When Participatory Design Projects End
Designing a Toolkit for Teachers

DISSERTATION

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by

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Erklärung zur Verfassung der Arbeit

Laura Scheepmaker, MSc.

Hiermit erkläre ich, dass ich diese Arbeit selbständig verfasst habe, dass ich die verwendeten Quellen und Hilfsmittel vollständig angegeben habe und dass ich die Stellen der Arbeit – einschließlich Tabellen, Karten und Abbildungen –, die anderen Werken oder dem Internet im Wortlaut oder dem Sinn nach entnommen sind, auf jeden Fall unter Angabe der Quelle als Entlehnung kenntlich gemacht habe.

Wien, 22. September 2022

Laura Scheepmaker
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As this work was based on a participatory design project, the children who were part of the Social Play Technologies project and the teachers who participated in the studies contributed to this work. This work aims to support teachers to evolve their practices around PD and technology design workshops. The participating children and teachers also supported me to evolve my own practices and understandings as a researcher. I am utterly thankful for each of the participants who supported the SPT project and this thesis.

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Kurzfassung


Um die Forschungsfrage zu beantworten, entwickelte ich ein Toolkit. Dieses besteht aus unterschiedlichen Ressourcen, die Lehrer:innen dabei unterstützen können, Kindern in technischen Gestaltungsprozessen eine aktive Rolle zu geben. In diesen Prozessen

Diese Arbeit liefert zwei Beiträge:

1. Ein Toolkit für Lehrer:innen, was sie dabei unterstützt mit Kindern auf PD basierte technische Entwicklungsprozesse zu durchlaufen.

2. Leitlinien für zukünftige PD Projekte die Forscher:innen helfen können ihre Arbeitsweisen und Erfahrungen bei ähnlichen Zielgruppen zu etablieren.

Abstract

Enabling participants of participatory design (PD) projects to maintain the practices and experiences of the project and sustaining PD practices and experiences for similar audiences not involved in the initial project, is an ongoing struggle in Human-Computer Interaction (HCI) and PD. Especially in PD with children, many PD projects result in positive and meaningful experiences of the participating children. Nevertheless, many of the practices that are established during PD projects are not maintained by participants, or sustained for similar audiences not involved in the initial project after the project ends. Such projects often take place in schools where the teachers are part of their respective schools’ setting and constraints structures. This makes it harder for the teachers to adopt new practices (for instance PD workshops as part of the curriculum).

In this thesis, I reflect on the experiences and challenges in enabling participants of the PD project (primary school teachers) and teachers not involved in the initial project to conduct PD and technology design activities after the initial research project, the Social Play Technologies (SPT) project, ended. The aim of the SPT project was to design interactive technologies which support neurodivergent children with social play. Towards this, we conducted 50 PD workshops with three groups of neurodivergent primary school children. We co-designed social play technologies, resulting in both technological prototypes and methodological outcomes. The participating teachers were enthusiastic about our approach to involve children actively in the process of designing, and re-thinking technologies. However, they did not feel able to evolve their own practices based on the experiences of working with us. Nearing the projects’ end, we focused on creating resources that enable teachers which were involved and not involved in the SPT project to conduct PD and technology design activities with their class, aiming to enable SPT experiences for children not involved in the SPT project. This required us to think about the school’s context and what teachers would need to be able to conduct PD activities with children. Hence the guiding research question for this thesis is: “How can we increase the likelihood that the positive experiences and practices of PD projects in a school context are sustained for teachers participating in the project and teachers and children not involved in the initial project?”.

To address this question, I created a toolkit as a collection of resources that supports teachers to empower children to engage with technology in creative and critical ways and to create their own technologies. Toolkits have been successfully applied in the past to
empower new audiences (such as teachers), enable creative exploration and support the integration of resources in current practices and environments (such as schools). This thesis reports on my process and findings from developing a toolkit for teachers. I give a critical overview of current technology design toolkits which are mainly stand-alone artefacts, arguing for building upon the notion of infrastructuring to design socio-material tools that meet the constraints of a school context and needs of teachers. After exploring the characteristics of a school context, I developed a toolkit in collaboration with teachers. The toolkit aims to sustain targets of the SPT project, sustainability targets (positive experiences of children participating in the SPT project which we aim to sustain for children not involved in the initial SPT project), and enablers (SPT practices which enabled children in the project to participate in technology design activities) of the SPT project. The enablers are practices that empowered children to engage in technology design activities supporting creativity, problem solving and critical engagements with existing technologies. The toolkit aims to support teachers to engage in SPT practices through which children are enabled to engage in similar PD activities and have experiences similar to the children involved in the SPT project. The evaluation of the toolkit suggests that the teachers are able to evolve their own practices around the toolkit. Hence, using a toolkit approach could be a first step to enable similar audiences to have PD experiences beyond the initial PD project’s end.

My work makes two main contributions:

1. A socio-material toolkit which supports teachers to engage in technology design activities with children, using methods based on PD practices and a support network

2. Considerations for future PD practices which can help researchers to enable participants and similar audiences not involved in the initial project to evolve their practices around PD

This work contributes to the field of PD and HCI, aiming to support researchers when taking preparations for enabling participants and similar audiences not involved in the initial project to have PD experiences. The considerations take into account the complexity of project contexts, suggesting a toolkit as approach to create socio-technical infrastructures which enable participants and new groups of people to evolve their practices around PD practices.
Publications

Peer-reviewed conference papers


Peer-reviewed extended abstracts


Laura Scheepmaker, Christopher Frauenberger and Katta Spiel. 2018. Exploring Roles of Technology in Co-Design Activities. In PDC ’18 Workshop Giving a Voice
Through Design – Adapting Design Methods to Ensure the Participation of People with Communication Difficulties (2018)

Workshop contribution & doctoral consortium

These additional, juried contributions are not attached to this dissertation but are used to document further contributions to the scientific community.


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CHAPTER 1

Introduction

1.1 Motivation

In this thesis I address the challenge of enabling teachers to conduct PD and technology design practices. I aim to enrich their practices and explore ways to enable similar experiences beyond the end of the initial PD project. Sustaining positive experiences and practices of PD projects is a challenge in Human-Computer Interaction (HCI) and Participatory Design (PD) with children, especially when it is in a situated context (Schepers, Schoffelen, Zaman & Dreessen, 2022a, 2022b; Iversen & Dindler, 2014). I build upon the tradition of PD to sustain outcomes (Poderi & Dittrich, 2018; Bossen, Dindler, Garde & Pipek, 2014; Kensing & Blomberg, 1998), but going one step further: Instead of sustaining direct outcomes of PD projects for people involved in the PD project, I aim to sustain experiences and practices of the initial project for teachers involved in the initial project and teachers and children not involved in the initial project.

However, teachers lack the resources (e.g. skills or funds) to be able to maintain or build technological artefacts, adopting the practices of the researchers, or the practices are not sufficiently embedded in the context and cannot be adopted by them (Bødker, Dindler & Iversen, 2017). Especially when technological artifacts are created or design skills are needed for the process, researchers should be aware of their greater access to resources like technologies and design skills. After PD projects end, teachers need sustainable technological or methodological resources to be enabled to conduct PD practices and technology design activities.

Enabling teachers to conduct PD design activities also poses challenges of sustaining PD practices and positive experiences (Iversen & Dindler, 2014). Especially in PD with children, many of the practices that are established during PD interventions are not carried on beyond the project’s end. PD projects with children often take place in schools where teachers are part of their respective schools’ and policy-makers’ setting.
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and constraints. This makes it harder to adopt PD practices (i.e. technology design workshops) \{Iivari & Kinnula 2016; Bødker et al. 2017\}.

With the term sustainability, I refer to efforts which have “the quality of being able to continue over a period of time” \{The Cambridge Dictionary 2019\}. In terms of sustainability, I was particularly interested in the period of time after a research project has ended and how researchers can enable PD experiences and practices of a PD project for similar audiences not involved in the initial project. I use the term similar audiences referring to children and teachers not involved in the initial research project. I aim to sustain the experiences and practices of the initial project for those similar audiences, in addition to enabling the teachers who were participating in the research project to maintain our PD practices and experiences at the respective schools involved in the project.

Working with children in a situated context required us, thus, to think more closely about how we can enable teachers to embed PD practices in the school’s context in ways that the likelihood is increased that PD practices and positive experiences of the research project are sustained. The work reported in this thesis takes place as part of a broader research project, called the ‘Social Play Technologies’ (SPT) project \{Scheepmaker, Frauenberger & Spiel 2018; Frauenberger, Spiel, Scheepmaker & Posch 2019; Frauenberger, Kender, Scheepmaker, Werner & Spiel 2020; Kender, Frauenberger, Pichlbauer & Werner 2020\}.

In the SPT project, we collaboratively designed interactive, digital play technologies in co-located groups of neurodivergent \[^1\] children and explored how they can scaffold and mediate social play activities in a school context. We conducted three series of PD workshops (50 in total, each lasting approximately one hour) with three groups of children (15 in total) at two different schools. The children were aged 8 to 11 years. During the workshops, we co-designed social play technologies and built working prototypes which were later evaluated with empirical studies in the school context. We defined social play technologies as “interactive, technological playthings that are intended to be used socially by children within the same physical space in an embodied way” \{Scheepmaker et al. 2018\}. Next to the prototypes, that supported and mediated social play among children, our outcomes were methodological insights, empowerment of children in designing and re-thinking technologies and mutual learning for both teachers and researchers on how to facilitate those processes \{Frauenberger et al. 2019, 2020\}.

Before exploring how I could sustain experiences and practices of the SPT project, I reflected on the SPT project to define \textit{what} exactly it is we aim to sustain from the SPT project and what PD and SPT experiences are. As the SPT project was deeply rooted in democratic values and ideals of PD, children were actively involved in technology design processes for the sake of empowerment and democratising technology design processes (see for instance \{Iversen, Halskov & Leong 2010\}). Having those experiences around empowerment and technology design activities can contribute in a positive way to their personal development, as skills such as creativity, autonomy and problem-solving

\[^1\]I use the term neurodiversity as coined by Judy Singer, referring to people with neurological differences, for instance autism or ADHD.
are supported (Iversen, Smith & Dindler, 2017a; Skinner, 2020). Hence, I defined positive experiences centering around empowerment in technology design processes as sustainability targets: Positive experiences of the children involved in the SPT project which I aim to sustain for children not involved in the initial project. Next, I reflected on the practices we applied in the SPT project which enabled those positive experiences in the SPT project: The enablers (see Chapter 4). As further elaborated in Section 4.3 and Chapter 2 the SPT practices were grounded in PD practices and enabled the empowerment of children in design processes.

Not only the researchers of the SPT project were motivated to sustain the experiences and practices of the project: The participating teachers were enthusiastic about our approach to involve children actively in the process of designing, and re-thinking technologies and stated that the children benefitted from our collaboration. They reported for instance that the children re-created situations from the SPT workshops in the classroom to have similar experiences. When the education authority in Vienna visited our lab, he was also enthusiastic about our work in the SPT project and asked us: “How can we bring this [the way children engage with technologies] to schools?”. When asking the teachers who participated in the SPT project if they would like to continue doing technology design activities with children, they felt unable to evolve their own practices based on the experiences of working with us. This was due to multiple reasons, for instance, that they lacked the technical or methodological skills to facilitate similar design processes. This raises the questions how we could support teachers involved in the SPT project to maintain SPT practices and experiences, and how we could scale the SPT practices and experiences to enable teachers not involved in the initial SPT project to replicate and evolve SPT practices at their own schools. I use the four terms maintaining, scaling, replicating and evolving as introduced by Iversen and Dindler (2014) to conceptualise the different sustainability aspects I aim for in this thesis (as further illustrated in Chapter 2).

Hence, nearing the projects’ end, I focused on creating resources that enable teachers involved in the SPT project and teachers not involved in the initial project to conduct PD and technology design activities with their pupils. This required me to gain a deeper understanding of the school’s context characteristics and which resources it requires to increase the likelihood that positive experiences and practices of PD projects are sustained in a school context.

