Leaving the Field: Designing a Socio-Material Toolkit for Teachers to Continue to Design Technology with Children

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ABSTRACT

Leaving the field when conducting research in situated contexts, and finding ways to sustain project outcomes beyond academia, is an ongoing struggle in HCI. In our research project, we co-designed technologies with children in classroom contexts for three years. Nearing the projects' end, we focused on creating resources that enable teachers to continue our work with their pupils. In collaboration with teachers, we developed socio-material tools that support them in empowering neurodiverse children to engage with technology in creative ways and create their own technologies. While the majority of technology design toolkits are stand-alone artefacts, part of our toolkit is an infrastructure to keep guiding and supporting teachers beyond the project's end. In this paper, we discuss the teachers expectations and requirements for a toolkit and argue that an infrastructure must be part of a toolkit. We present a set of guidelines for researchers planning for a project's end.

CCS CONCEPTS

• **Human-centered computing → Participatory design**.

KEYWORDS

Children, Education, HCI, Infrastructuring, Neurodiversity, Participatory Design, Toolkit

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1 INTRODUCTION

For the past three years we have co-designed technologies with neurodiverse children [1] [17, 20, 30, 41]. We organised participatory design (PD) workshops at two different schools and designed social play technologies with three groups of children. The outcomes of this project are, next to published insights in academic venues, three prototypes created together with the children. The teachers were enthusiastic about our design workshops and PD approach, however, they did not feel able to evolve their own practices based on the experiences of working with us. Our project outcomes did not sufficiently support them, or other teachers who did not participate in this research, to continue doing similar work after we would have left the field. Hence, we saw it as a critical part of our work to leave tools behind so that other teachers and pupils in the future can continue to benefit from our work. To enable teachers to facilitate similar design activities with children, we decided to build a toolkit, comprised of various socio-material tools. We argue that we need a combination of *material* tools (for instance methodological guidelines to facilitate design processes) and *social* tools, i.e. a social community that supports teachers in using the toolkit. This paper reports on the design process of this toolkit, especially focusing on the teachers requirements and building an infrastructure to ensure support beyond the project's end.

To design such a toolkit, we conducted an interview with two special education teachers involved in our project. Since they are part of their respective schools' and policy-makers' setting and constraints, they have limited resources such as money, time, technological equipment or skills. The teachers we have worked with therefore found it challenging to implement the insights they gained from our collaboration. Leaving the field is a familiar challenge in HCI, especially when it is "in the wild": in a situated context [23, 48]. Participants lack the resources (e.g. skills or funds) to be able to maintain prototypes, continuing the work of the researchers or the left artefacts are not sufficiently embedded in the context and not usable anymore [48].

There are only few technology design toolkits available that support the inclusion of neurodiverse populations in a design process [25]. Neurodivergent children might have a more differing perspective on technologies [6], and, thus, a toolkit especially designed for

[1] By neurodiverse we refer to heterogenous groups of neurodivergent and neurotypically developing children.

this target group might look differently. As there was no toolkit already available that would meet the specific requirements of the collaborating teachers and neurodiverse groups of children, we co-designed our own toolkit.

The term toolkit is defined as a "set of tools that are used to making or repairing something", and "skills and knowledge that are useful for a particular purpose or activity" [10]. The majority of existing toolkits within the HCI context are technology design toolkits, aimed to inform people about technologies and to enable them to build their own technologies [7, 12, 31, 35, 36, 44]. Contrary to our toolkit, existing toolkits are usually "stand-alone" materials, consisting of technical, theoretical or methodological tools. Despite the fact the teachers we collaborated with already introduce technological tools to the children from a user perspective (for instance a programmable robot [2]), enabling children to create their own technological solutions remains a challenge for them.

We interpret the term toolkit as a collection of *socio*-material tools that are used to facilitate design workshops for neurodiverse children, empowering them to build their own technologies. We learned from our collaboration with the teachers, that their situated context requires not only stand-alone materials, but also a social infrastructure in which the digital or physical materials are embedded. This could be, for instance, a local support community of technology experts, policy makers or other teachers using the toolkit. As a conceptual lens we build upon the notion of infrastructuring. We use this term as defined in Science and Technology Studies and used by Karasti et al. as "a multifaced concept referring to interrelated technical, social and organizational arrangements involving hardware and software technologies, standards, procedures, practices and policies together with digital configurations in support of human communication and capabilities" [29]. Those socio-material relationships and are defined by the things in it and their relationships that change continuously [28].

Socio-materials can be tools to facilitate a PD process with children, like methodological guidelines or workbooks for children, technologies, but also a social network of people. Their characteristics can evolve over time, for instance could the content of the toolkit be extended and adapted by teachers or other members of the support community.

In this paper, we present the design process of a socio-material toolkit for teachers to empower neurodiverse children in designing and re-thinking technologies. We facilitated this in our project by inviting children to a design process, giving them creative spaces to collaboratively design their own technological artefacts, for instance during fantasy workshops. The toolkit was co-designed based on an interview and a co-design workshop with special education teachers, and initial feedback on the final prototype was gathered afterwards from additional teachers with an online survey. The scope of this paper reports on this process and insights we gained when developing the socio-material toolkit.

We contribute to the field of HCI by demonstrating how a project's end can be facilitated in ways so that the participants of research projects, in our case special education teachers, have sufficient socio-materials tools to continue empowering neurodiverse children in the design processes of novel technologies. By demonstrating this process we assist future creations of toolkits within situated contexts, to enable participants to continue researchers' work after they leave the field. We believe that future researchers can benefit from our experiences in how infrastructuring can support a toolkit design process.

[2]https://www.tts-international.com/bee-bot-programmable-floor-robot/1015268.html

2 BACKGROUND AND RELATED WORK

We first introduce the challenge of leaving the field and how other researchers approach this topic. Next, we explore existing toolkits and what is missing in the field of toolkit design. Last, we introduce the notion of infrastructuring.

2.1 Leaving the field

Planning for what happens after a research project has ended is often challenging [48]. Given discusses the ethical issues which arise when leaving the field- relations between researchers and participants should be faded out carefully, and promises made during the project should be kept [23, 45]. Researchers should also be aware of possible power relations and their greater access to resources, compared to the participants. In line with Given's ethical concerns, Watts argues that researchers who work closely with participants in a situated context, like many HCI practitioners, are confronted with ethical challenges like intrusion, relationship boundaries and attachment issues when leaving the field [50].

