideas in the classroom.

Marsden et al.’s (2008) critical point for HCI, in which they problematise the expansion of digital technology for developing countries, is how we design appropriate digital technology for those who do not know what digital...
technology is. We did not define the challenge as designing appropriate digital technology for an educational context of non-literate users, but rather: How do we design educational processes and frameworks that enable (teachers to enable) students to develop critical understandings of digital technology and allow them to become part of creating future change? This reframed and extended the objective, beyond the common focus on technology itself, to develop nuanced conceptions of technology and digital practices for a generation of students and teachers. This approach is clearly in line with the (early) political ambitions of participatory design to create an emancipatory practice in which users, through their own commitment to the design of new technologies, could become capable of influencing their practice (Bjerknes et al., 1987). While tangible technological products were also an important part of the early political participatory design, the core objective was the education and encouragement of users to actively participate in the design of technology through a mutual learning process, involving new-won insights, skills, visions and democratic awareness through their engagement in the process.

Our research underscored the importance of developing new literacies of technology and design, rather than applying fabrication technologies to existing educational goals. Hence, we scaffolded a design process through which students and teachers could explore complex challenges and (co)develop new educational practices based on their own experiences and contexts. Our understanding of digital technology builds on Wartofsky’s (1978) argument that different perceptions of technologies coexist. He identifies three levels of artefacts (primary, secondary and tertiary artefacts) which can be elaborated into a more detailed understanding of digital fabrication technologies in a school context. On a primary level, fabrication technologies provide students with a new tool for fabricating with digital technologies. Here, focus is on the new production of opportunities that students get from working with fabrication technologies. On a secondary level, fabrication technologies are the representations embodied in the primary artefacts which preserve and transmit skills in the production and use of the tool. In other words, fabrication technologies also provide students with an opportunity to familiarise themselves with the practice and skills related to digital production. These are embedded in the fabrication technologies, such as the interface, the production procedure etc. Finally, fabrication technologies on a tertiary level provide children with visions or a world outlook that embodies technologies. Here, the fabrication technologies can potentially provide students with means for reinterpreting or even transforming their lives and their conceptions of digital technology. The design process we developed for the FabLab@School project included all three levels. It involved working with digital fabrication tools such as Arduino, 3D printers, laser cutters and electronics to produce new artefacts (primary), as well as creating a hybrid educational environment and framework for engaging with digital and analogue materials and developing new skills (secondary). Ultimately, through complex problem solving and working
with new educational practices, it involved transforming the students’ conceptions of technology and the digital practices of the schools (tertiary).

This shift from technology-based to design process-based learning was central challenge for the schools. In one of the most advanced schools in our observational studies, teaching in innovation and technology was already an elective subject called The Scientist mixing 7th—9th grade students. The teacher experimented with shorter $2 \times 3$-hour modules in which the students solved fictive design cases using preselected technologies. Nine cases were briefly read aloud to the students: The Danish Association of the Blind need help to develop a safety cup that can show the amount of liquid in a cup, and a company is experiencing substantial loss in their chemicals and would like theft alarms to be installed on cupboards and draws, possibly using a camera, etc. Students were cast as ‘experts’ and ‘inventors’ with the simple brief of “inventing something innovative” in response to the problem. They listened carefully to the teachers’ instructions and two instructional videos on Makey Makey and littleBits. “So, these are the two technologies you can fill into the things you invent”, the teacher stated. The students explored the cases independently, but they lacked scaffolding of the process. Their ideas remained trivial and based on immediate applications of the technologies. Complexity and context, beyond mere technical obstacles, were lacking so no understanding of the problem, process or product was developed.

The development of a complex design process for the schools (see Figures 1 and 4, design experiment 1) broadened such approaches, framing the technology as primary, secondary and tertiary artefacts and focussing on learning outcomes at various levels. This meant working with a real-life challenge (as described in Section 4), from problem framing of the design brief to understanding the context through field studies, before integration of digital and analogue materials during activities of ideation and fabrication. Adding activities of argumentation and reflection to the process emphasised the students’ ability to connect decisions in the design process to learning outcomes based on the process and product. Hence, the end goal was not merely the fabrication of artefacts or functional prototypes, but the students’ ability to engage in an open-ended process and reflective conversation with the diverse materials of a design situation (Schön, 1987).