1.2 Research questions and approach

The guiding research question for this thesis is:

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2One group of children built ‘caves’ from furniture and fabrics they felt comfortable playing in, which became one of the main practices during the workshops. Their teacher told us that the children were enthusiastic about this element of the workshops and started to build similar ‘caves’ in their classroom.

3‘Stadtschulrat’
1. Introduction

“How can we increase the likelihood that the positive experiences and practices of PD projects in a school context are sustained for teachers participating in the project and teachers and children not involved in the initial project?”

Research question 1:

What does sustainability mean for a PD research project?

To answer this research question, I analysed existing work in the context of sustainability and PD (with children). I discuss PD projects with adults, before narrowing down the focus to PD projects with children. I argue for using infrastructuring as a lens to support sustainability of PD research projects. This contributes to a better understanding of the problem space, gives first insights in how I could approach the challenge and on what existing work I can build upon.

I formulated a sub research question which focuses on the specific context of the SPT project: What does sustainability mean in the context of the SPT project and what could be possible targets and enablers to sustain?. To answer this research question, I analysed the positive experiences children had during the SPT project which we aim to sustain for children not involved in the initial project, the sustainability targets, and what was needed to support those targets. I reflected upon the design process and which practices enabled the children to engage in designing and re-thinking technologies (the enablers).

Research question 2:

What makes it challenging to have sustainable PD practices and experiences in a school context?

To answer this research question, I interviewed teachers involved in the SPT project to discuss constraints and requirements of the school context and conducted a co-design workshop were we re-design the initial toolkit prototype. Teachers are part of their respective schools’ and policy-makers’ setting and constraints, which makes it harder to adopt PD practices (i.e. technology design workshops) (Iivari & Kinnula, 2016; Bødker et al., 2017). Hence, exploring their contextual constraints was crucial in the toolkit design process. I introduced the idea of a toolkit to the teachers as a collection of resources to support them to enable children to design technologies. I conducted an online survey with teachers not involved in the SPT project to further deepen my understanding of the characteristics of the school context, and to initially evaluate the idea of using a toolkit. This contributes to a better understanding of the school context, leading to a list of design implications for a toolkit.

Research question 3:

What does a toolkit need to contain to support teachers to evolve their own practice around technology and participatory design?
To answer this research question, I first conducted a scoping review of existing toolkits for children in the field of HCI and PD. The previously defined sustainability targets and enablers informed the first toolkit concept. However, what worked well in a PD project run by researchers, does not necessarily have to work in school projects or lessons run by teachers. Teachers are bound to the school context requirements, rigid structures and existing power imbalances between children and teachers in ways researchers are not. Schools have for instance a high pupil-teacher ratio which makes PD practices, which require individual support of children, and children-centred teaching approaches, challenging. Hence, I developed a first toolkit concept based on 1) enablers from the SPT project and 2) first explorations of the school context. Next, I re-designed the first toolkit concept in a co-design workshop with teachers, leading towards the second toolkit concept. After conducting an online survey with teachers not previously engaged in the SPT project or toolkit design process, I developed the third toolkit concept. This iterative design process contributes to a more refined understanding of the school context and final toolkit prototype which aims to support teachers involved and not involved in the initial SPT project to enable children to engage in designing and re-thinking technologies.

Research question 4:

*How can teachers not involved in the initial SPT project incorporate the toolkit into their own practice around technology and participatory design?*

To answer the final research question, I conducted an evaluation study with teachers who planned how to use the third toolkit concept in class. The participating teachers were not involved in the initial SPT project. Based on their written lesson plans I gained first insights into how teachers would incorporate the toolkit into their own practice. In focus groups and a semi-structured interview, I discussed with the teachers how they would appropriate the toolkit and explored how their practice could evolve when using it. This contributes to an initial understanding how teachers not involved in the initial project would incorporate the toolkit, appropriate it and how it might affect their practices around technology design activities and PD.

1.3 The impact of COVID-19 on this thesis

Parts of the research which led to this thesis was conducted during the COVID-19 pandemic. After I conducted the co-design workshop with teachers, I was facing restrictions caused by the COVID-19 pandemic. This influenced the choice of research methods to meet the rules regarding social distancing, and the availability of participants. Researchers were not allowed to enter schools in Vienna and during each lock-down the children were home-schooled. Hence, I could not organise studies involving children. The restrictions at schools also led to an increased workload for teachers, which had a negative

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1. Introduction

Impact on their availability and motivation to participate in my research project. I had for instance a low response rate for the online survey and the evaluation study. Hence, my findings (especially from the evaluation study) are presented as suggestions instead of definitive guidelines.

1.4 Contribution

I contribute to the field of HCI and PD by exploring how audiences involved and not involved in the initial PD project, in this case study primary school teachers, can be enabled to conduct PD and technology design activities together with their pupils and have PD experiences centred around empowering children in technology design processes. As part of the contribution, I present design implications for a toolkit and challenges that are linked to the special context of the case study - a school setting. The first main contribution is a socio-material toolkit which supports teachers to engage in technology design activities with children, using methods based on the SPT practices and a support network. Based on the critical overview of current technology design toolkits which are mainly stand-alone artefacts, I argue for building upon the notion of infrastructuring to design socio-material tools that meet the constraints and characteristics of a school context. First insights from the evaluation study show that the toolkit supported teachers to evolve their practices around PD and technology design activities and how they appropriated the toolkit. The second main contribution are considerations for future PD projects which aim to help PD researchers to increase the likelihood of sustaining PD practices and experiences beyond the project’s end. I hereby address the challenge that projects often take place in a situated context and participants lack the resources or skills to evolve their practices around PD and technology design activities. The considerations draw, like the toolkit, on infrastructuring as approach to analyse, utilise and evolve existing infrastructures as pathway to increase the likelihood of sustaining positive experiences and practices of PD projects. In this way, participants of the PD project and similar audiences not involved in the initial project remain supported (with resources or skills, for instance) after the research project’s end.

1.5 Thesis structure

The thesis overview is presented in Figure 1.1. The overview shows how the research questions relate to each other and the contributions. The main research question is answered and the two main contributions are made:

In Chapter 2 I first explore what sustainability means in the context of this work and how it relates to the field of PD. Second, I introduce infrastructuring as an approach to sustain positive experiences and practices of research projects. Third, I present the results of two systematical literature reviews: Sustainability aspects PD projects with children and an overview of existing toolkits for children in the fields of HCI and PD.
1.5. Thesis structure

**Main Research Question:**
How can we increase the likelihood that the positive experiences and practices of PD projects in a school context are sustained for teachers participating in the project and teachers and children not involved in the initial project?

<table>
<thead>
<tr>
<th>Related Work</th>
<th>Research Question 1: What does sustainability mean for a PD research project?</th>
</tr>
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<tbody>
<tr>
<td>Scoping review 1: Sustaining practices and experiences in PD with children</td>
<td>Infrastructuring</td>
</tr>
<tr>
<td>Scoping review 2: Overview of existing toolkits</td>
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<table>
<thead>
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<th>SPT project</th>
<th>Sub-Research Question: What does sustainability mean in the context of the SPT project and what possible targets and enablers could be to sustain?</th>
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<tr>
<td>Sustainability targets</td>
<td>Enablers</td>
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<tr>
<th>School context</th>
<th>Research Question 2: What makes it challenging to have sustainable PD practices and experiences in a school context?</th>
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<tbody>
<tr>
<td>Insights in contextual constraints</td>
<td>Needs and wishes of teachers</td>
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<tr>
<th>Toolkit</th>
<th>Research Question 3: What does a toolkit need to contain to support teachers to evolve their own practice around technology and participatory design?</th>
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<tbody>
<tr>
<td>Design implications toolkit</td>
<td>Three toolkit concepts</td>
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<tr>
<th>Evaluation</th>
<th>Research Question 4: How can teachers not involved in the initial SPT project incorporate the toolkit into their own practice around technology and participatory design?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Considerations for future PD practices</td>
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Figure 1.1: Overview of this thesis and visualisation of the research questions related to the steps taken to answer the main research question.
In Chapter 3, I motivate the research paradigm in which this thesis is positioned, the chosen methodological approaches and discuss ethical considerations. I present the SPT project which lays the foundation for this thesis and the toolkit.

In Chapter 4, I reflect upon the sustainability targets (experiences of participating children we aim to sustain for children not involved in the initial project) and the enablers (SPT practices which enabled children in the initial project to engage in technology design processes).

In Chapter 5, I present the design process of a toolkit which aims to support teachers to empower children to engage with technology in creative and critical ways and to create their own technologies. During the toolkit design process, I iteratively explore the characteristics of the school context. By introducing the toolkit concepts, I discuss the needs and wishes of the teachers and gain a deeper understanding of contextual challenges in a school context.

In Chapter 6, I present the findings of the evaluation of the final toolkit prototype and extend the list of design implications for the toolkit.

In Chapter 7, I reflect upon the lessons I learned during the toolkit design process and suggest considerations for future PD practices.

In Chapter 8, I outline the contribution of this thesis by summarising research questions and answers.
Related Work

This chapter discusses the related scientific context this work is grounded in. First, I discuss the challenge of sustaining practices and experiences of PD projects and define what sustainability and related terminology means in the context of this work. I give a brief overview of the history of PD and how this work relates to existing work and challenges in this field. Second, I present the results of two scoping literature reviews: How sustainability is addressed in PD projects with children and an overview of existing toolkits for children in the field of HCI and PD. Fourth, I introduce infrastructuring and toolkits as approaches to sustain experiences and practices of PD projects.

This chapter answers the first research question: What does sustainability mean for a PD research project? and gives first insights for answering the second research question: What makes it challenging to have sustainable PD practices and experiences in a school context?

2.1 Defining terms used in this thesis

This work aims to explore how we can increase the likelihood that practices and experiences of PD projects in a school context can be sustained after the initial PD project ends. This question contains terminology which is not clearly defined and might mean different things depending on the context. Hence, I illustrate how those terms are defined and how I use them in this thesis.

2.1.1 Sustainability

Scholars have been struggling with sustainability and sustaining practices and experiences of PD projects since the beginning of PD history. In 1993, Clement and Van den Besselaar took a retrospective look on early PD projects and came to the conclusion that PD practitioners struggle with creating sustained impact ([1993](#)). One
2. Related Work

of the first and most known PD projects, UTOPIA, failed to create a labor-oriented technological alternative or changed practices of the company. However, the project definitely had a long-lasting impact on the history of PD, its political values and methods (Kyng, 2010).

There is no single agreed-upon definition of what sustainability means for PD projects, and the term is interpreted differently by scholars (Poderi & Dittrich, 2018). Hence, I illustrate here how I define sustainability in the scope of this thesis. The term sustainability is used in different contexts, it addresses for instance environmental issues. More generally defined, sustainability can be translated as “the quality of being able to continue over a period of time” (The Cambridge Dictionary, 2019). Design projects, especially in academia, are time-limited. In terms of sustainability, I am particularly interested in the period of time after a research project has ended and how we can sustain PD practices and experiences for audiences not involved in the initial project (and hence beyond the initial project’s time). Referring to the first part of the definition, PD practices and experiences ideally continue over time.