However, leaving the field also poses challenges beyond the personal level, such as the challenge of sustaining impact [2, 11, 15, 24, 34, 43]. Especially when technological artefacts are created, it is challenging to ensure lasting engagement with the technology which is left behind. Taylor et al. worry about long-term use of resulting technologies from research projects and have examined how researchers prepared for their sustainable use. The participants struggle with usage, technology and resource issues [48].

In the fields of PD and Educational Sciences, researchers have experienced similar challenges [16, 26, 39]. Fishman et al. have examined factors that relate to sustainability of a mathematics curriculum supported by technology [16]. The authors highlight the importance of lasting effects of research project outcomes in education. Their findings are twofold: If teachers perceive the technology enhanced innovation to be coherent with their own or the school's agenda, they are more likely to be committed to apply the innovation. The second factor is the perceived utility of the innovation, related to learning, instructional practice and their own practice.

This research indicates that a toolkit should be aligned with the specific school context (the school's and teachers' agendas, practice and curricula), if we aim for its lasting use.

In PD with children, many of the practices or outcomes that are established during PD interventions are reversed after the researchers or practitioners leave. Projects often take place in schools and the teachers are constrained by the settings and structures of their respective schools' and policy-makers' [8, 18, 21, 51], This makes it harder for the teachers to adopt new practices (for instance PD workshops as part of the curriculum). Working with children requires us, thus, to think more closely about how we can set up participatory projects, and embed them in the school's context, in ways that it is more likely that positive impacts are sustained when we leave the field.

A fundamental aspect in PD are user gains, for instance mutual learning, which remain with the participants after the project's end [8, 22, 26, 42]. In a school context, Barendregt et al. have explored the concept of defining learning goals with children and how to support children in achieving those during PD activities [3]. Another PD project in a school context explored the user gains of teachers, who point out that they valued working with novel technologies and how IT facilitated new ways of teaching [8]. Having access to technology seems to be a key element which would be lost after the researchers, who provide this access to the children and teachers, have left the field.

It remains relatively unexplored how mutual learning between teachers and researchers can be supported in ways that teachers can evolve their own practices around PD and designing technologies. Furthermore, PD practitioners argue that sustainability of project outcomes is not inherently covered in the mutual learning process [26]. Iversen and Dindler attempted to anchor PD initiatives in a school context, pointing out that it is necessary to scale up information systems or insights through the PD process, and ensuring replicability of PD initiatives. Eventually, PD initiatives will evolve beyond the project's end, for instance during network activities among project partners.

While researchers seem to agree that we should plan for what happens after a research project ends, and suggest strategies for how to do so [16, 23, 26, 39, 48, 50], it still depends on the specific project context if those strategies are feasible. To identify the situated requirements for our toolkit, we deemed a co-design process with teachers as a suitable approach.

2.2 Existing technology design toolkits

2.2.1 Toolkit goals and their relevance when leaving the field. One approach to prepare for the project's end is to "pack up" project outcomes in a toolkit. A wide range of different technology design toolkits has been developed in the past years, aiming to teach people about technological components and how to design their own technologies, for example [7, 12, 31, 35, 44]. Most toolkits are developed for adults, especially IoT toolkits [7]. The value of toolkits for HCI is stated by Ledo et al. who define five goals of toolkits [32]:

(1) Reducing authoring time and complexity
(2) Creating paths of least resistance (toolkits structure the problem solving process)
(3) Empowering new audiences
(4) Integrating with current practices and infrastructures
(5) Enabling replication and creative exploration (to enable scaling)

The first, third, fourth and the fifth goal are especially relevant when researchers prepare for leaving the field. With toolkits that continue to be used and shared across a growing social infrastructure after the end of a project, we can reach with toolkits people beyond the initial project over an extended period of time, and empower them without being involved as researchers in this process. The last goal is in line with our aim to scale solutions for an increasing number of people, without losing its core ideas (which are embedded in the toolkit).

2.2.2 Technology design toolkits for children. Next, we will discuss a selection of existing toolkits used to teach children about technology and design. We searched the ACM library for toolkits developed in a research context, using the search terms "toolkit", "children", "PD" or "participatory design" or "HCI" or "technology" or "IoT". We selected papers based on the criterion that the toolkit enables children to design their own technology. Next to toolkits described in academic outlets, we looked for commercially available toolkits by using the google search engine.

There is already a wide range of different toolkits for neurotypically developing children available, as displayed in Table 1. In summary, most technology design toolkits for children are either based on physical, mostly electronic components, or based on cards with guidelines or instructions. None try to have a self-sustaining infrastructure aimed to evolve from participant contribution. Furthermore, there may be issues with using some of them within a specific setting, such as a school context. Teachers face constraints, i.e. pedagogical challenges, curriculum challenges, structural challenges and a lack of (peer) support [37]. Adopting new practices and implementing technology design toolkits might thus be challenging for them.

As Ledo et al. pointed out, toolkits should be carefully integrated in current practices and infrastructures, to enable scaling [32]. We would like to pick up this idea and explore how we could integrate a technology design toolkit in a school context.

Not developed specifically for children, but one of the few toolkits developed for neurodiverse populations are TapeBlocks [25]. Neurodiverse individuals might have a differing perspective on technologies, and unique skills and needs [6]. The majority of STEM activities is not designed to be inclusive for neurodiverse populations [25]. Responding to this gap, Ellis has developed "TapeBlocks", electronic modules which do not require fine motor skills to build a circuit with. The feedback is accessible as well, for instance to visually impaired users, through vibration and light [25].

As the TapeBlocks example shows, toolkits for neurodiverse populations can look different from toolkits developed exclusively for neurotypical people. We aim, thus, to design a toolkit that supports the inclusion of neurodiverse children, stemming on our own experiences and by collaborating with special education teachers.

2.3 Infrastructuring

Following the advice of Ledo et al. to integrate toolkits in current infrastructures and practices [32], we build upon the notion of *infrastructuring* as a conceptual approach to explore possibilities for a better integration of the toolkit in the schools' context.

The concept of infrastructures was originally introduced by Star and Ruhleder in 1994 [47], who emphasize the contextual and situated nature of developing and using infrastructures. They consider socio-technical relations as relationships between "humans" organized ways of doing things and the technologies that enable and support those methods" [28]. Neumann and Star were especially interested in the building and use of infrastructures, and the alignment of different interests of involved people in the projects [46].