The design process model became an iconic representation of our approach, which encompassed the complexity of working with and understanding digital technologies at various levels of abstraction. Learning how to navigate a complex design process was part of developing the students’ skills, language and competences in the schools, and also used to train the teachers in the Master’s course (see also Hjorth et al., 2016; Smith et al., 2015). Students’ roles shifted from receivers of learning to producers of possible futures and co-developers of their own learning practices. Teachers used the
framework for grounding a structured design process with creative approaches to problem-based learning with technology. This way, the iconic design process became a vital outcome of the research project, which scaffolded the students’ and teachers’ ability to develop more nuanced understandings of technology and design literacy, enabling the development of new digital practices and educational environments within and across the schools. As a participatory framework, the model allowed us to explore potentials for digital fabrication in education with diverse stakeholders, while supporting the growth of protagonist communities. This process-oriented focus on developing new digital practices and literacies was instrumental in scaling the project towards sustainable change, which is extended in the third dimension of engagement described below.

6 Scaling: from tangible outcomes to sustainable social change

Our theoretical commitment to suggesting a change of focus regarding the outcome of participatory design projects reflects the work of Bødker et al. (2017) and Dindler and Iversen (2014), as also reflected in the first two dimensions. According to Bødker et al. participatory design researchers should approach the design outcome as a collection of material and immaterial artefacts produced during a design process. Accordingly, as demonstrated in our
approach, participatory design extends beyond the development of digital or other artefacts to include the infrastructures that are built around them during the process. It is a process of participatory infrastructuring where designers and stakeholders co-develop these artefacts and the infrastructures by which new social, technical and organisational changes can be meaningfully introduced, maintained and developed within existing organisations or communities. Dindler and Iversen (2014) developed the discourse when picking up on Carroll and Rossen (2007) and Merkel, Clitherow, Farooq, and Xiao (2005) to discuss how organisations develop self-sustaining learning processes, and the important task of establishing and reinforcing social networks within communities. They suggest four ideal-typical forms where participatory design initiatives are sustained, of which maintaining and especially evolving are relevant here. Whereas these forms of sustaining projects may differ in scope and outcome, they are pursued through the design process with a high degree of user involvement, and can be seen as a strong element of participatory infrastructuring as proposed by Bødker et al. (2017).

Evolving is the form of sustainability where initiatives from a project become a catalyst for ongoing development. Here the participatory engagement has a ‘snowball effect’ in terms of continuously developing initiatives in the project. In the interest of creating long-term sustainable change, our concept of scaling includes aspects of both infrastructuring and evolving. In the FabLab project, this was supported by efforts of: (1) providing frameworks for co-exploring, understanding and evaluating the project’s progress, as seen above with the design model, (2) building learning environments for developing design literacy inside the schools and also regionally for the teachers through the development of a Master’s course, and (3) developing strategies and infrastructures, both horizontal and vertical, within and beyond the schools, which could help the communities evolve the project toward long-term change. In practice, the research results and outcomes, and the ongoing developments in the project at large, were continuously co-developed through dialogue and negotiations.

To exemplify the outcomes of the project, the framework below (Figure 5) was developed based on an end-line survey and interviews with students in the FabLab schools concerning their digital experiences and competences gained from the project (see Figure 1, endline survey). The survey (including 449 students from 17 FabLab and control schools) mirrored the baseline survey’s but included questions for the FabLab schools targeting the design process and process model (Figure 4). In order to validate the survey responses, interviews were conducted with pairs of (22 male and female) students, as speak-aloud interviews following the survey. The students were pointed out by the teachers to represent those who had gained or learnt most through the FabLab-
oriented teachings. Based on analysis of the interviews, five archetypical student categories were developed, which were further validated through the survey analysis. The framework below (Figure 5) includes the five archetypical student categories found within the schools, identifying types of engagement and learning with technology and design in education. The category of ‘the design competent’ students represented an ideal category, demonstrating how systematic engagement with complex problem solving over time developed the language, repertoire and digital design literacies among the students.