In this thesis, I do not aim to sustain or continue to design any technological artefacts which were developed during the initial SPT project. Instead, I focus similar to Iversen and Dindler (2014) on aiming to sustain PD practices and experiences of the initial SPT project for teachers involved and children and teachers not involved in the initial SPT project. I build upon the terms of Iversen and Dindler (2014) introduced to conceptualise different aspects of sustainability in PD projects: maintaining, scaling, replicating and evolving. Maintaining focuses on integrating PD practices into existing practice, sustaining PD practices by enabling people involved in the initial PD project to continue PD practices (for instance by inviting them to PD workshops). The context (in the work of Iversen and Dindler, and in this thesis: schools) in which the PD practices take place remains the same. Scaling relates to sharing insights from the PD project with a larger group of people, hence, PD practices can be sustained by informing people of a different context (for instance educational authorities) whereas the practices and core ideas of the initial PD project remain the same. Similarly, replicating is concerned with making PD processes replicable in other contexts, for instance when teachers share their experiences of being involved in a PD project with teachers from another school. The PD practices are then conducted at schools not involved in the initial schools and sustained by them. The final form, evolving, supports the evolution of PD practices beyond the initial idea or insights of the project and across different contexts. Evolving PD practices can be facilitated by creating social networks (including new audiences not involved in the initial PD project and from a different context, i.e. educational authorities or parents). Those social networks can enable ‘self-sustained learning processes’ in which the initial PD practices are evolving and appropriated by the new audiences not involved in the initial project to embed them in their own context. In Section 2.5, I illustrate how I relate those four terms to this work.
2.1. Defining terms used in this thesis

2.1.2 Toolkit

In my thesis I use the term ‘toolkit’ when referring to the resources I developed for teachers to support them to design technologies with children. I have chosen this terminology, because it represents a set of tools teachers can choose from and apply in their own practice. Toolkits have been developed in the field of HCI for multiple means: for constructing, storytelling or evaluating technology, and they range from physical toolkits to digital or online resources (see Section 2.6).

2.1.3 Empowerment

The empowerment of children in design processes is a central element in the SPT project and this thesis. There are multiple interpretations of empowerment in the PD and HCI community (Schneider, Eiband, Ulrich & Butz, 2018). In the history of PD (see Section 2.2.1), the empowerment of workers played a central role in the field (Simonsen & Robertson, 2013). Empowerment was related to working life democracy and workplace democracy in early PD projects and the involvement of workers in the development of computer systems (Bjerknes & Bratteteig, 1995). In more recent PD projects, the empowerment of marginalised groups in developing computer systems became a topic of concern in the field of PD until now (Beck, 2002). Recent work in the field of Child-Computer Interaction (CCI) focuses at Computational Empowerment (CE): Empowering children to take critical and informed decisions about the role and effects of technologies in their lives (Iversen, Smith & Dindler, 2018). Kinnula et al. (2017) criticized that, despite the focus on empowerment of children in CCI, researchers take the concept of empowerment as self-evident and often do not provide a definition or explanation of this concept. They referred to the understanding of empowerment in CCI as ‘mainstream tradition of empowerment’: “Motivating and inviting children to take part in design actions initiated by others.” (Kinnula et al., 2017, p.13). Kinnula et al. argued that, next to the mainstream tradition of empowerment, there is a variety of views on empowerment with ontological, epistemological and ethical differences. They concluded that researchers should acknowledge and explain which view of empowerment they handle.

In this thesis I present a toolkit, aiming to enable teachers to empower children to create their own technologies and to develop a critical understanding of existing technologies by playing an active role in technology design process. This toolkit advocates three views of empowerment, as defined by Kinnula et al.:

1. Educational/competence view: Empowering children through offering them important skills and competencies.

2. Democratic view: Empowering children to participate in decision-making processes through giving them a leading role in design processes.

3. Critical view: Empowering children through encouraging them to critically engage with, and re-think (existing) technologies.
2. Related Work

2.2 Participatory design

This work contributes to the field of PD by addressing issues around sustaining PD experiences and how we can encapsulate PD practices into a toolkit and make it work in a school context, without researchers being present. Hence, PD is a central element in this thesis. I present here how this work relates to the field of PD and PD with children, what exactly it is which makes PD practices PD and why we should aim to sustain PD practices.

2.2.1 History of participatory design

The history of PD goes back to the 70s when Scandinavian research projects applied user participation as a strategy for increasing working life democracy and workplace democracy. Working life and workplace democracy build upon the basic principles of democracy: That everyone has a right to have a different opinion and different perspectives are necessary to build knowledge. In this process, equal rights are given for people with little or no power so everyone has the opportunity to take part in decision making (Bjerknes & Bratteteig, 1995). In a workplace context this means that employees have the same rights as stakeholders and superiors to influence their work situation and to participate in decision making processes. Putting those ideas into practice, researchers in Scandinavia and the Norwegian Iron and Metal Workers Union aimed to give workers a voice in the development and introduction of new technologies in their workplace (Simonsen & Robertson, 2013). The outcomes of this project were technology agreements, textbooks and technology training programmes (Bjerknes & Bratteteig, 1995). The focus of this project was to support social and democratic values and the project had a political agenda rather than a design agenda. The democratic values of PD projects and the empowerment of marginalised groups remained a topic of concern in the field of PD until now (Beck, 2002).

In the 80s, design ideals were given a more explicit role in PD practices (Simonsen & Robertson, 2013). The Utopia project aimed to develop technologies to support graphical workers (Bødker, Ehn, Kammersgaard, Kyng & Sundblad, 1987). Researchers and designers collaborated with graphic designers by using mock-ups to provide hands-on experiences. The revolutionary approach to use low-tech prototypes had a large impact on IT design. User participation was in the early days of PD considered as a way of gaining knowledge about work and thus of improving the quality of the computer application (Bødker, 1996). Since then, a shift in values has occurred and the field has grown and moved beyond user participation. PD practitioners in the 80s built upon the soft systems’ analysis and design approach which informs designers how to engage users in the design process and highlights that a variety of stakeholders with different perspectives are involved in design processes (Simonsen & Robertson, 2013). This requires negotiation between different agenda’s and interests, a core aspect in PD projects.

Looking back at the history of PD, crucial elements of PD practices were:
• Empowerment: People who have traditionally no voice in decision making or design processes are empowered to actively participate in them.

• Democratic values: Different perspectives are involved to build knowledge.

• Hands-on experiences: Low-tech mock-ups are used to give participants materials they can appropriate easily.

More recent PD efforts deal with ethical and societal challenges and researchers put empowerment of marginalised groups on their agendas (Frauenberger, Makhaeva & Spiel, 2016; Frauenberger et al., 2019; Benton, Johnson, Ashwin, Brosnan & Gravemeyer, 2012; Benton, Johnson, Brosnan, Ashwin & Gravemeyer, 2011; Wilson, Brereton, Ploderer & Sitbon, 2018; Druin, 1999). The elements listed above were embedded in the practices of the SPT project: We empowered a diverse group of neurodivergent children with different perspectives to actively participate in design processes, supported with low-tech prototyping activities to enable children to actively engage in (re)-designing prototypes. More details about the SPT project are presented in Chapter 3 and 4, but this illustrates that the practices in the SPT project are closely related to the early PD practices. More recent examples of PD practices and pathways to sustain those PD practices are discussed in Section 2.3.

2.2.2 Sustaining PD practices with educational resources in the history of participatory design

Before 1998, three main topics were dominant in the literature of PD: The politics of design, the nature of participation and the development of methods, tools and techniques for carrying out design projects (Kensing & Blomberg, 1998). PD practitioners had a double agenda: to design ‘useful’, experimental technologies and practices that are created in collaboration with future users of the artefacts or other stakeholders and to develop PD methods and practices which could be adopted by participants or similar audiences not involved in the initial project (in the 70s and 80s those audiences were design professionals).

Clement and van den Besselaar (1993) criticized that most PD projects result in small-scale projects and when the projects ends, the PD practices are often not scaled to other parts of the organization. To address this challenge, they suggested that a wide range of actors not involved in the initial PD project ‘must learn of the achievements and care about its survival’. A different approach was formulated for instance by Bødker (1996), who argued for developing a local knowledge base that can help sustain PD practices beyond the initial PD project’s end. Hence, PD has a long history in aiming for sustaining and scaling PD practices for audiences involved and not involved in the initial project, and exploring pathways to support sustainability is an ongoing challenge in the field.

A first attempt to sustain PD practices was a collection of programmatic and empirical discussions of the system design projects, discussing for instance institutional and
2. Related Work

professional politics, expertise, skill, computerization, traditional women’s employment and opportunities for supporting marginalised groups of people (for instance disabled people) with technologies. A more recent example of educational resources for PD projects is the Kids Team toolkit developed by Skinner (2020) to support Librarians with planning, implementing and facilitating KidsTeam co-design sessions with children. The KidsTeam project is rooted in the work of Druin (see for instance (Druin, 1999)), a collection of PD practices to empower children to design new technologies for children. In the past years the KidsTeam practices were adapted to make it available for public libraries and to support librarians to conduct similar PD and technology design workshops with children.

In this thesis, I build upon the tradition of creating educational resources for participants and similar audiences not involved in the initial project which could enable them to sustain PD practices and experiences. As argued in Section 2.2.1, PD has always been concerned about empowerment, democracy and how participation could be maintained for participants and facilitated for similar audiences.

2.2.3 Participatory design with children

Since the late 90s, children were involved as active participants in design processes (Druin, 1999). A cornerstone in PD projects with children is the empowerment of children: Children are enabled to participate in technology design processes (see for instance (Malinverni et al., 2014)). Their active involvement in design processes is enabled by balancing adult-child power relationships (Yip et al., 2017; Druin, 2001), using methods which meet their skills (for instance low-fidelity prototyping) (Druin, 1999), and by carefully choosing and adapting methodological design approaches (Makhaeva, Frauenberger & Spiel, 2016; Frauenberger, Makhaeva & Spiel, 2017a).

The roles of children in PD projects were initially described as users, testers, informants or design partners (Druin, 2001). The roles of adults in the design process were accordingly conceptualised as observer, test facilitator, interpreter and design partner (Yip et al., 2017). Recent work built on this discussion, empowering children as process designer of PD workshops (Schepers, Dreessen & Zaman, 2018c).

Hence, empowering children as design partners in design processes and using low-tech prototypes to meet their skills are (similar to PD with adults) main elements in PD with children. As argued in Section 2.2.1 those elements are deeply rooted in the practices of the SPT project.

2.2.4 Child-Computer Interaction

Another field in which practices are centred around the empowerment of children as design partner is Child-Computer Interaction (CCI). In the field of CCI, which is concerned with the interaction between children and computational technologies, PD methods are applied frequently to actively involve children in design or evaluation processes (Read & Markopoulos, 2013). Topics in CCI are interaction techniques, evaluation methods,
design practice and the development and evaluation of learning applications. Recent work in the field of CCI focuses on Computational Empowerment (CE). CE aims to empower children to make critical and informed decisions about the role and effects of technologies in their lives (Iversen et al., 2018).

The goals in CCI are often twofold: to design child-centric products and that the design process has an impact on the children’s personal development (Skinner, 2020). By empowering children as design partners in design processes, creativity, autonomy, problem-solving, learning and other important skills are supported. This contributes in a positive way to the personal development of the children involved in the design process is in line with recent PD projects with children (see for instance Iversen et al., 2017a).

2.2.5 Participatory design with neurodivergent children

The SPT project focused in particular on PD approaches which empower neurodivergent children to engage in technology design processes. Previous work has shown how neurodivergent and neurotypical children can be included in a design process (Makhaeva et al., 2016; van Rijn & Stappers, 2008; Benton et al., 2011, 2012; Drinu, 2001; 1999; Frauenberger, Makhaeva & Spiel, 2016; Frauenberger et al., 2017a; Malinverni et al., 2014). Researchers focused on design methods and tools that enhance the involvement of the children (Makhaeva et al., 2016; Frauenberger, Makhaeva & Spiel, 2016; Frauenberger et al., 2017a; Malinverni et al., 2014), frameworks for design workshops (Benton et al., 2011, 2012), the experiences of the participating children (Spiel, 2017) and the roles researchers and children have in participatory design projects (Drinu, 2001; Iversen et al., 2017a; Yip et al., 2017). As neurodivergent children are a vulnerable group within western societies, researchers need to consider ethical challenges when involving them in research projects (Spiel, Bruè, Frauenberger, Bailly & Fitzpatrick, 2018). By forming close relationships with the children and by carefully interacting with them, researchers can build an understanding of how ethics could manifest in the collaborations with the children.