This concept has gained an interest in PD as an opportunity to engage with politics and power relations [28]. Building upon the

Table 1: Overview of existing technology design toolkits for children

Toolkit Name	Description
DisCo [49]	Computer-based co-design online tool for asynchronous, geographically distributed design partners
Khandu Cards	Card Game based on creative persona for problem solving
Lego Education	Modular electronical parts based on LEGO parts, programmable
LittleBits	Electronical, pre-programmed modules
ModBot [35]	Making toolkit for underwater technology
RoboWunderkind	Modular robotic toolkit, programmable
PD toolkit [12]	Collection of PD methods to facilitate PD workshops with children

notion of infrastructures, PD practitioners also explored long-term infrastructuring efforts that unfold in the "wild". Infrastructures might, thus, be a promising angle to prepare socio-material tools that can last beyond the project's end.

In design research, the notion of infrastructuring was used to argue for integrate technology in its context of practice, instead of focusing on isolated products/objects [28]. Co-designing technology with domain experts (i.e. workers, teachers, children) is a well-known methodological approach in HCI, but with the conceptual approach of infrastructuring, we go one step further: We argue that we should collaboratively design the technological *and* the social.

To give an example of building upon the notion of infrastructuring in design research projects, we briefly introduce Ehn's concept of "design games" [1]. The term design games describes design processes as entangled socio-material activities. Researchers faced the challenge that project time is limited and thus makes it difficult to design useful systems. infrastructures could help to design possibilities for "design games" beyond the project's end.

In the Atelier project, researchers gave architectural students toolkits with elements that could be used to configure their workspaces and personalize them [1]. The Atelier project aimed to create knowledge instead of specific devices. Therefore, a shift in focus from design-games aiming at products and services and projects that result in technological artefacts, to design-games that create good environments for design-games at time of use and in the future, will be necessary. That means that during the project, it will be necessary to identify, design and support social, technical and spatial infrastructures that are flexible and yet supportive enough to facilitate future design work in everyday use. Flexibility can be supported by deliberately including incompleteness into infrastructures and creating space for unanticipated events.

Learning from Ehn's experiences, we argue that careful infrastructuring can help teachers facilitate future "design games", or design workshops for children in our context, for example by creating a social network of technology experts, a platform for toolkit users to share their experiences, and providing teachers with a toolkit which is flexible enough to be configured by the teachers based on their personal needs or contextual constraints. Infrastructuring has been applied in the educational context in the past to support the implementation and sustainability of resources that enhance student learning in a design-based research project [39].

3 PROJECT CONTEXT

The work reported in this paper takes place as part of a broader research project called "Social Play Technologies" (SPT), which was focused on PD workshops with children. During this project, we identified the challenge of leaving the field and providing the teachers with a toolkit to support them to integrate design workshops in their own practice.

The research reported in this paper was about addressing this challenge and is based on an interview, a co-design workshop and a survey with teachers. Before describing this methodology in more detail, we first provide an overview of the SPT project as background context.

3.1 SPT project context

In the Social Play Technologies project, we explored how interactive, digital play technologies can scaffold and mediate social play activities in co-located groups of neurodiverse children, aged six to eleven years. The work was conducted in Austria through undertaking three series of design workshops (50 in total, each lasting one hour) with three groups of children at two different schools. During the workshops, we co-designed social play technologies which were later evaluated with empirical studies in the school context.

The project resulted in three outcomes: three social play technology prototypes that support and mediate social play among children; methodological insights and mutual learning for both teachers and researchers on how to co-design technologies with neurodiverse children. The prototypes were evaluated at the end of the project during short term and long term evaluations with the children. At the end of the project the prototypes remained at the researchers lab. In previously published papers [17, 20, 30, 41], we described in detail our design process.

3.2 SPT PD methods

During the workshops with the children, we applied and adapted a variety of PD methods to involve the children actively in every step of the design process. We developed PD activities by combining, blending, re-interpreting and adapting techniques and tools based on the children's characteristics, our context and our own skills [19]. Methodological building blocks we used are for instance Co-operative Inquiry [13], role play or prototyping.

Especially in the context of neurodiverse children, we carefully balanced structured activities and freedoms to enable the children to participate actively in the design activities. We therefore applied the concept of a Handlungsspielraum [36], which allows children to be creative and act upon their individual characteristics and strengths during design activities. The workshops' structure was mainly based on the IDEAS framework [5]: We had a fixed routine for the introduction of each session, i.e. presenting a visual schedule of the sessions activities or prioritising visual activities (drawing, crafting, low-tech prototyping).

The children shaped the design process in diverse ways, i.e. as design partner, informant or tester and user at later stages of the design process to evaluate prototypes [14, 52].

3.3 Role of teachers

During the first two years of the project, two special education teachers were involved in the project. With one design group, the teacher was always present in the room during the workshops and helped us to engage the children in our activities. Their teacher was mainly mediating social interactions among the children, and their supporting anchor in the process.

In the other two design groups, we were alone with the children. In the last two years, two new special education teachers joined the project, since we had a new design group and one previously involved teacher left the school.

3.4 Leaving the field

We had many mutual learning experiences over the course of the project, which is not an uncommon outcome for PD/HCI [8, 22, 26, 38, 42]. The teachers were glad that the children had been invited to a design project. At the very beginning of our collaboration, a special needs teacher emphasised how thankful she was that her pupils, for once, were chosen. She pointed out that, usually, only neurotypically developing children are granted access to after-school activities and funded projects like ours. Nearing the project's end, she and her colleague were both eager to continue our collaboration between the researchers and the children, which was not possible since our funding was over.

During the last year of the project, we were exploring possibilities to leave something behind for the teachers to enable them to evolve their own practices based on the experiences of working with us. While we succeeded in publishing the majority of our methodological and theoretical insights for the scientific community and future research and development, we struggled to find pathways to sustain the interventions we had at the schools and in the educational context. For instance, we left the prototypes behind for long term evaluation, but they broke and had to be taken back to the lab.

As first attempt to explore opportunities of sustainability, we invited a policy-maker from the city council to our lab. He was eager to see our design work with the children being continued after the project has ended. He raised a question we could not answer at this point: "How can we bring this into the schools?" On his way out he had already ordered a set of LittleBits, after seeing how we used these frequently during our design workshops with the children.

However, having only the physical materials we used during our workshops would not be sufficient to run similar design workshops with children. So far, we had no accessible records of our methodological insights (besides academic publications, which are not easy to access by the general public) or strategies on how to actively involve children, and foster critical engagement with technologies. In addition, the technical skills we bring as engineers to the project, to e.g. build interactive prototypes, would also need to be considered. As we were facing the challenge of providing teachers with the necessary tools to continue our work after we had left the field, we decided to discuss with two involved special education teachers what they, and other teachers, would need to take over our work and empower children to design their own technologies. This leads us to the research we report here on the design of a socio-material toolkit for teachers.