<table>
<thead>
<tr>
<th>Archetypical student categories</th>
<th>Digital technology</th>
<th>Design process</th>
<th>School, spare time and future prospects</th>
<th>Technology and society</th>
</tr>
</thead>
<tbody>
<tr>
<td>The design competent</td>
<td>Master technologies and enjoy increasing their own repertoire. Work independently and creatively with new technological application areas based on complex problem areas.</td>
<td>Work creatively with technology and design. Have in-depth knowledge of the design process and are able to work in a structured way following key activities in a structured design process.</td>
<td>Work with technology and design in school and out of school contexts. Often use technologies from school in inter-disciplinary settings and in their spare time. Acknowledge technology as a premise of their future.</td>
<td>Capable of reflecting on the connections between design and technology in a societal context.</td>
</tr>
<tr>
<td>The technology interested</td>
<td>Master many technologies and enjoy learning about new technological possibilities in school. Work independently and creatively with development of new technological application areas.</td>
<td>Find working with the design process less motivating. Prefer working and experimenting with technologies to following a systematic design process.</td>
<td>Work with technology and design in school and out of school contexts. Find school work with technology relevant for advancing own interests. Wish to work with digital technology in their future career.</td>
<td>Want to solve concrete identifiable problems, where the solutions are based on the design of digital technology.</td>
</tr>
<tr>
<td>The well-schooled</td>
<td>Understand new technologies and can work creatively with them. Do not see a clear connection between working with technology and curriculum-based school work/subjects.</td>
<td>Understand the phases of the design process and can relate it to other subjects. Do not value work with design highly in relation to ordinary school work.</td>
<td>Work with technology in their spare time. Do not see the connection between digital technology in school and their own future.</td>
<td>Understand the importance of technology for society, but do not see it as their task to take part in the development of the technologically mediated society.</td>
</tr>
<tr>
<td>The undecided</td>
<td>Use digital technology but have limited experience with working creatively with technology in school. Are generally motivated towards school and IT but have not understood the potential of digital technology.</td>
<td>Are to a less extent able to work creatively with design in a process model, and can name the key activities in the design process.</td>
<td>Use technology in their spare time for communicating with friends and as a medium for schoolwork. Do not connect school knowledge about technology with their own use of media or future opportunities.</td>
<td>See connections between technology and societal developments, but do not reflect on these connections.</td>
</tr>
<tr>
<td>The not (yet) motivated</td>
<td>Find it difficult to be motivated by the application and understanding of digital technology in school.</td>
<td>Have experience with design by following instructions, and do not find the work with design processes relevant for schoolwork.</td>
<td>Use technology in their spare time for communicating with friends and doing schoolwork. Do not connect school knowledge with the use of digital technology in their spare time.</td>
<td>See few or no connections between technology and societal developments.</td>
</tr>
</tbody>
</table>

Figure 5 Five archetypical student categories developed based on student interviews (22 students) and survey data from 449 student respondents. The highlighted categories are central characteristics for the respective categories of students.
Through the project, these students had developed their ability to address complex design challenges and connect them to more critical conceptions of technology and society. These students differed from ‘the technology interested’ students, a relatively small group of male students, who were often hailed as tech-nerds or digital natives by their teachers and co-students, and were highly motivated for working with technology. However, they were interested in the technical aspects *per se*, more than the challenges, contexts or learning process surrounding these. This affected their ability to collaborate with peers, work systematically through the design process, and to develop relevant solutions for real-life problems. Another point of interest was the relatively large group of ‘the undecided’ students who were not convinced by the relevance of teaching in technology and design, but could easily be motivated by and engaged in its realms, given the right circumstances. Many of these were girls, some deeply engaged in social media and critical discussions of personal data, internet security etc., but who experienced the FabLab activities served by their teachers as a series of two-hour sessions focused on technical problems or skills with little personal or societal relevance. Others had keenly worked through a few design processes with digital fabrication but saw it as a passing part of their school work, and not of particular personal relevance.

Besides the academic importance of highlighting different student categories, the framework forged new understandings in the project about the challenges of developing hybrid learning environments and competences. The research showed that a dedicated effort integrating digital fabrication and design thinking had a positive impact on developing digital design literacies, 21st-century skills, etc. through education. But the research also demonstrated that students’ learning was highly dependent upon the individual schools’ implementation of this new field, the learning environments created and the teachers’ competences and conceptions of technology and design. Through the design experiments, we scaffolded opportunities for students to work creatively with design and digital technology through structured activities and complex problem-solving, and for the teachers to acquire the mindset and ability to develop future learning practices. The empirically grounded framework provided an image of the students’ capabilities and interests as well as mapped out potentials and challenges of working with diverse student categories. If schools and municipalities aimed for future generations to co-develop our digitalized society, the idealised educational focus on the (male) ‘technology interested’ students needed to be extended to an inclusive approach, empowering all students to be part of this future.