As the reflections on the empowerment of children in design processes illustrates, PD is rooted in values. Using PD methods does not necessarily mean that the work is PD, and it is not only the methods which make PD projects successful (Iversen et al., 2010). It is the values that drive PD practitioners (myself included) and the methodological approaches. PD considers not only the values of the involved participants, but also the researchers’ values that influence the PD process. For the SPT project, a central element was the empowerment of children in technology design processes. Hence in this work, empowerment remains a core aspect and is embedded in the PD practices and experiences I aim to sustain for the participating teachers and similar audiences (teachers and children not involved in the initial project).
2. Related Work

2.2.6 Participatory design and teaching technology design in schools: What makes a PD project PD

As previously discussed in Section 2.2.4, learning is (next to empowerment) a core element of PD with children and previous PD projects resulted in educational resources targeted at new audiences to involve children in PD and technology design activities. In the field of design and technology education, researchers have a similar aim: To give children autonomy in the design process.

In design and technology education, researchers argue for child-centred approaches: Teaching is based on the perceptions of the children and the focus is on learning rather than teaching, giving children autonomy and control in the design process. Figure 2.1 visualizes the spectrum of teaching activities, ranging from narrow activities with low control of children over the (design and learning) process to activities in which children are in control of the process. Bowen argued that any technology design activity can be placed on this spectrum but most activities would cover a span, balancing teacher controlled and child controlled activities.

The value of child-centred teaching approaches and giving children control over their (learning) process has been earlier discussed by Cross, who aimed to give children the opportunity to exercise decision making during lessons and support pupil’s autonomy by for instance proposing open questions. Similar to Bowen, Cross concluded that it is the task of the teacher to negotiate a balance in controlling the activities and facilitating a dialogue between children and teacher.

This is in line with the aim in CCI and PD projects where children are empowered.
2.3 First scoping literature review: Sustaining PD practices and experiences in PD projects with children

to create technologies based on a child-centred approach, supporting their creativity, autonomy, problem-solving, learning and other important skills (see for instance Iversen et al. [2017a]). This raises the question: What makes a PD project different from design and technology education following a child-centred approach?

As illustrated in 2.2.1, PD is deeply grounded in democratic values and ideals. Children are actively involved in technology design processes for the sake of empowerment and democratising technology design processes (see for instance Iversen et al., 2010). While the approaches used in PD projects and child-centred technology and design project might be similar (i.e. children are in control of activities and decision makers in the process), the motivation to apply such approaches are often different. In design and technology classes, children are empowered to play an active role in design processes to enable learning outcomes (for instance learning to design Flinn & Patel, 2016, practicing creative cognitive processes Bower, 2009) or learn practical skills such as measuring (Benson & Lawson 2017). The design process itself might also differ from design and technology projects: In design and technology classes, children design for other ‘users’ or target group (Benson & Lawson, 2017), whereas in PD projects, participants contribute to solutions for their own context or situation, resulting eventually in design of technologies that are tailored to their needs, interests and abilities (see for Iivari, Kinnula & Molin-Juustila, 2018).

2.3 First scoping literature review: Sustaining PD practices and experiences in PD projects with children

After illustrating how PD practitioners approach sustainability challenges in PD projects with adults, I will narrow down my focus on PD projects with children and explore specific contextual challenges when working with children. To understand the gap and existing work this thesis builds upon, I conducted a scoping review across different databases.

2.3.1 Research approach

I conducted a scoping literature review to structure the search process of relevant articles, and grouped the findings into categories to analyse the resulting collection of articles (Munn et al. 2018). I chose a scoping review approach for two aims: 1) to identify key characteristics of sustainability (and sustainability related aspects) of PD work with adults and children and 2) to identify and analyse possible gaps related to sustainability aspects in PD with children.

I conducted two cycles of literature searches to collect the final paper corpus for the review as visualised in Figure 2.2. Since sustainability is conceptualised differently in the field of PD, and I wanted to ensure that our final search array in the field of PD with children covered a variety of different aspects, I performed an initial literature search in the field of PD with adults. The terms used to conceptualise sustainability were then used in the second literature search as search terms.
2. Related Work

Planning

In the first cycle of literature search for the aspects of sustainability in PD work with adults, I aimed to add to the previously discussed related work of Poderi and Dittrich (2018) by specifying what kind of language PD practitioners use when referring to sustainability, in order to find suitable search terms for the second cycle literature review (sustainability of PD practices with children).

In both cycles, I searched the ACM digital library, the hcibib and Co-Design Journal, based on their focus on PD and HCI. I did an initial search for papers in scopus but my search terms resulted in many irrelevant articles (with a focus on sustainability related to ecological topics, for instance) and the articles which were relevant were included in the smaller digital libraries, too. Hence, I searched only in digital libraries for HCI and PD related venues.

First cycle of literature search in PD work with adults

For the search of the first cycle, I used the search terms sustain* AND (participatory design OR PD). I searched in any of the Title, Abstract, and Keywords fields. The search
2.3. First scoping literature review: Sustaining PD practices and experiences in PD projects with children

resulted in 126 unique papers. I rejected 81 of them after reading the abstract and 16 after reading the full paper, because they did not meet all inclusion criteria or met any rejection criteria:

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Rejection criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Article must report on sustainability related concepts</td>
<td>Article has no focus on ecological sustainability</td>
</tr>
<tr>
<td>Article must focus on sustaining PD practices and experiences</td>
<td>(e.g. no focus on sustainable energy)</td>
</tr>
<tr>
<td>Article must report on applying a participatory design approach</td>
<td>Article has no focus on sustainable behaviours</td>
</tr>
<tr>
<td>Article must report on adults involved as participants</td>
<td></td>
</tr>
<tr>
<td>Article must report original research</td>
<td></td>
</tr>
<tr>
<td>Article must be peer reviewed</td>
<td></td>
</tr>
<tr>
<td>Article must be a journal-, full- or short-paper</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1: Overview of inclusion and rejection criteria for the first cycle.

A total of 29 papers were included in the literature corpus of the first cycle that met the criteria. The papers were specifically analysed to find concepts and terms related to sustainability. To categorise the aspects the authors describe in relation to sustainability, I read the papers two times. During the first round of reading, I looked for potential categories and coded the relevant pieces of text. I used an excel sheet in which I kept notes of all initial categories and codes. During the second round, I refined the categories by re-reading all articles and adding codes to the excel sheets. If a concept related to sustainability did not match the initial categories, I added or changed the initial categories.

2.3.2 Findings of literature search in PD with adults

Traditionally, mutual learning and user gains were considered as sustainable PD aspects (Bossen, Dindler & Iversen, 2010). By building networks among stakeholders, researches and users (Dindler & Iversen, 2014), finding common ground between different disciplines (Kensing & Blomberg, 1998) and empowering participants to engage actively in the design process, participants acquire new skills and competences (Bossen et al., 2010) or growth of knowledge. However, researchers often are the driving force in the mutual learning process, and after the project ended, learning experiences can no longer be sustained since the researcher side is missing (Iversen & Dindler, 2014). Hence, the majority of research projects, in total 18, aimed for sustaining PD practices and experiences, for instance by building upon the notion of infrastructuring, which was the most prominent aspect related to sustainability used in eight articles. Infrastructuring is gaining more popularity in the field of PD (Karasti, 2014; Pipek & Wulf, 2009; Björgvinsson, Elm & Hillgren, 2010; Meurer, Müller, Simone, Wagner & Wulf, 2018) and is more deeply discussed in Section 2.4.

The resulting categories, which were used as search terms for the second cycle in the context of PD with children, are displayed in Table 2.2.


### Second cycle of literature search in PD work with children

In the literature search for the second cycle, I focused on papers reporting on PD work with children. As search terms, the aspects of sustainability from the previous round of literature search were chosen to find papers related to sustainability. I included the sustainability aspect as search term in the search array for the second cycle when it was used in at least 2 papers of the first cycle (see Table 2.2).

I used the search terms (sustain* OR outcome* OR impact OR change OR scaling OR mutual learning OR gains OR infrastructur* OR design in use OR ownership OR organizational practices OR organizational structures) AND child* AND (participatory design OR PD). I searched in any of the Title, Abstract, and Keywords fields. The search resulted in 375 unique papers (see Table 2.3). I then used the inclusion and rejection criteria from the first literature search, but swapped the inclusion criteria “Article must report on adults involved as participants” with: “The articles must report on a project in which children were actively engaged or the article is a follow-up study with adults based on a previous research project where children have been actively involved”.

I rejected 331 papers after reading the abstract and 18 after reading the full paper, because they did not meet my criteria. A total of 26 papers were included in the literature corpus of the literature review that met the criteria.

I analysed the resulting 26 articles similarly as described in Section 2.3.1 by categorising and coding the articles. I read the articles two times. During the first round, I familiarised myself with the articles and searched for topics relevant for my research question: *What does sustainability mean for a PD research project?* (RQ 1) and *What makes it challenging to have sustainable PD practices and experiences in a school context?* (RQ2). Related to RQ 1, I was particularly interested in the sustainability aspects described by the authors in PD projects with children and what kind of experiences and practices were reported in PD projects with children (which might be sustained beyond the project’s end). Related to RQ 2, I focused during the analysis on challenges and pathways to sustain experiences and practices in PD projects with children in and outside a school.

#### Table 2.2: Overview of sustainability aspects in PD with adults.

<table>
<thead>
<tr>
<th>Aspects</th>
<th>References</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructuring</td>
<td>Baumann, Stokes, Bar &amp; Caldwell 2016 Hansen et al. 2019</td>
<td>8</td>
</tr>
<tr>
<td>Change</td>
<td>Simonsen &amp; Hetraalm 2018, Hetraalm &amp; Simonsen 2019</td>
<td>3</td>
</tr>
<tr>
<td>Design in use</td>
<td>Dittrich, Ersson &amp; Hanson 2009 Poderi 2019</td>
<td>2</td>
</tr>
<tr>
<td>Impact</td>
<td>Hansen et al. 2019, Krenwall &amp; Kyng 2011</td>
<td>2</td>
</tr>
<tr>
<td>Mutual learning</td>
<td>Haskel &amp; Graham 2014, Bossen et al. 2010</td>
<td>2</td>
</tr>
<tr>
<td>Organizational practices/structures</td>
<td>Dindler &amp; Iversen 2014, Renning &amp; Blomberg 1998</td>
<td>1</td>
</tr>
<tr>
<td>Ownership</td>
<td>Haskel &amp; Graham 2014, Yuki Uchida 2014</td>
<td>2</td>
</tr>
<tr>
<td>Scaling</td>
<td>Iversen &amp; Dindler 2018, Yuki Uchida 2014</td>
<td>2</td>
</tr>
<tr>
<td>(User) gains</td>
<td>Bossen et al. 2010, Hansen et al. 2019</td>
<td>2</td>
</tr>
</tbody>
</table>
2.3. First scoping literature review: Sustaining PD practices and experiences in PD projects with children

<table>
<thead>
<tr>
<th>Database</th>
<th>Keywords</th>
<th>Results</th>
<th>Unique</th>
<th>Data searched</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACM Digital Library</td>
<td>sustain* OR outcome* OR impact OR change OR scaling OR mutual learning OR gains OR infrastructur* AND PD OR participatory design AND children</td>
<td>341</td>
<td>341</td>
<td>03.02.2021</td>
</tr>
<tr>
<td>hcibib <a href="http://hcibib.org">http://hcibib.org</a></td>
<td>sustain* OR outcome* OR impact OR change OR scaling OR mutual learning OR gains OR infrastructur* AND PD OR participatory design AND children</td>
<td>30</td>
<td>27</td>
<td>23.04.2021</td>
</tr>
<tr>
<td>Co-Design Journal</td>
<td>OR change OR scaling OR mutual learning OR gains OR infrastructur* AND PD OR participatory design AND children</td>
<td>6</td>
<td>6</td>
<td>22.04.2021</td>
</tr>
</tbody>
</table>

Table 2.3: Overview of search results.

context. I also categorised the involved adults in the projects to explore who could support sustaining practices and experiences of PD projects beyond the project’s end.