4 METHODOLOGY FOR THE TOOLKIT DESIGN PROCESS

The design process of the socio-material toolkit consists of three research activities as displayed in Table 2. We have involved a total of nine teachers, six of them are special education teachers. All teachers signed a consent form and were informed about the data collection process.

We developed the toolkit in three phases:

1) Preparation: Before designing our own toolkit, we analysed already available toolkits, either based on literature or by trying out the toolkit. To explore the requirements of teachers and to understand their situated context of practice at the schools, we conducted one semi-structured interview with two special education teachers. To embed the toolkit in the school context, we wanted to ensure that it meets the needs of the teachers and is feasible to be applied.

2) Design: After the teacher interviews, we designed the first prototype of our toolkit. This prototype was discussed and re-designed during a co-design workshop. The workshop lasted for two and a half hours and two special education teachers, who were not part of the initial interview, participated. We chose a co-design approach to gain a deeper understanding of the teachers' context and to identify concrete directions for the resources we were designing for them. Having a first prototype already at hand, the teachers felt comfortable to comment on the artefacts, for instance the card deck of technology cards, and engage in re-design activities. After the co-design workshop, we re-designed the prototype.

3) Evaluation: The final prototype of the toolkit was evaluated in an online survey with five teachers (special education teachers and primary school teachers) who were not involved in the earlier design process. We evaluated if teachers would be interested in having a community of different experts and peer support, feel prepared sufficiently and would be willing to use the materials in their own class. We also wanted to get initial feedback on digital parts of the toolkit.

We explicitly invited primary school teachers without a background in special education to the online survey, to find out if the materials would also be suited for teachers who work with neurotypically developing children.

The original plan was to evaluate the toolkit with additional co-design workshops at a school. Unfortunately, this became impossible during the COVID-19 pandemic. We also faced restrictions in building a social infrastructure to support teachers in using the toolkit materials.

4.1 Data Collection

We collected data of the interview and co-design workshop with audio records. Researcher diaries were written after the co-design

Table 2: Overview of research activities with teachers

Method	Goal	Participants
Interview	requirements of teachers	two special education teachers
Co-Design Workshop	feedback on toolkit prototype, re-design of prototype	two special education teachers
Online Survey	feedback on digital toolkit	five primary school teachers

workshop with the teachers by two researchers that were present. We found the researcher diaries especially useful for the analysis, since they reflect the researcher's first thoughts and insights gathered during the workshop. The diaries also play an important role in retracing the process of knowledge generation. The audio recordings allowed us to look back at the initial data, so we could check if we missed anything in the diaries, and the interview recording was used for the Thematic Analysis.

The data of the evaluation was collected with an online survey. Five primary school teachers, who did not participate earlier in the design research, completed the survey. The survey consisted of 21 questions (a mix of open and closed questions). Since all of the lesson materials are available online, the teachers could look at them before answering the questions. The survey was anonymous.

4.2 Data Analysis

The audio recordings of the co-design workshop and the interview were transcribed and analysed using Thematic Analysis, based on the approach of Braun and Clarke [9]. One researcher analysed the interview. Two researchers performed the analysis of the co-design workshop, first individually and then later comparing the results. The diaries of the co-design workshop informed the analysis. We were mainly looking for insights into the needs and requirements, as well as possible challenges, for teachers, and to explore the situated context in which the toolkit would be used and its constraints. The last step was adjusted: instead of a report, we made a table of requirements (Table 3) for the resources we are developing. The following list shows the steps taken during the analysis:

- Transcription of audio records.
- Generating initial codes of data that seems relevant for the analysis and toolkit design process.
- Searching for themes (main- and subthemes).
- Reviewing themes and refinement, which themes are relevant for the design of the toolkit?
- Defining and naming themes.
- Summarising results and conclusions: How does the data influences the design process?

5 FINDINGS

In this section, we present the findings of the interview, the co-design workshop and the online survey.

5.1 Contextual challenges - Lack of resources

During the interview with the teachers, it became apparent that the most important point for them was that they did not have the resources to spend 1) much money on materials, 2) much time to engage with the materials or learn about technologies beforehand. The latter correlates to their perceived lack of technological skills and their doubts about being able to lead children through a design process of technological artefacts.

5.1.1 Funding. An important factor which was repeatedly discussed during the interview and the workshop was the lack of resources in terms of funding to buy, for instance, new materials. Even when the conversation about a possible toolkit turned from purchasing LittleBits towards printing booklets, we were still faced with worries and doubts as to the financial ramifications.

When we introduced the idea of a technology design toolkit to the teachers, we had a toolkit in mind which would be a mix of physical electronic components and methodological guidelines. However, the teachers' budget is rather tight, so including electronic components like the LittleBits became unrealistic. This quote from the workshop illustrates the teachers' budget: "We receive 200 euros for each semester, however, we have to buy other materials such as crafting materials or books as well and there is no money left at the end of the year."

Based on the requirement to design a low cost toolkit, the first prototype we took to the co-design workshop consisted of text and graphics-based materials the teachers could print out, for instance card decks with QR codes that would lead children to websites where they could find information about certain technologies. We used colour codes to distinguish between different types of technologies, for instance sensors/input (pink) or output (green). We also included two booklets, one with workshop guidelines and the other as a diary for each child (Figure 1 shows the diary of the first toolkit prototype).

During the co-design workshop, the teachers asked for more modular, digital content and only black-and white cards and booklets, since they do not have the budget for colour printing. Acting on their feedback, we changed the colour codes to black-and white pattern codes.

5.1.2 Time. One of the themes in the conversation during the interview was the "A4-Page", which the teachers felt would be the ideal length for an explanation or a guideline for them to become familiar with a new topic or a teaching technique: "Information shouldn't be longer than an A4 page. Otherwise it won't be read (by the teachers)." They were concerned that they would need to invest an increased amount of time to prepare for teaching technology design workshops if it were any longer, compared to other classes they teach, since they are less familiar with technology or design education.

When designing the toolkit material, we kept the "A4-page rule of thumb" in mind and tried to keep the information short. We also aimed to provide information about technologies in ways that the children could engage on their own with the materials, without needing a teacher who explains it to them. The cards and the videos both present knowledge in formats the children can understand, for instance by using easy language and visual representations. The goal was that, by empowering the children to be their own "instructor", their teachers wouldn't need to acquire technological skills or knowledge in advance, saving preparation time.

5.1.3 Skills. The teachers mentioned during the interview that they did not feel confident enough in their knowledge about technologies to explain them to children, but considered it very important for children to learn about technologies: "As teachers we must know everything, English, crafting… but we are also father, mother, soulmate, comforter to the children. At some point, we have reached our limit. Electricity is not my "thing" (…) so I need someone to give me short explanations."