Building on the framework and our knowledge of the schools’ efforts in the project, a second framework was developed presenting archetypical school groupings was developed to communicate to stakeholders at various levels of authority. This connected school initiatives and strategies on a number issues including: variation in use of digital materials, learning focus integrating...
both the processual design aspects and the digital fabrication technology, systematic teaching in complex problem solving, as well as the ability to link explorative education in digital fabrication and design to the schools’ pedagogical and didactical approaches. Again, extending the political technology-driven and discourse, the frameworks reflected experiences and results from the schools’ efforts in the project, but also laid out possible visions for future strategies at multiple levels. A clear difference was found between schools who had introduced a few technologies in Craft and Design, or established a FabLab course depending on one teachers’ interest in technology, and a few schools who had developed a systematic approach to design and digital fabrication across subjects and grades, drawing in diverse stakeholders and resources in and outside the school, through a strong commitment to building holistic educational practices for the future. Whereas the former schools had invested in the project but the teachers struggled to create any real impact, the latter schools where able to generate ‘design competent’ students, and visions of transformation beyond the school. Hence the school categories correlated with the student categories, but drew attention to the broader ecosystem of stakeholders and policymaker who needed to invest in the long-term transformation of such efforts. Such results where aligned with the political ambitions of educating children for a digitalised 21st century, but cut across the actual governmental focus on ‘Office literacies’, technical skills, increasing implementation of measurable learning outcomes, and ambitions of introducing coding and computational thinking in schools.

The frameworks connected efforts of horizontal and vertical infrastructuring in the project by providing stakeholders and decision- and policy-makers with directions and incentives for action to sustain the efforts beyond the project. The research indicated a large potential for integrating digital technology and design in education, but also showed that the project was merely the beginning of a long-term effort towards developing sustainable practices and digital cultures within the broader educational system. Importantly, the frameworks were non-normative and did not present schools or policymakers with strategies for technology learning. Rather, they served as tools for reflecting upon their efforts and investments in the project, and as visions for driving forward the ambitions of diverse stakeholders and communities. The ‘ideal’ categories in each framework presented a utopian vision; but a vision that was already tangible in a few cases, and hence within reach for the community at large. At the same time, the highlighted areas in the frameworks indicated the high-potential zones in which schools and communities could decide to invest in order to make substantial and sustainable change (See Figure 6).

Obviously, this long-term approach to participatory research is less focused on technological outcomes, tool kits or educational goals for assessment. Neither is it targeted at pre-structured processes of participation or appropriations of
design and use often represented in participatory design projects. It involves a holistic and empirically grounded approach to the wider socio-technical and political contexts in the development of emerging possibilities and protagonist communities to create sustainable change. Here, questions of scaling and vertical infrastructuring are central for stakeholders to evolve the project beyond research. However, our framing of the research enables stakeholders to co-develop their understanding and legitimise their efforts in navigating through unknown terrain as pioneer communities. In this sense, the intangible research outcomes, such as the development of knowledge and practices, design processes and teachers’ education, complements the concrete building of labs, learning spaces and infrastructures developed through, and as a result of, the FabLab@School project. The participatory engagement and infrastructuring hence does not provide solutions — but a foundation, vision or a common horizon according to which diverse stakeholders can develop their potential futures in more sustainable ways.

7 Foregrounding three dimensions of participatory design engagement

In the introduction, we pointed to some central challenges in contemporary participatory design research. Even if participatory design is increasingly used in diverse settings across public and private sectors, the value-driven and political dimensions of participatory design are often lost in the pursuit of more pragmatic and short-term gains. Projects often become small-scale monolithic timelines aimed at involving users in participatory processes and providing pragmatic design solutions. Outcomes and objectives are repeatedly measured in terms of IT artefacts or systems rather than the intangible
production of knowledge and organisational and community transformation. Such projects are difficult to sustain and scale beyond the involvement of the researchers, as they lack embeddedness in the socio-political contexts and emergent concerns that are co-developed through the design process.

In this article, we show what might be achieved by a strong commitment to core political participatory design values, and through a long-term approach to developing protagonist communities, perspectives and infrastructures for sustainable change. What we suggest are three dimensions of engagement from which to develop holistic approaches of participatory design aligned with contemporary conditions of increasing digital and societal complexity (see Figure 7). The dimensions are not tools or methods, but foreground aspects and qualities of structures, perspectives and possible new practices for participatory design research. To reduce complexity, we have divided the three dimensions into themes. In practice, these intersect at different scales and timelines throughout the entire process.