After the first round of reading, I identified six categories which were frequently discussed in the articles and were relevant for my research questions: Sustainability aspects mentioned in the article (see Table 2.4), gains and experiences of children, involved people, pathways to sustain PD practices and experiences (see Table 2.7), settings in which PD projects with children are conducted and which challenges occurred in relation to their context. The excel sheet with all codes is presented in Appendix A 8.3.6. During the second round of reading, I coded the articles in relation to the six identified categories using an excel sheet. Based on the excel sheet, I wrote a summary of the results.

2.3.3 Findings of literature search in PD with children

The results are presented along the guiding questions and focus on how PD is currently conducted within the projects, since only two papers report on researcher activities beyond the project’s end (Franco & de Deus Lopes, 2009; McNally, Mauriello, Guha & Druin, 2017).

Aspects of sustainability - what is sustained?

Table 2.4 shows the different aspects of sustainability, which I will further analyse in the following parts of the analysis. I identified two main aspects of sustainability the articles focus on: sustainable outcomes on an individual level; and sustainability on a broader, societal level, related to future use or growing networks.

Gains and experiences of children

The majority of the articles, in total 18, mentioned gains and experiences of the participating children. The authors reported on diverse gains the children experience, ranging
### Table 2.4: Overview of sustainability aspects in PD with children.

<table>
<thead>
<tr>
<th>Aspect of sustainability</th>
<th>References</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gains and experiences of directly involved children</td>
<td>Barendregt, Bekker, Borjesson, Eriksson &amp; Torgerson, 2016</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Barendregt, Eriksson, Torgerson &amp; Bekker, 2016</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dreessen &amp; Schepers, 2015</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Franco &amp; de Deus Lopes, 2009</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Iversen &amp; Haesen, 2013</td>
<td></td>
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<tr>
<td></td>
<td>Ivani et al., 2017</td>
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<tr>
<td></td>
<td>Iversen &amp; Haesen, 2013</td>
<td></td>
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<tr>
<td></td>
<td>Jansen &amp; Schepers, 2017</td>
<td></td>
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<tr>
<td></td>
<td>Van Mechelen, Schut, Gielen &amp; Soderberg, 2019</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Van Mechelen, Schut, Gielen &amp; Klapper, 2019</td>
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<td>Van Mechelen, Schut, Vanina Atto, Laden &amp; Zaman, 2014</td>
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<td>Melonio et al., 2020</td>
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<td></td>
<td>Robinson, Haanstra &amp; Middelbeek, 2018</td>
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<td>Schepers, Dreessen &amp; Zamanit, 2018</td>
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<td></td>
<td>van Rijn &amp; Stappers, 2008</td>
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<tr>
<td>Gains and experiences of directly involved adults</td>
<td>Borjesson et al., 2019</td>
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<td></td>
<td>Dreessen &amp; Schepers, 2018</td>
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<td></td>
<td>Franco &amp; de Deus Lopes, 2009</td>
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<td>Ivani et al., 2017</td>
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<td>Iversen et al., 2017</td>
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<td></td>
<td>Robinson et al., 2020</td>
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<td>Infrastructures</td>
<td>Dreessen &amp; Schepers, 2015</td>
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<td></td>
<td>Schepers, Scholteest, Zaman &amp; Dreessen, 2021</td>
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<td></td>
<td>Smith, Iversen, Jermiessie &amp; Lynggaard, 2018</td>
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<tr>
<td>Design Outcomes</td>
<td>Duh &amp; Chen, 2010</td>
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<tr>
<td>Maintaining, Scaling,</td>
<td>Iversen &amp; Jentoft, 2019</td>
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<tr>
<td>Replicating, Evolving</td>
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<tr>
<td>Societal Impact</td>
<td>[Waki &amp; Dalgaard, 2019]</td>
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From learning gains to growing social skills: 12 of the articles described learning gains, nine of them related to actual knowledge of technology and the creation of it (for instance programming skills [Franco & de Deus Lopes, 2009], or creativity [McNally et al., 2017, Van Mechelen et al., 2019], and seven of them reported on learning gains related to increased social skills, such as self-esteem (Schepers et al., 2018a, 2018b) or empathy (Van Mechelen et al., 2019, 2018).

Another experience of children that was mentioned in four papers was a change in perspective towards technology: Either by developing a critical and reflexive stance towards technology and the development of it [Iversen & Smith, 2012, Iversen et al., 2017b], or by developing a meaningful relationship to technology design and making.

Other gains and experiences of children were the development of ownership, genuine participation and sparking interest in design and making, empowerment of children or an overall positive impact on the participants’ lives.

Two papers focused on the adoption of design outcomes to support sustainability. The children involved in the work of Duh & Chen (2010) generated design recommendations, which were then evaluated by game designers. The authors highlighted the importance of adopting those recommendations in future game design practice. Duveskog et al. (2009), had a very different aim. They co-designed a HIV and AIDS counseling guide for youngsters in Tanzania, supporting behavioural changes of youngsters in the future.
2.3. First scoping literature review: Sustaining PD practices and experiences in PD projects with children

<table>
<thead>
<tr>
<th>Gains and experiences</th>
<th>References</th>
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<tbody>
<tr>
<td>Learning gains related to technology or design</td>
<td>Börjesson et al. (2019), Franco &amp; de Deus Lopes (2009), Iivari et al. (2018)</td>
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<td></td>
<td>Van Mechelen et al. (2019), Schepers et al. (2018a, 2018b)</td>
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<tr>
<td>Learning gains related to growing social skills</td>
<td>Börjesson et al. (2019), Van Mechelen et al. (2018a, 2018b)</td>
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<td>Iversen &amp; Smith (2012), McNally et al. (2017), Schepers et al. (2018a)</td>
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<tr>
<td>Change in perspective towards technology</td>
<td>Iversen &amp; Smith (2012), Iversen et al. (2017b), Iivari et al. (2018)</td>
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<td>Presser &amp; Hansen (2019)</td>
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<td>Empowerment</td>
<td>Melonio et al. (2020), Iivari &amp; Kinnula (2016), Schepers et al. (2018a)</td>
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<td></td>
<td>Schepers et al. (2021)</td>
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<tr>
<td>Genuine participation</td>
<td>Iivari et al. (2018), Iivari &amp; Kinnula (2016)</td>
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<td>Adoption of design outcomes</td>
<td>Iversen &amp; Smith (2012), McNally et al. (2017)</td>
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<td></td>
<td>Duh &amp; Chieli (2019), Duveskog et al. (2009)</td>
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<tr>
<td>Positive impact on life</td>
<td>Robinson et al. (2020)</td>
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<tr>
<td>Ownership</td>
<td>Van Rijn &amp; Stappers (2008)</td>
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Table 2.5: Overview of gains and experiences of children in PD with children.

Involvement, gains and experiences of adult participants

Adult participants were also involved in the projects. Adult participants included teachers, parents, politicians, domain experts, decision-makers, designers, programmers, school management, IT managers, youth workers, care professionals, anthropologists, museum curators and researchers other than those leading the PD project (See Table 2.6).

Next to the gains and experiences of children, eight authors mentioned gains and experiences of the involved adults, for instance of parents or teachers. Börjesson et al. (2019) focused explicitly in their work on expected and perceived user gains of teachers. The teachers participated with their classes in PD projects and were interviewed afterwards. The teachers mentioned multiple perceived gains, such as learning new skills in terms of technology and teaching.

Franco and Lopes (2009) found similar outcomes for teachers who participated in PD projects with children. Other gains of adult participants were sustainable relationships with local people, they could collaborate with in the future (Dreessen & Schepers, 2018; Iversen & Dindler, 2014).

Parents of participating children felt ownership and pride (van Rijn & Stappers, 2008), and that their participation had an overall positive impact on the life of their child and their own (Robinson et al., 2020).

Other sustainability aspects PD projects mentioned in the articles

Next to adult participants’ gains and experiences, the authors discussed other sustainability aspects they aimed to achieve in their projects. Dreessen and Schepers (2018) and Schepers et al. (2018a) aimed to develop long-term engagements and relationships.
2. Related Work

<table>
<thead>
<tr>
<th>Involved adults</th>
<th>References</th>
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<tbody>
<tr>
<td>Teachers</td>
<td>Barendregt et al. (2016)</td>
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<tr>
<td></td>
<td>Iversen et al. (2017)</td>
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<td>Dreessen &amp; Schepers (2018)</td>
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<td>Böjesson et al. (2019)</td>
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<td>Iivari et al. (2018)</td>
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<td>Iivari &amp; Kinnula (2016)</td>
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<td>Versen &amp; Dindler (2014)</td>
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<td>Smith et al. (2019)</td>
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<td>Van Rijn &amp; Stappers (2008)</td>
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<td>Politicians</td>
<td>Iversen et al. (2017)</td>
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<td>Iversen &amp; Dindler (2014)</td>
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<td>Smith et al. (2019)</td>
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<td>Decision-makers</td>
<td>Iversen &amp; Dindler (2014)</td>
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<td></td>
<td>Iversen &amp; Hansen (2013)</td>
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<td>Smith et al. (2019)</td>
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<tr>
<td>IT-managers</td>
<td>Iversen &amp; Dindler (2014)</td>
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<td>Iversen &amp; Hansen (2013)</td>
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<td>Smith et al. (2019)</td>
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<tr>
<td>Parents</td>
<td>McNally et al. (2017)</td>
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<td></td>
<td>Robinson et al. (2020)</td>
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<td></td>
<td>Van Rijn &amp; Stappers (2008)</td>
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<tr>
<td>School management</td>
<td>Iversen &amp; Dindler (2014)</td>
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<td>Iversen &amp; Hansen (2013)</td>
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<td></td>
<td>Smith et al. (2019)</td>
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<tr>
<td>Designers</td>
<td>Iversen &amp; Smith (2019)</td>
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<td></td>
<td>Duh &amp; Chen (2010)</td>
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<td>Domain experts</td>
<td>Iversen &amp; Dindler (2014)</td>
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<td></td>
<td>Smith et al. (2019)</td>
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<tr>
<td>Researchers</td>
<td>Dreessen &amp; Schepers (2018)</td>
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<tr>
<td></td>
<td>Iivari et al. (2018)</td>
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<tr>
<td>Anthropologists</td>
<td>Iversen &amp; Smith (2019)</td>
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<tr>
<td>Care professionals</td>
<td>Van Rijn &amp; Stappers (2008)</td>
<td>1</td>
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<tr>
<td>Museum curators</td>
<td>Iversen &amp; Smith (2019)</td>
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<td>Programmers</td>
<td>Iversen &amp; Smith (2019)</td>
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<tr>
<td>Youth workers</td>
<td>Dreessen &amp; Schepers (2018)</td>
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Table 2.6: Overview of adults involved in PD projects with children.

between involved adults, which should keep supporting vulnerable children in the future. The authors drew on this insight further and suggested an infrastructural approach to empowerment (Schepers et al., 2021), by offering activities on a social and interrelational level to children who were involved in the initial project, organising matchmaking with children and local organisations. Similarly, Smith et al. (2013) were interested in collaborations between stakeholders beyond the project’s end, by creating sustainable ecologies which support appropriation and sustainable use practice. Sustainable ecologies are defined by the authors as constellations of actors and technologies in particular hybrid environments, which result from design projects and keep existing beyond the projects’ end. As a more pragmatic aspect of sustainability, authors mentioned creative output (Wakil & Dalsgaard, 2013) or sustainable design outcomes which should be adopted in the future by game designers (Duh & Chen, 2010).