In Austria, STEM (Science, Technology, Engineering, Mathematics) education is getting more attention and technical subjects like programming are part of the curriculum at secondary schools. The information teachers need to run technology design workshops is twofold: First, basic knowledge about technologies that are relevant for designing new technologies and second, guidelines for how to "teach" children the creative design of technologies. They expect from a toolkit that all knowledge required to design technology is provided. Hence, we decided to include technology card decks in the toolkit and made for each technology card a video, explaining and demonstrating how specific sensors, outputs or manufacturing techniques (e.g. 3D printing) work. In addition, we created a booklet with guidelines and methodological tips to support teachers with engaging the students in the design process step by step.

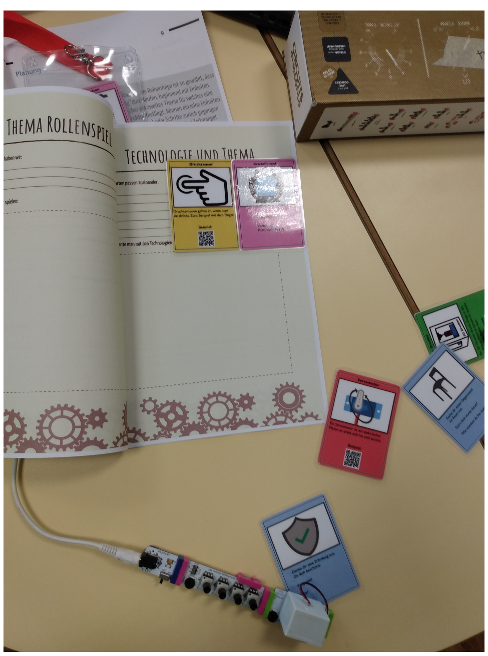

Figure 1: Impression of activities during the design workshop with the teachers.

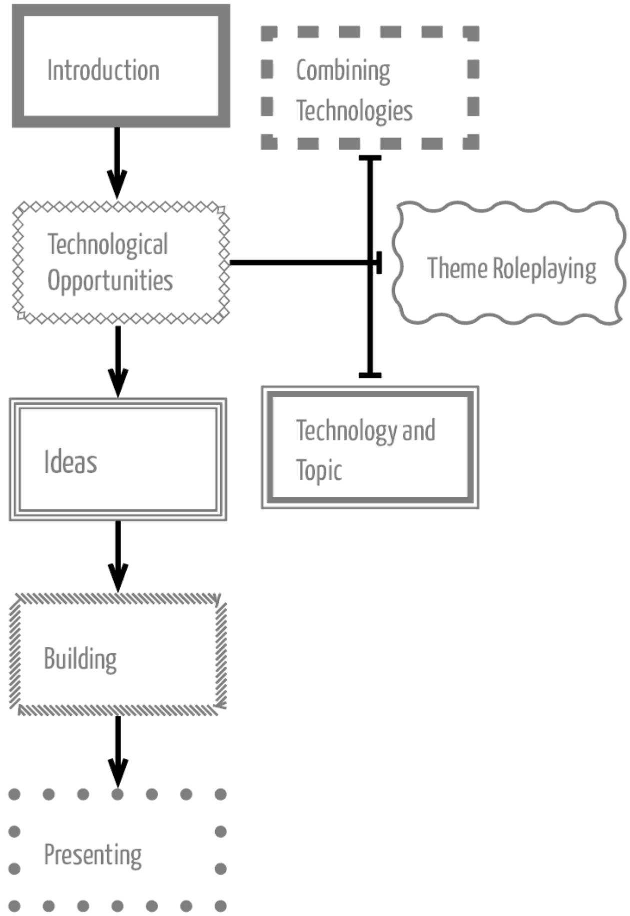

Figure 2: Schedule for design workshop modules as displayed in the teacher handbook.

5.2 Toolkit design - Modularity

During the co-design workshop, it became apparent that time was not only a constraint for preparing the toolkit activities, but also for running them. Schools have different curricula so the teachers wanted, and need to be, flexible about when and how often they run design workshops with the toolkit.

We, thus, prepared toolkit activities with modular blocks, as the schedule in Figure 2 shows. Following the different blocks, the children are guided through a design process (including idea generation, lessons about technology, prototyping and presenting their design). Each module takes one hour to accomplish, so the teachers can choose if they want to do one module each day/week or several modules one after the other. Some modules are strongly advised to include, for instance the prototyping module, while others are optional and provide the children with additional inspiration, like a fantasy workshop.

Another adaptability issue which was raised when discussing the curriculum, was content related. In order for the teachers to view our toolkit as useful, the toolkit needed to be adaptable to any content the teacher is meant to be teaching the children according to the curriculum. A quote from the survey illustrates this: "Toolkit topics should be related to the school's curriculum, for instance hydrologic cycle." Therefore, the design trigger and technologies should be separated, so that any other content can be substituted. So compared to toolkits which focus on a specific topic, like the ModBot underwater technology toolkit [34], we deliberately avoided choosing a topic for the teachers or children. Nevertheless, we suggested open themes (fantasy and sci-fi) the teachers could use to inspire the children to find a context they would like to design technology for.

One primary school teacher who completed the online survey criticised this decision - the participant was not sure how to use the toolkit materials in class since we did not propose particular topics which are in the school's curriculum. The participant suggested using typical primary school themes, for instance the four seasons or fire brigade, in the technology examples like the cards. The third flexibility related challenge was brought forward by one of the teachers during the co-design workshop. She was wondering how we would distribute the toolkit, e.g. if they would receive already printed materials or digital content they could easily re-use. The teachers explained that they prefer materials they can use several times with the class, because the children become familiar with certain structures and methods. Moreover, it saves preparation time for the teachers. For the greatest flexibility, we need to distribute the lesson materials in a digital form, for instance on a website.

6 FINAL TOOLKIT PROTOTYPE

For the final toolkit prototype which was evaluated by teachers not participating in earlier design stages, we developed a set of digital tools and applied the concept of infrastructuring.

6.1 Material tools

Table 4 shows the material tools. All tools are available online on the toolkit's website [3]) and can be downloaded for free. To avoid usability issues, cards, handbooks and diaries are in the pdf format.