<table>
<thead>
<tr>
<th>Dimensions of PD engagement</th>
<th>What</th>
<th>Where</th>
<th>How</th>
<th>Objectives of PD for sustainable change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scoping</strong></td>
<td>Rethink the role of user(s’) involvement in PD</td>
<td>Focus on 0 stage activities – before the PD project is initiated</td>
<td>Support protagonist communities emerging from diverse agendas and loosely coupled networks</td>
<td>From user involvement to protagonist communities</td>
</tr>
<tr>
<td><strong>Developing</strong></td>
<td>Redefine the outcome measures of a PD project</td>
<td>Focus on the (mutual) learning aspects of the PD process to develop new mindsets and digital practices</td>
<td>Build understandings of technological artefacts as digital tools, educational environments and ways of engaging with the world</td>
<td>From technological artefacts to digital practices and conceptions of technology</td>
</tr>
<tr>
<td><strong>Scaling</strong></td>
<td>Consider scaling opportunities as an integral part of a PD project</td>
<td>Focus on organisational and technical infrastructures (horizontal and vertical) to support the research outcomes</td>
<td>Support sustainable infrastructures and ways of evolving projects at different levels of authority beyond limited timelines</td>
<td>From tangible outcomes to sustainable social change</td>
</tr>
</tbody>
</table>

Figure 7 Three dimensions of participatory design engagement for social change

With the first dimension, Scoping: From User Involvement to Protagonist Communities, we suggest to shift focus on how to involve predefined stakeholders in predefined activities and timelines of co-design with a view to initiating the development of protagonist communities. This work begins far earlier than what is traditionally reported in PD projects. We suggest the importance of an extended period, Stage 0, in which the co-exploration of a research field with diverse stakeholders allows for the emergence of relevant participants and research questions for the project. Defining user and configuring participation in this approach is part of the project and community itself, and not something that is necessarily defined by the researchers prior to the project. This involves developing activities and strategies in the project that are uncertain, messy and beyond the immediate scope of the core research focus with the aim of involving dialogues and structures for building common understandings and potentials for changing conceptions and practices among both stakeholders and researchers.
The second dimension, Developing: From technological artefacts to new digital practices and conceptions of technology, shifts the focus from the outcome of technological artefacts or tools (or mere mutual learning) towards an extended approach to developing more nuanced conceptions of technology and new digital practices. In the FabLab project, this meant working with technologies at different levels of abstraction together with the stakeholders, creating frameworks and processes for developing understandings and digital design literacies among students and teachers. The activities and frameworks that were produced corresponded closely to the contexts and insights gained form our research, but without outlining specific or normative procedures. Rather, building understandings of technological artefacts as digital tools, educational environments and ways of engaging with a digitalised world allowed the stakeholders to experiment and co-develop their own educational practices.

Thirdly, Scaling: From tangible outcomes to sustainable social change, extends the objective of participatory design research beyond the project, into long-term processes and impacts for the communities themselves. The outcomes in such an approach can be seen as collections of material and immaterial artefacts, networks and structures produced during the design process. Again, they are not predictable or easily identifiable as particular outcomes. Rather, they rely on ongoing dialectic processes of exploring and producing relevant insights and outcomes for particular contexts, ends and stakeholders. Sustainable change is always challenging to create and must be addressed and supported throughout a project, and not at the end, as a common responsibility across domains, interests and levels of authority. Based on previous research, we emphasise both the horizontal and vertical aspects of participatory infra-structuring and ways of evolving projects beyond limited timelines. This involves developing networks, frameworks and visions for stakeholders to negotiate and develop their own long-term strategies.

Perhaps the most challenging aspect of an extended approach to participatory design research as proposed in this article is dealing with the complexity of ‘a bigger picture’, which is always partly out of reach and continuously emerging through the process of co-exploration. This means that users and research objectives, configurations of participation and project outcomes are continuously negotiated and constructed as part of the participatory design process itself. As design (and) anthropological researchers of potential futures, the uncertainty of emergent concerns, agendas and knowledge means risking ourselves in real-life processes of shaping potential long-term impact. This, we argue, demands us to constantly (re)invent and (re)position ourselves through heterogeneous forms and levels of engagement, empowering diverse stakeholders to become co-agents in the scoping, development and scaling of participatory initiatives for sustainable social change.
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