2.3.4 Challenges when aiming for sustainability in PD projects with children

The majority of projects, in total 17, took place in schools (coded as ‘context’ in the excel sheet in Appendix A 8.3.6). An explanation of this phenomena might be, as argued by (Iivari et al., 2018), that a large number of children can be reached at schools. While schools as context for PD projects are considered an ideal place to reach a large number of children/participants (Iivari et al., 2018), and the majority of the projects discussed in this article took place in schools, researchers experienced context related challenges. Three papers reported on problems caused by the school’s rigid structures and inbuilt power relations between pupils and teachers, impacting design sessions (e.g. (Barendregt et al., 2016)). Children do not usually have much authority in schools, which is contrary to their traditional role in PD projects as decision-makers. They are also less likely to be allowed to decline participation in certain activities, while in PD or research in general, participants do have this option (Iivari & Kinnula, 2016). The authors also described problems they experienced with the roles of teachers: They were either trying to influence
2.3. First scoping literature review: Sustaining PD practices and experiences in PD projects with children

activities (Barendregt et al., 2016), or were too passive during design activities (Börjesson et al., 2019), and the children lacked freedom to choose activities or topics (Iivari & Kinnula, 2016).

The childrens’ experiences also differed when the design workshops took place in a school context: In schools, they “needed to listen to the teachers and the tasks are always aimed at learning and never just fun, whereas during the “LYWO” activities they just can have fun with their friends” (Dreessen & Schepers, 2018, p.7). Researchers tried to work around this challenge by either moving the activities to a different context, or by doing something children would not expect in a school situation (i.e. providing sweets) (Iversen & Hansen, 2013). There was also the challenge of unequal power within groups of children, resulting for instance in the dominant children forcing their ideas and values on the whole group (Van Mechelen et al., 2014). Furthermore, researchers needed pedagogical justification for the children’s participation, as the project had to be integrated well within the school context (Iivari & Kinnula, 2016). Hence, in order to support sustainability of PD projects, they must culturally and pedagogically fit the school context (Iivari et al., 2018). However, there were also differences among schools, for instance in their working practices, cultures or resources (Iversen & Dindler, 2014), suggesting that there is no ‘one-fits-all’ solution.

In a project which took place outside schools and in collaboration with several stakeholders, the authors mentioned that the collaborating designers and programmers were challenged by the childrens’ opinions, values and thoughts (Iversen & Smith, 2012). Other challenges to sustain PD practices when working with other stakeholders were their limited time and commitment. As a result, PD practices might be abandoned after the project has ended (Iversen & Dindler, 2014).

2.3.5 Approaching the challenge of sustaining practices and experiences in PD with children

Like the diversity in sustainability aspects, PD practitioners have applied different strategies to sustain their projects’ practices and experiences. In all included papers children were involved actively in PD workshops, during which they created their own technologies. The childrens’ level of engagement differed across the projects, depending on the contextual circumstances of the project and abilities of the children.

As previously discussed in section 2.1.1, Iversen and Dindler (2014) approached the challenge of sustaining PD practices and experiences beyond the individual project of the participating people for the first time in the field of PD with children. As presented previously in Section 2.1, they proposed to categorise sustainability into four forms: Maintaining, scaling, replicating and evolving. In their project they explored how PD practices can be maintained at schools by inviting teachers to their workshops, replicated in different schools by inviting similar audiences to activities and supporting knowledge.

4“LYWO” is the name of a local branch of youth work organisation. The activities took place in a FabLab (Dreessen & Schepers, 2018).
2. Related Work

Table 2.7: Overview of pathways to sustain practices and experiences in PD with children.

<table>
<thead>
<tr>
<th>Pathway</th>
<th>References</th>
<th>#</th>
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</thead>
<tbody>
<tr>
<td>Active involvement of children in design</td>
<td>[Barendregt et al., 2016; Börjesson et al., 2019]</td>
<td>25</td>
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<tr>
<td>processes</td>
<td>[Derboven, Van Mechelen &amp; Schepers, 2018]</td>
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<td></td>
<td>[Duh &amp; Chen, 2019]</td>
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<td>[Duveskog et al., 2009]</td>
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<td>[Franco &amp; de Deus Lopes, 2009]</td>
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<td>[Iivari et al., 2018]</td>
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<td>[Iversen &amp; Dindler, 2015]</td>
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<td></td>
<td>[McNally et al., 2017]</td>
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<td>[Van Mechelen et al., 2019, 2018]</td>
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<td>[Melo et al., 2020]</td>
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<td></td>
<td>[Robinson et al., 2020]</td>
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<td>[Schepers et al., 2018a, 2018b, 2021]</td>
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<td></td>
<td>[van Rijn &amp; Stappers, 2008]</td>
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<tr>
<td>Children experience programming</td>
<td>[Franco &amp; de Deus Lopes, 2009]</td>
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<td>[Iivari et al., 2018]</td>
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<td>[Schepers et al., 2018a, 2018b]</td>
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<tr>
<td>Children experience making</td>
<td>[Duveskog et al., 2009]</td>
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<td>[Iivari &amp; Kinnula, 2018]</td>
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<td>[Schepers et al., 2018a, 2018b]</td>
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<td>Children experience storytelling</td>
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<td>[Duh &amp; Chen, 2019]</td>
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<td></td>
<td>[Van Mechelen et al., 2019]</td>
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<tr>
<td>Toolkits for expression</td>
<td>[Van Rijn &amp; Stappers, 2008]</td>
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<tr>
<td>Parents as proxies</td>
<td>[Robinson et al., 2020]</td>
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<tr>
<td>Presenting outcomes at science fair</td>
<td>[Franco &amp; de Deus Lopes, 2009]</td>
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<tr>
<td>Matchmaking between children and local</td>
<td>[Schepers et al., 2021]</td>
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<td>organizations</td>
<td>[Schepers et al., 2018a, 2018b]</td>
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<tr>
<td>Communicating findings</td>
<td>[Iversen &amp; Dindler, 2015]</td>
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<tr>
<td>Ecological Inquiry</td>
<td>[Smith et al., 2013]</td>
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</table>

exchange, scaled by embedding PD practices in new contexts and reaching out to new audiences, and evolved by providing visible and accessible outcomes and building a support network among project partners. Those social networks could support ‘self-sustained learning processes’.

In projects that aimed to support the learning outcomes of children, special attention was paid to the practical skills of designing (see Table 2.7). This was facilitated for instance by offering children experiences in programming (eight projects), making (five projects) or storytelling (four projects). The methods were also adapted to the specific abilities of the children, supporting them to express themselves: Van Rijn et al. (2008) supported autistic children with toolkits for expression, consisting of sensorial materials, to enable them to take an active role in the design process and experience a feeling of ownership as outcome. Robinson et al. (2020) worked with a child affected by brain damage and unable to speak, but who enjoyed expressing himself and making choices. The researchers based their methods on the child’s abilities, by keeping the design process flexible and let the child guide it, and involving his parents as proxies.

Another pathway to sustain PD experiences and practices was to engage external stakeholders after the project’s end, for instance, by presenting the project’s outcomes at a science fair (Franco & de Deus Lopes, 2009). A visitor of the science-fair, a teacher, adapted his own practice inspired by the project and applied the knowledge from the project. The project resulted also in a change in the participating school’s curriculum.
2.4 Infrastructuring

Schepers et al. (2021) built upon the notion of infrastructure to sustain the empowerment of children beyond the project’s end. Schepers et al. aimed to extend the children’s participation by empowering the children involved in the project outside the PD workshops, referring to ‘empowerment-in-use’. They suggested a two-phase process for PD projects with children, consisting of conducting the traditional PD workshops (during project time) and the infrastructural form of empowerment (after the project has ended, or ‘design-in-use’). In the second phase, participants (the children) utilized the created infrastructure to continue to contribute. Their empowerment is thus sustained beyond the project’s end. They also enabled empowerment-in-use during the project, for instance by enabling children to set up and sustain communities, and by enabling children to critically engage in the PD processes (i.e. by giving children explicit opportunities to question the researchers suggested activities).

Summing up, the majority of articles approached the challenge of sustaining practices and experiences in PD with children by focusing on participants which are directly involved in the projects. Iversen and Dindler (2014) suggested to explore different pathways, for instance by informing audiences not involved in the initial project about PD practices. However, not much is known about sustaining practices and experiences for those audiences. This indicates that more research is necessary to explore how PD practices and experiences can be sustained for participants and similar audiences not involved in the initial project.

2.4 Infrastructuring

As discussed in the previous Section, recent work in PD with children builds on the notion of infrastructure to sustain PD experiences and practices. In PD with adults, building upon the notion of infrastructure is an established practice (Baumann et al., 2016; Hansen et al., 2019; Capaccioli et al., 2016; Hirscher, 2020; Poderi, 2019; Haskel & Graham, 2016). Building upon the notion of infrastructure can extend the practices and experiences of PD projects beyond the project’s time by supporting for instance design-in-use of PD outcomes (Saad-Sulonen, Eriksson, Halskov, Karasti & Vines, 2018). Hence, infrastructuring plays an important role in the field of PD to support and sustain practices and experiences of PD projects.

Neumann and Star introduced in the 90s the ‘notion of information infrastructure’. They understood socio-technical relations as a relationship between people’s organised ways of doing things and the technologies that enable these methods (Neumann & Star, 1996). Star and Ruhleder argued that technological artefacts are never ‘stand-alone’ things, but their development process and use are embedded in complex relationships and require collaboration by different people (Star & Ruhleder, 1996). The challenge of supporting the use of technological artefacts is not just the collaboration or communication between technologies and peoples/organizations or between different people, but between different contexts. They argued for designing systems or technological artefacts by taking into account the complexity of the different contexts the technologies will be used in. Star
and Ruhleder defined three different levels on which problems can occur:

- First level issues: Problems related to setting up and using technologies, such as informational issues, lack of physical access and lack of skills and expertise

- Second level issues: Problems related to unforeseen contextual effects, such as technical choices and clash of cultures (e.g., different levels of affinity with technologies), paradoxes of infrastructure (contextual effects, e.g., lack of problem ownership) and tensions between a discipline in flux and constraints as resources (constraints can become resources, e.g., deadlines which motivate people)

- Third level issues: Problems related to interdisciplinary groups, such as triangulation and definition of objects (collaboration between people from different disciplines affecting information sharing) and tool building and the reward structure (no reward within someone’s own discipline for building/maintaining tools while they would be helpful for other disciplines)

When aiming to sustain PD practices in a school context (which is different from a research project context), similar challenges might occur. Schools have for instance different structures and cultures which might cause unforeseen contextual effects, teachers have different expertise and skills than (design) researchers and teachers will probably not be rewarded for adopting or evolving a toolkit.

The notion of infrastructure has been reinterpreted and adapted since the 90s by PD practitioners. (Information) Infrastructures as noun refers to “a relationship between humans’ organized ways of ‘doing’ things and the technologies that enable and support these practices.” ([Simonsen, Karasti & Hertzum, 2020](#)) p.1). Infrastructuring as verb refers to “activities that contribute to the successful establishment of an information system usage (equivalent to a work infrastructure improvement).” ([Pipek & Wulf, 2009](#)) p.447). In this thesis I use the term infrastructuring when referring to all activities that analyse, observe, build or evolve infrastructures.

Recent infrastructuring ambitions focus on the creation of dynamic, socio-technical infrastructures, that support long-term use and beyond a project’s end ([Björgvinsson, Ehn & Hillgren, 2012](#)). Infrastructures can be created on a technical level (for instance utilizing protocols like internet communication protocols to make procedural agreements for future design activities ([Ehn, 2008](#))), on a social level (for instance by building long-term relationships with stakeholders to create networks from which design opportunities can emerge ([Hillgren, Seravalli & Emilson, 2011](#))) and on a spatial level (for instance by identifying and articulating spatial configurations in buildings and towns ([Ehn, 2008](#))). An important characteristic of infrastructures is their ‘openness’, they are no rigid structures, but socio-technical processes ([Star & Ruhleder, 1996](#)).