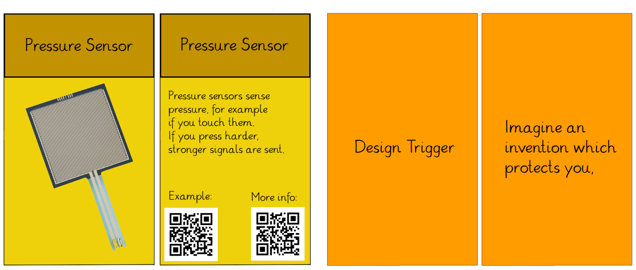

Figure 3: First prototype of technology card (pressure sensor) and design trigger card, saying: "Imagine an invention that protects you."

The toolkit parts (especially the cards as displayed in Figures 3 and 4 and the diaries) can be printed by the teachers beforehand - to enable greyscale printing, we relied on icons, patterns and contrast more than colour-coding and photographs. Figure 3 shows examples of the first card prototypes which were taken to the

[3]https://spttoolkit.wordpress.com.

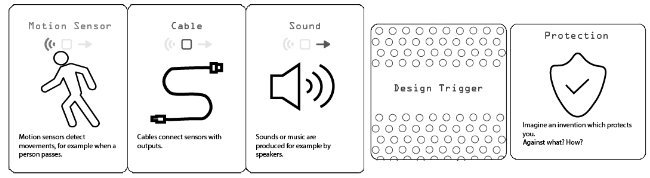

Figure 4: Final prototype of technology cards (motion sensor, cable, sound) and design trigger card (protection).

co-design workshop with the teachers, Figure 4 displays the final version of the cards, re-designed based on the teachers' feedback and in black and white.

We recommend using the LittleBits, or other electronic components designed for children, in addition to the main toolkit. However, the toolkit is just as complete without them. For instance, instead of using the LittleBits, other examples of sensors/outputs could be used as well, depending on what is available at the school. In case nothing else is available, there are videos explaining and demonstrating each technology on the cards, as well as its different applications.

6.2 Infrastructuring

During the toolkit design process, we explored what kind of *social* and *material* aspects would be necessary for teachers to evolve their own practices and implement insights from our collaboration. After presenting the material toolkit parts, which are similar to existing toolkits as described in the background section, we will now focus on the *social* aspect of our social-material tools. Linked to theme of lacking resources, we came to the conclusion that a stand-alone toolkit cannot meet all requirements and constraints of the school context. The teachers need additional *social* support to be able to meaningfully apply the toolkit in class.

We approached this by building upon the notion of infrastructuring. As was shown in the Atelier project, infrastructures can support the use of toolkits after the research project has ended [1]. We want to use a similar approach in our context and apply infrastructuring in the context of PD with children in a school context. Hence, we explored what kind of additional *social* support teachers would need.

Figure 5 shows an overview of all socio-materials we created and continue working on for the toolkit. We first lay out the parts of the social infrastructure we already are building (collaboration, online platform), including what the teacher's feedback was from the online survey on the proposed support communities and give at the end an overview for future infrastructuring possibilities.

6.2.1 Collaborations. The situated context of schools and teachers comes with requirements and constraints, for instance limited resources, as we pointed out in the findings. Partly, we could approach this challenge by focusing on digital, low/non-cost materials (i.e. videos). But we learned from the design workshops with the children, that the children greatly benefit from experiencing technologies like sensors or outputs, and enjoy seeing their ideas realised in working prototypes.

Table 3: Overview of requirements.

List of requirements		
Requirement	Source	Number of teachers supporting this requirement
Little effort for teachers to prepare activities	interview, workshop, survey	5
Materials designed for teachers who have no/little experiences with technology	interview, workshop, survey	4
Only brief information for teachers	interview, workshop	3
Short and modular activity units	workshop, survey	3
Free toolkit	interview, workshop	4
Toolkit digital available	workshop	2
Activities match curriculum	workshop, survey	3
Technology examples match children's life-world	interview, survey	2
External support/infrastructures (i.e. FabLabs, Makerspaces)	workshop, survey	6

Table 4: Overview of material tools

Tool	Function
Technology cards	Set of 18 different technology cards: each card explains either a sensor, output or technology (e.g. 3D printing)
Technology videos	Short videos (30 seconds) show and explain technologies listed on the cards
Theme cards	Two chosen themes (Fantasy & Sci-Fi) support children thinking out-of-the-box, themes are adaptable for other topics if teachers want to explore curriculum related topics
Design trigger cards	Design trigger for children by raising questions or challenges that could be solved with technology.
Teacher handbook	Short, structured, "scan at one glance" workflows and introductory explanations to use for workshops, with modular build: steps can be left out or switched
Inventor diary	Booklet for children, with pages for notes, to record design process for each workshop

To realistically facilitate design and technology experiences for the children, access to FabLabs or collaborations with design/engineering experts will be necessary. Creating networks of people with the technical resources, for instance people working in FabLabs, could support teachers to at least partially implement the design ideas of the children and to have them experience technologies without needing to be experts themselves.

As an alternative way dealing with the issue of constraints and missing resources is to address it on a political level. Part of the constraints are related to full curricula or structural challenges, which teachers cannot change easily [37].

Addressing this matter, we introduced our research project to the education authority of the city. He was supportive about our work with the children and raised the question how we could bring parts of it into the city's schools. Although this meeting was only a first step to raise the awareness of policy-makers about our work and had not led to changes in the school's context (for instance by funding toolkits like ours for all schools in Vienna), we want to show with this example how infrastructuring on different levels and from different angles can support our aims. For instance, by engaging key stakeholders like policy-makers, who have the power to influence the school's structures and resources.

Another finding, the teachers' lack of technical skills, could be approached on a societal level. We previously suggested to provide teachers with contacts of Fablabs. A different solution could be to collaborate with teacher training colleges and introduce the topic of technology design and PD with children there.

We started a collaboration with a college for teachers in training in our city to explore if they could use (parts of) the toolkit in their curricula and to get in touch with other teachers (in training) as possible toolkit users. We believe that this could be a promising route to lay the groundwork for future teachers, enabling them to include technology design in their skillset.

6.2.2 Online platform. So far, we discussed possible collaborations and partners as one approach of infrastructuring. The second attempt relates to the facilitation of those collaborations: an online platform for peer support and as a source for toolkit materials.

We had already decided to make the core part of the toolkit digital (cards, videos, teachers booklet and the inventor diary) and

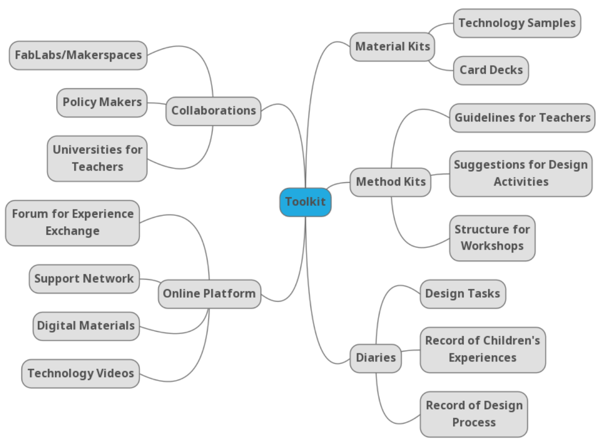

Figure 5: Associated infrastructures in the socio-material toolkit.

available on a website [4]. This website was also shared with the participants of the online survey.

In terms of scaling, an online toolkit gave us the chance to increase the reach of the toolkit beyond the researchers' contacts, and allow multiple uses of the toolkit materials at the same time. Furthermore, it allows an online exchange of the teachers' experiences (for instance on a forum) and peer support. The latter was only evaluated theoretically, we have not built or tested a forum yet, but suggested the concept in the online survey.

6.2.3 Feedback from teachers from the online survey. To get initial responses from teachers on our approaches to create a support community that would aid them using the toolkit, we asked participants of the online survey if they would be interested in collaborations.

One question in the online survey was dedicated to explore the teachers interests in the collaboration with FabLabs. Indeed, three of five teachers would like a collaboration, two of them answered maybe.

We also presented the idea of an online platform to them in the online survey, to share their design workshop experiences with each other. The teachers who participated in the online survey had mixed opinions about this platform, two were in favour, two unsure and one teacher was not interested.

7 DISCUSSION

In this paper, we have shown how we prepared for leaving the field by developing a socio-material toolkit for teachers. Our findings show that we deal with a complex situated context at schools and teachers are facing a number of constraints. We argued for embedding the socio-materials as in their context and meeting their requirements. Coming to the conclusion that a "stand-alone" material toolkit is not sufficient to enable teachers to evolve their practices around technology design with children, we build upon the notion of infrastructures and elaborated on how we have applied this concept to re-think existing toolkit approaches. We added *social* components to our toolkit by corresponding with policy-makers and university for teachers in training, and suggested further possibilities to create a socio-material infrastructure.

After presenting the findings and the final toolkit prototype, we reflect on them and suggest more general guidelines and implications to inform future projects.

7.1 Guidelines for planning the project's end

7.1.1 Infrastructuring the social. We have built in this paper upon the notion of infrastructures and socio-material systems that support the integration of technologies in practice [28].

Prior to integrating the toolkit in practice, we explored the context specific requirements and constraints of teachers. We quickly realised that a "stand-alone" toolkit wasn't sufficient to support teachers adequately in their situated context. We have shown in our case study what kind of support, either with physical materials or as social support, would be needed to implement the toolkit in their context of practice.

On a broader level, the case study shows how infrastructuring can support a toolkit design process by emphasising the importance of collecting and aligning socio- and material resources. Our case study gives first insights about the different angles that are worth exploring when collecting resources, for instance a collaboration with technology experts (i.e. FabLabs) or policy-makers. We are still in the process of aligning socio- and material tools to create a stable community for sustaining a toolkit beyond the projects' end.

Infrastructures can further enable participants to adopt and appropriate socio-material tools beyond the initial design and involve new participants not engaged in the research project [28]. Reflecting on our findings, we think that a toolkit designed for a complex situated context like schools could greatly benefit from being open for appropriation. We previously discussed the need for modularity of a toolkit and how we could achieve this with carefully chosen methodological materials (for instance a flexible workshop structure). On a social level, we support appropriation by creating an (online) environment for peer exchange and support, inviting toolkit users to their adaptations.

We thus recommend two things: First, to consider all infrastructures which are necessary to embed a toolkit in a specific context and second, playing with modularity to support the evolvement of the toolkit.

7.1.2 Exploring contextual restraints. We have pointed out the challenges we experienced during the process, mainly linked to the requirements of teachers - in short, lack of resources available to teachers, such as time, money and skill, and a need for adaptability to different curricula and classroom situations. The challenge of organizational conditions has been reported previously in the literature, when researchers aimed to integrate new teaching practices in an educational context [39]. We believe that those challenges are not unique about our research context, as pointed out in the literature as well [32, 39, 48]. It is for instance a common problem, that participants lack sufficient skills to maintain technological project outcomes [48].

For a toolkit to be continued to be used, it must be embedded in the context of practice and meet the requirements of its users. Therefore the first step of the development process was to capture

[4] https://spttoolkit.wordpress.com.

important requirements of the teachers' work context in which the toolkit should be applied. Since we became aware of the complex situation, we iteratively discussed requirements with the teachers and asked during the co-design workshop if all materials were feasible to use. During the evaluation with teachers who were not previously involved, we raised the question again, since other schools might have different requirements. While the requirements did not differ much, our presented materials often raised new challenges or prompted teachers to suggest novel ideas to avoid resource problems. For instance, using pattern instead of colour codes for the technology cards categories (see Figure 3).

Hence, we strongly recommend to carefully explore the contextual restraints in which the toolkit will be used, preferably as an iterative process.

7.1.3 Considering the project's core values. When developing the content of the toolkit, we not only took into account the expectations and requirements of the teachers, but which visions and insights of the project we wanted to live on as part of the toolkit.

A central part of our PD work is the empowerment of children through participating in a design process. We were faced with the challenge of how to "pack the spirit of PD in a bag". In the toolkit, this was solved for instance with the diaries. They enable the children to keep track of their own design process and assume the role of "inventors", and this plays an important part in framing the toolkit activities as self-driven creative research.

Values are a core element of PD projects [27]. Considering the project's values contributes to our argument that we should think of toolkits in broader ways. A toolkit, like this example shows, has the potential to incorporate and carry on visions or values that researchers would like to outlive the initial project. In this case-study we wanted a PD lens to be part of the toolkit, which entails empowerment notions.

7.1.4 Inviting and designing for new audiences - Shifting from local to broader contexts. Ledo et al. previously stated that toolkits have the opportunity to empower new audiences [32]. Drawing upon this, we aimed for our toolkit to be used in the future by teachers not previously involved in our research project. However, those new audiences might have different contexts, and different expectations or requirements, as we explained in the previous point. We argue that, knowing the contextual dependencies, can support the transfer of toolkits [33].

Another reason to do this, is that teachers who are familiar with the research project already have a basic understanding of design workshops and the researchers' work. Others might have more difficulties to engage with the toolkit when the topic is new to them.

Hence, we suggest to invite participants not previously involved to different phases of the toolkit design process, to ensure that the toolkit is open for new audiences as well. Inviting new participants allows researchers to get a better understanding of the broader context and enables them to identify possible mechanics of adaptation, which are necessary for future anticipated use.