Simonsen et al. ([2020](#)) defined different infrastructuring strategies for PD projects, referring to them using the term “infrastructural inversion”. Bowker ([1994](#)) initially
introduced this term to describe the efforts to make infrastructures visible. Simonsen et al. built upon this term and define three infrastructural inversion strategies: *conceptual-analytic* strategy, *empirical-ethnographic* strategy and *generative-designerly* strategy. The *conceptual-analytic* strategy aims to uncover infrastructures, consisting of hidden socio-technical relations that support the working mechanisms of the infrastructure. The *empirical-ethnographic* strategy aims for instance to uncover infrastructures by observing disruptions or breakdowns of socio-technical relations, using them as a starting point to explore the characteristics of the infrastructures (and eventually to explore opportunities for improvements). Another *empirical-ethnographic* strategy is to identify participants or actors, who are already engaged in infrastructuring activities, as “infrastructural allies”. Infrastructural allies could support researchers to embed the project’s outcomes within existing infrastructures. The *generative-designerly* strategy follows a similar approach. Identifying actors which could be infrastructural allies generate new infrastructures by defamiliarising their existing infrastructure, uncovering hidden working mechanisms of knowledge production. By engaging critically with existing infrastructure, new opportunities for infrastructure are created. The three infrastructuring inversion strategies illustrate how infrastructuring as approach can be used in different stages and for different aims: To observe and analyse existing infrastructures or as designerly tool to actively generate or evolve infrastructures.

Karasti (2014) discussed how infrastructuring is applied and conceptualized in PD projects. Reflecting on the work of Ehn and colleagues (Ehn 2008; Björgvinsson et al. 2012), the author argued that infrastructuring has been initially considered as a form of “design games in use” and “design-after-design” (Karasti 2014). Both concepts refer to the idea that, after a project has ended, the design process remains open for design activities. Design-after-design is aimed at defining and creating social and technical infrastructures which support new forms of (collaborative) design and allows future users to explore potential design beyond a project’s end (design-in-use) (Ehn 2008). In PD projects, the design process is traditionally limited to design activities with identifiable users (those which are actively engaged in the project). Other stakeholders or future users might appropriate the design results in different ways than intended by the researchers, or unforeseen challenges might prevent future use. In design-after-design and design games in use, design activities take place in separated time and space and the aim is to create environments and opportunities (infrastructures) for continuing design activities beyond the project’s end.

Reflecting on the discussed work, infrastructuring as Ehn and colleagues applied it can be considered as creating social and technical resources for sustaining similar (participatory) design activities, enabling audiences not involved in the initial project to maintain using and evolving the initial design (Bødker et al. 2017). In this process the users become co-developers or co-designers. In this thesis, I aim to sustain PD experiences as those from the children participating in the SPT project, but targeting next to the participating teachers children and teachers not previously involved. The main aim is not to create resources that enable to maintain the use or evolution of the designed artefacts in the
2. Related Work

SPT project (which would be in line with design-after-design or design-in-use), but to support maintaining, replicating, scaling and evolving the experiences and practices of the SPT project. This differs from approaches such as design-in-use and design-after-design (Ehn, 2008) since the designed artefacts by the children from the initial projects are not sustained, maintained or evolved. However, the core idea of design-after-design and design-in-use remains the same: Teachers who are going to use the toolkit developed in this thesis to maintain, replicate, scale and evolve SPT practices and experiences, become co-designers of the toolkit, practices and experiences. To support this process and enable the teachers to evolve them, social technical infrastructures might be necessary.

Infrastructuring as an approach to sustain aspects of PD projects is conceptualised by PD practitioners more recently as “establishing the social, organisational and technical arrangements that will secure that the results achieved during the project lead to sustainable outcomes (Hansen et al., 2019, p.7).” This process is supported by involving various stakeholders who “secure long-term impact through participation and commitment”. Through workshops and other collaborative activities, knowledge is shared and networks are created. Other infrastructuring results could be physical artefacts, and the adoption and integration of PD outcomes by stakeholders, leading to long-term impact (Hansen et al., 2019). Hence, Hansen emphasises the involvement of stakeholders as key to enable long-term impact of PD projects.

Meurer et al. (2018) explored how infrastructures which remain beyond the research projects’ end can sustain the use of a IT-based solutions as an outcome of a PD project. They differentiated sustainable outcomes on different levels: individual-level outcomes (for instance to sustain learning), community-level outcomes (for instance to sustain activities) and organization-level outcomes (for instance to sustain the implementation of activities). In their research projects, they engaged in community building and embedding PD initiatives in the existing social context of the participants. They conducted PD workshops with elderly people and observed that the participants continued to communicate, meet and support each other beyond the project’s end, using for instance the communication channels which were established during the project (WhatsApp).

Hence, infrastructuring can play an important role when aiming to sustain experiences and practices of a PD project. As discussed in Section 2.3.5, researchers recently started to explore opportunities for infrastructuring in the field of PD with children. I used infrastructuring in this thesis in two different ways: First, by following a conceptual-analytic infrastructuring strategy to explore the characteristics of the school context (on a material, organisational and social level) and by following a generative-designerly infrastructuring strategy to as part of the toolkit design process.
2.5 Sustaining practices and experiences of PD projects with a toolkit

Toolkits have been widely used in HCI as a collection of resources to enable people beyond a project’s end to continue to engage in technology design activities. I discuss the benefits and drawbacks of using a toolkit to sustain practices and experiences of a PD project for participants of PD projects and similar audiences not involved in the initial PD project.

2.5.1 Possible benefits of using a toolkit to sustain practices and experiences of PD projects

The value of toolkits for HCI is stated by Ledo et al. who defined five goals of using toolkits (Ledo et al., 2018):

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)

Educational resources and toolkits have been used by PD researchers successfully in the history of PD (Bjerknes et al., 1987) and more recently (Skinner, 2020) to enable audiences not involved in the initial PD project to evolve their practices around PD practices and experiences, as illustrated in Section 2.2.2. A toolkit which contains educational resources based on learning outcomes of PD projects is one approach to support empowerment, democracy and participation of new audiences.

A toolkit could also support the integration process with current practices and environments (Ledo et al., 2018). Hence, the usage of of existing toolkits is in line with the ambitions of PD researchers who aim to sustain their project’s practices and experiences, by enabling maintaining, replicating, evolving and scaling of PD practices and experiences (Iversen & Dindler, 2014). As explained in Section 2.1.1 I use those four terms as language to describe which aspects of sustainability are addressed in this work and which aspects are not addressed. This work aims at maintaining PD practices and experiences from the SPT project in the schools which participated in the project. Therefore, I aim to support the participating teachers with a toolkit approach to continue to conduct SPT practices beyond the project’s end. I further aim to scale PD practices and experiences by supporting teachers not involved in the SPT project to conduct SPT practices and have similar experiences with their class as the participating children and teachers in the SPT project. Since a school context differs from a research context (in terms of agendas...
and resources, for instance), teachers need to evolve those practices and experiences in their own context. A toolkit can offer teachers resources the teachers can choose from and appropriate based on their individual needs. Finally, I aim to replicate SPT practices and experiences in participating schools and schools not involved in the project. A toolkit approach can support to scaffold the practices and experiences from the SPT project to support sharing knowledge among teachers, for instance when teachers share and spread the toolkit with other teachers.

2.5.2 Possible drawbacks of using a toolkit to sustain practices and experiences of PD projects

As discussed in Section 2.3.4, a school context and children’s environments are comprised of rigid structures, for instance the educational system, curricula or power imbalances between teachers and children. Those structures and power imbalances might make it challenging to use a toolkit to sustain PD practices and experiences in this context. As discussed in Section 2.2, an inherent value of PD practices is empowerment and in PD projects with children, the children are decision-makers. This is contrary to their traditional role in schools. PD researchers reported about their experienced problems with teachers (Barendregt et al., 2016; Börjesson et al., 2019; Iivari et al., 2018; Iivari & Kinnula, 2016). While child-centred approaches, which are closely related to PD practices in terms of empowerment of children as decision-makers, are getting more popular in education since the 90s, they are criticized for requiring a lot of resources from teachers and schools and are often not practical in classroom settings (Shah, 2019). Current classroom settings have for instance a high pupil-teacher ratio which make PD practices which require individual support of children and children-centred teaching approaches challenging. Hence, a toolkit approach might support to sustain the practices and experiences of the initial PD project, but it might be challenging to design a toolkit which meets the restrictions of a school context and classroom setting.

Other possible drawbacks of using a toolkit in a school context were discussed in Section 2.4 and relate to potential infrastructuring issues: Schools have different organizational structures and cultures than a research project and teachers have different expertise and skills than researchers. This might cause contextual problems when we aim to create a toolkit to support teachers to adopt or evolve their practices around PD practices. Star and Ruhleder argued that toolkits can be useful, especially when aiming to transfer information from one context to another, but there is often no reward for those building or evolving the toolkits (Star & Ruhleder, 1996). This might be the case for teachers as well, hence, it might be challenging to support teachers not involved in the initial SPT project to evolve the toolkit.

Hence, a school context entails challenges which ask for a different toolkit scope than the educational PD materials developed in the early years of PD (Bjerknes et al., 1987). I did not compare a toolkit approach which other approaches to sustain practices and experiences in PD projects with adults (other than educational materials), because the
contextual challenges are quite different from the contexts PD projects with adults take place in.

2.5.3 Extending the scope of a toolkit

In this thesis I broaden the scope of the term ‘toolkit’ by developing a socio-material toolkit as argued in Section 2.5 including social ‘materials’ in addition to educational resources. This could be for instance social networks as suggested by Iversen and Dindler (2014), or local communities (Meurer et al., 2018), which support the use of the educational materials. Previous work has shown that, when aiming to sustain PD practices in a school context, social networks are crucial to support teachers to embed PD practices in their own context (Bødker et al., 2017). By exploring the characteristics of the school and developing a toolkit which meets the constraints and requirements of teachers, I aim to develop a toolkit which can address the possible drawbacks as discussed in the previous section. Broadening the scope of toolkits as socio-material resources might support participating teachers and teachers and children not involved in the initial PD project to have SPT experiences and engage in PD practices.

2.6 Second scoping literature review: Existing toolkits for children

After motivating why toolkits might support PD researchers to sustain their project’s practices and experiences, I present here a literature review of existing toolkits for children in the field of HCI. To explore how existing toolkits engage children in technology design processes, what kind of resources are included and what kind of resources might be missing for the context of this thesis, I conducted a scoping literature review of existing toolkits for children in the field of HCI. I chose a scoping review approach to categorise existing toolkits, what kind of resources are already available as toolkits and to identify possible gaps of existing toolkits. This literature review answers partly the third research question: What does a toolkit need to contain to support teachers to evolve their own practice around technology and participatory design?, but without narrowing down the focus on teachers yet. The aim of the analysis was to explore the characteristics of current technology toolkits for children (in all contexts) and how they are used. Toolkits designed in and for a school context are part of this literature review, but having a wider scope at this point allowed me to find inspiration from the whole field of HCI with children and to explore potential gaps in the field. I did not conduct a literature review on toolkits designed for teachers on different topics since a central element of the SPT project and our practices was the empowerment of children to engage actively in technology related topics. Hence, to enable SPT experiences with a toolkit, empowerment of children as designers is a central element in the toolkit as well.
2. Related Work

2.6.1 Research approach

In the literature search for existing toolkits, I focused on papers reporting on toolkits developed for children in the context of technology design processes. I used the search terms toolkit* AND child* in the field abstract and title. I searched the ACM digital library, the hcibib and Co-Design Journal, based on their focus on PD and Human-Computer Interaction. I did an initial search for papers in scopus, but my search terms resulted in many irrelevant articles (toolkits in a health context, for instance) and the articles which were relevant were duplicates I found in the smaller digital libraries, too. Hence, I searched only in digital libraries for HCI and PD related venues. Figure 2.3 shows an overview of the search and filtering process.

I applied inclusion and rejection criteria to filter the articles which are relevant to my thesis. The criteria are listed in Table 2.8.

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Rejection criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toolkit is developed for children</td>
<td>Toolkit is developed for adults</td>
</tr>
<tr>
<td>Toolkit is used to engage children directly</td>
<td></td>
</tr>
<tr>
<td>Article must report original research</td>
<td></td>
</tr>
<tr>
<td>Article must be peer reviewed</td>
<td></td>
</tr>
<tr>
<td>Article must be a journal-, full- or short-paper</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.8: Overview of inclusion and rejection criteria.