7.1.5 Considering scalability. Most existing technology design toolkits for children are based on physical materials, for instance electronic components [25, 31, 35, 44]. In case of commercially available toolkits, scalability is less an issue, but research projects usually do not have the financial resources to produce physical materials at a large scale. After a project (and its funding) has ended, building more material will become even more difficult. As our findings show, schools and teachers also lack financial resources to buy physical toolkits.

Dealing with this challenge and to ensure scalability of our socio-materials, we decided to focus on digital materials (that can be printed by teachers) and embed them in a social infrastructure. Scaling social infrastructures is a more complex challenge, but could be achieved by collaborating with people who are part of a broader infrastructure they can share the toolkit with (for instance policy-makers or school administrators).

We recommend to explore opportunities for scalability when developing a toolkit, which might look different in other contexts.

7.2 Implications for PD practices

Finally, we want to reflect upon what we can learn from our experiences for future PD practice.

7.2.1 Pro-active attitude. It is not an uncommon phenomena that, in PD, project interventions or outcomes are reversed after the researchers have left the field [8, 18, 21]. When setting up the project, we were concerned about how to embedding our projects outcomes in the school's context and ensuring that the children will benefit from the collaborations. However, what would happen after the project and how those positive experiences could be sustained and made available to new teachers and children not involved in the project, was not a priority until later in the project.

We made choices at the beginning of the project, for instance in terms of connecting to participants and local stakeholders. At that point, we were mainly interested in school contacts (mainly teachers) who would help us to organise PD workshops. In hindsight, inviting a broader range of participants to the project, for instance Fablabs or policy makers, would have helped us at the end to set up a supportive community for the toolkit. Doing this at the project's end brought up challenges: we could not invite prospective collaborators to PD activities with children since the workshops were already coming to an end and we had less time to invest in networking. An unforeseen event [5] led to a cancellation of meetings with possible supportive participants.

Reflecting upon this experience, we argue that researchers should start planning for the project's end as soon as possible. This process could start even during the planning of the project proposal when budget is calculated (which could be necessary to buy/build tools at the project's end for example) and possible stakeholders and participants are identified. In line with this argument, we suggest to have a pro-active attitude when considering to leave a toolkit or similar resources behind after a project has come to an end. In a complex situated context like schools, for instance, one could anticipate possible challenges and needs that come with a toolkit. Making it part of the project's agenda and part of the researcher's routine to explore possibilities for sustaining projects outcomes

[5]The COVID-19 pandemic in Austria resulted in strict rules regarding social distancing in the work and social context: https://www.who.int/emergencies/diseases/novel-coronavirus-2019

might spare time and ensure the building of fundamental structures that need to be in place at the project's end.

7.2.2 Infrastruturing as an approach to reintroduce politics and ethics. Two important notions of PD are ethics and politics, which both go a long way back to the Scandinavian roots of PD [4]. Karasti et al. pointed out that infrastructuring can be an opportunity to reintroduce politics into PD [28], and related ethical concerns [40]. Pihkala and Karasti argue that addressing political matters is always also an ethical one.

We have previously pointed out that a toolkit can be used to encapsulate values, for instance the empowerment of marginalised groups, in design practices. By implementing ethical considerations in a toolkit, they might challenge others (for instance teachers) to re-think their practices. In the case of the schools' rigid structures (e.g. curricula), this goes beyond the personal level of teachers. As such, a toolkit is a political artefact.

Empowering children to design and re-think technologies, for instance, is not part of the schools curricula we have worked with during the project. Our toolkit offers methodological suggestions and materials how to implement those disciplines in class. Hence, we challenge the current curriculum and understanding of teachers and policy-makers how technology classes look like.

By presenting the toolkit concept and research project to a policy-maker in education, we only started to explore the possibilities of infrastructuring on a political level with a toolkit. But we would like to encourage researchers to consider a toolkit as an opportunity to address ethical and political matters.

7.2.3 Leaving the field in PD. Finally we want to revisit the topic of leaving the field, what this means for PD practitioners and how infrastructuring can help with this challenge.

We first defined what leaving the field means in our project context and what is actually left behind. During the initial research project, the researchers were responsible for organising and running PD workshops at the schools. As identified previously by other PD practitioners who involve children, the pupils gained an impressive amount of design process knowledge [38]. The teachers observed similar positive effects on the children, however, their mutual learning experiences were challenged by their lack of time in participating in the PD workshops. Those who could be present expressed the concern that they feel unable to integrate design workshops in their own practice, related mainly to contextual restraints as the findings have shown. Furthermore, when aiming for scaling PD initiatives, mutual learning might not support new audiences who are unfamiliar with the initial research project. We thus need a strategy to enhance mutual learning when researchers have left the field. Without any support for the teachers, the initiative would have no lasting effect on schools, the teachers practice or children who were not involved in the initial research project.

Iversen and Dindler suggested network activities among project partners as an infrastructuring approach to support mutual learning activities [26]. In an educational context, collaborations with FabLabs or an online network connecting teachers, could create new possibilities for teachers to engage in mutual learning activities beyond the project's end.

8 CONCLUSION

Finding ways to sustain outcomes of research projects conducted in situated contexts is a challenge many HCI practitioners are facing. One approach to facilitate this is the development of a toolkit - "packing up" outcomes in tools which can be continued to be used by the participants. So far, most technology design toolkits are "stand-alone" tools that provide users with physical, theoretical or methodological materials. We argue that, in a particular situated context like schools, we need to think of a toolkit in broader terms - as a *socio*- material collection of tools to enable and support its use. During our research project, we co-designed technologies with children at primary schools and collected a variety of experiences in the field of technology design with neurodiverse children. To design the socio-material tools for teachers to continue our work, we conducted an interview, a co-design workshop and an online survey with primary school and special education teachers. We explored their requirements, needs and expectations and evaluated specific materials with the teachers. In addition to designing physical, digital and methodological tools, we actively engaged in creating a supporting community as part of the toolkit. Based on our experiences, we suggest a list of guidelines for a toolkit design process and implications for future PD practitioners how to prepare for leaving the field.

Since we had only limited resources and possibilities for developing the social network for the supporting community, future work will focus on developing this community. It would be also interesting to evaluate the long term use and impact of the toolkit. Evaluating the "success" of the toolkit would require to "measure" the user adoption in the future and the evolvement of the infrastructure after leaving the field [32]. Hence, an evaluation study is beyond the paper's scope.

The majority of participating teachers in this study have a background in special education, so future research will be necessary to explore if the approach is applicable for education in general.

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