I analysed the resulting 35 papers similar to the approach described in Section 2.3.2. First, I familiarised myself with the data by reading each paper during the selection process of relevant articles. Next, I re-read the papers and generated initial codes based on the chosen categories: Type of toolkit (see Table 2.9) and resources included in toolkit
I defined more categories which were not included in this thesis (see appendix A 8.3.6 for the excel sheet with all categories) after reading the papers. During the last round of reading, I refined the categories and completed the coding process.

2.6.2 Findings

Different types of toolkits

Table 2.9 shows an overview of existing toolkits for children in the field of HCI that were described in the selected articles, for instance: Storytelling toolkits, construction toolkits, wearable design toolkits, evaluation toolkits, robotic toolkits, game-design toolkits, crafting toolkits, IoT learning toolkits or a combination of different types (i.e. robot storytelling). The toolkits were diverse in terms of aims (for instance aimed at evaluating technologies or engaging children in designing their own technologies), level of engagement with technologies (for instance entertainment or construction of technologies) and resources included (ranging from non-tech crafting materials to high-tech robots).

Approaches to engage children in technology design activities

As the different types of toolkits already show, the toolkits used different approaches to engage children in technology related topics. Not all toolkits aimed to engage children actively in design processes. The widely used ‘Fun toolkit’ for instance is used to evaluate the experiences of children with already designed technologies (see for instance (Read, 2012)). In this part of the analysis, I focus on toolkits which aimed to engage children actively in technology design activities and explore how the toolkits facilitated and supported their engagement.

Seven toolkits used storytelling to engage children in creative processes. Interactive technologies supported the storytelling process, for instance by animating traditional hand puppets (Mayora-Ibarra et al., 2009) or supporting technology design processes by embedding them in a narrative. Another approach to support children in design processes was to let them explore different technologies, for instance electrical components like sensors (Z. Lechelt et al., 2016; S. Lechelt et al., 2020), so they can use their insights to design their own technologies.

Blending different kind of materials, for instance electrical or digital materials and crafting materials, such as the Chibitronics circuit stickers (Qi et al., 2015), allowed children to explore new electronic concepts through familiar materials (in this case stickers). The Chibitronics toolkit also contained a booklet with lessons and activities for crafting circuits onto templates, supporting children with structures. Other toolkits built upon existing objects of children, like shoes (Kazemitabaar et al., 2015), that children can manipulate using attachable electronic modules to design interactive behaviors.
Table 2.9: Overview of existing toolkits.

<table>
<thead>
<tr>
<th>Name of toolkit</th>
<th>References</th>
<th>Type of toolkit</th>
</tr>
</thead>
<tbody>
<tr>
<td>t-books</td>
<td>Sylla, Branco, Gonçalves, Coutinho &amp; Brito (2012)</td>
<td>Storytelling</td>
</tr>
<tr>
<td>MakerWear</td>
<td>Kazemitabaar et al. (2017)</td>
<td>Wearable construction</td>
</tr>
<tr>
<td>IoT toolkit</td>
<td>Wallbaum, Ananthanarayan, Matveenko &amp; Bold (2020)</td>
<td>IoT learning and design</td>
</tr>
<tr>
<td>Info Block &amp; Info Tree</td>
<td>Baek &amp; Lee (2009)</td>
<td>Building information architecture</td>
</tr>
<tr>
<td>TIP-Toy</td>
<td>Barbareschi, Costanza &amp; Holloway (2020)</td>
<td>Computational learning</td>
</tr>
<tr>
<td>Dr. Wagon</td>
<td>Chawla, Chen, Sanders &amp; Billstein (2019)</td>
<td>Tangible programming toy</td>
</tr>
<tr>
<td>I/O Stickers</td>
<td>Freed et al (2011)</td>
<td>Handcrafting personalized</td>
</tr>
<tr>
<td>StoryClip</td>
<td>Jacoby &amp; Buechley (2014)</td>
<td>Storytelling &amp; interaction design</td>
</tr>
<tr>
<td>Chabtronics circuit stickers</td>
<td>Qi, Huang, &amp; Paranjo (2019)</td>
<td>Crafting with electronics</td>
</tr>
<tr>
<td>ReWear</td>
<td>Kazemitabaar et al. (2016)</td>
<td>Designing wearables</td>
</tr>
<tr>
<td>MakerShoe</td>
<td>Kazemitabaar, Sorozou, Guia &amp; Froehlich (2019)</td>
<td>Designing wearables</td>
</tr>
<tr>
<td>Magic Words</td>
<td>Kosmopoulos &amp; Sorkin (2009)</td>
<td>Interactive worlds</td>
</tr>
<tr>
<td>Robo2Box</td>
<td>Kirlangic, Obaid &amp; Yaniz (2020)</td>
<td>Classroom robots design &amp; storytelling</td>
</tr>
<tr>
<td>ConnectUs</td>
<td>Z. Lechelt, Rogers, Marquardt &amp; Shumi (2016)</td>
<td>IoT learning</td>
</tr>
<tr>
<td>Magic Cubes</td>
<td>S. Lechelt, Rogers &amp; Marquardt (2020)</td>
<td>Sensor learning</td>
</tr>
<tr>
<td>Modkit</td>
<td>Mihalas &amp; Hashi (2011)</td>
<td>Computational construction</td>
</tr>
<tr>
<td>TECHTILE Bits</td>
<td>Shibasaka, Tachiya &amp; Amanizawa (2017)</td>
<td>Computational construction</td>
</tr>
<tr>
<td>Fun toolkit</td>
<td>Head &amp; MacFarlane (2006)</td>
<td>Survey and evaluation</td>
</tr>
<tr>
<td>HandiiMate</td>
<td>Seehra, Verna, Pepper &amp; Ramani (2019)</td>
<td>Construction and animation</td>
</tr>
<tr>
<td>This or That</td>
<td>Sim &amp; Horton (2012)</td>
<td>Survey and evaluation</td>
</tr>
<tr>
<td>Storytelling Shapes</td>
<td>Speck &amp; Van Meeuwen (2013)</td>
<td>Storytelling</td>
</tr>
<tr>
<td>Neverwinter Nights Toolkit</td>
<td>Steiner, Kaplan &amp; Monthop (2006)</td>
<td>Game-design</td>
</tr>
<tr>
<td>TUK</td>
<td>Sylla, Branco, Coutinho, Coquet &amp; Sharoupen (2017)</td>
<td>Storytelling</td>
</tr>
<tr>
<td>Mechanix</td>
<td>Tseng, Bryant &amp; Hakstein (2011)</td>
<td>Social learning &amp; interaction design</td>
</tr>
<tr>
<td>Arbites</td>
<td>Villameves et al (2020)</td>
<td>STEM &amp; electrical circuitry</td>
</tr>
<tr>
<td>Scene-Driver</td>
<td>Wolf, Mulholland &amp; Zdrahal (2013)</td>
<td>Entertainment</td>
</tr>
<tr>
<td>No name</td>
<td>Carozzito &amp; Geneina (2013)</td>
<td>Tangible environment &amp; RFID tags</td>
</tr>
<tr>
<td>No name</td>
<td>Soute &amp; Nijmeijer (2014)</td>
<td>Robot storytelling</td>
</tr>
</tbody>
</table>

Toolkits also aimed to teach children about technologies, like computational topics (Barbareschi et al., 2020), building information architecture (Baek & Lee, 2008) or programming (Wallbaum et al., 2020). Based on the gained knowledge and skills, children can design their own technologies.

Children were supported in creative processes by including playful elements or supporting playful behaviours of children, for instance by using toys (Mayora-Ibarra et al., 2009), designing technologies to play with (Kindborg & Söker, 2007) or by including gaming elements (Steiner et al., 2006).

Overall, existing toolkits offered children diverse ‘hands-on’ experiences with technologies and use methodological approaches like storytelling to embed design activities in the children’s lifeworld. Further, children learned about technology related topics and acquire skills like programming that help them to design technologies.
2.6. Second scoping literature review: Existing toolkits for children

Resources included in the toolkits

To explore what kind of resources are included in toolkits to enable children in technology design activities, and which resources already exist, I made an overview of the resources which are included in the toolkits (see Table 2.10).

The majority of existing toolkits, 17, included electrical components as resources to involve children in technology design activities. The electrical components were used for instance to have children physically prototype and explore technologies, i.e. (Scheltenaar et al., 2015), to support creative elements such as storytelling, i.e. (Mayora-Ibarra et al., 2009), or to enhance existing objects to make them interactive, i.e. (Kazemitabaar et al., 2015).

Eleven toolkits were based on digital infrastructures, for instance visual programming environments (Wallbaum et al., 2020), and sometimes in combination with physical materials like electrical components (Liu et al., 2020). Other digital toolkits included digital components such as files, ranging from text/image files to 3D printing files.

Eleven toolkits included physical materials not including electrical parts, for instance crafting materials (Baek & Lee, 2008) which were open for appropriation and flexible use or 3D printed parts (Kırlangıç et al., 2020).

Two toolkits were based on existing toolkits, one is using the littleBits (Shibasaki et al., 2017), and one toolkit includes a workbook with instructions for children (Qi et al., 2015).

<table>
<thead>
<tr>
<th>Resources included in toolkit</th>
<th>References</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical components (i.e. sensors)</td>
<td>Sylla et al., 2012; Kazemitabaar et al., 2017; Wallbaum et al., 2020</td>
<td>17</td>
</tr>
<tr>
<td>Digital infrastructures (i.e. programming environment)</td>
<td>Wallbaum et al., 2020; Arora et al., 2019; Garzotto &amp; Gonella, 2011</td>
<td>11</td>
</tr>
<tr>
<td>Physical (no-tech) components (i.e. crafting materials)</td>
<td>Baek &amp; Lee, 2008; Barbareschi et al., 2020; Chawla et al., 2013</td>
<td>11</td>
</tr>
<tr>
<td>Digital components (i.e. 3D printing files)</td>
<td>Barbareschi et al., 2020; Chawla et al., 2013; Garzotto &amp; Gonella, 2011</td>
<td>10</td>
</tr>
<tr>
<td>Paper-based toolkits</td>
<td>Read &amp; McFarlane, 2008; Read et al., 2013</td>
<td>7</td>
</tr>
<tr>
<td>Existing toolkits (i.e. littleBits)</td>
<td>Shibasaki et al., 2017; Soute &amp; Nijmeeijer, 2014</td>
<td>2</td>
</tr>
<tr>
<td>Workbooks</td>
<td>Qi et al., 2015</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2.10: Overview of resources included in the toolkits.
Existing toolkits included and combined diverse physical and digital resources to allow children to engage with different kind of technologies. The majority of toolkits is based on physical resources, most of them electrical, which would need to be acquired by the people who want to use the toolkit. Other toolkits consisted of digital infrastructures, for instance web based applications, which only required standard devices like a computer or smartphone to be able to use the toolkit. Interestingly, existing toolkits focused on material resources, no toolkit included social infrastructures to support for instance people in using the toolkit. As argued in Section 2.4 I included social ‘materials’ as resources in the toolkit developed in this thesis.

2.7 Summary

In this chapter I addressed the first research question: What does sustainability mean for a PD research project?. I introduced the challenge of sustaining PD practices and experiences and how this challenge is addressed in PD projects. Related work in the field of PD with children shows important sustainability aspects, mainly gains and experiences of children related to learning, critical engagements with technologies and empowerment in technology design processes. Not only children, but also adult participants like teachers gain from their engagement in PD projects, they learned new skills related to teaching and technology. As those examples show, only participating children and adults in the project gain from their participation.

It remains unexplored how positive experiences of children participating in PD projects can be sustained for children not involved in the initial project. Iversen and Dindler (2014) have explored pathways to maintain, replicate, scale and evolve the practices of their project for participants and other audiences not previously involved. They have involved teachers and other audiences in the initial PD project to support maintaining, replicating, scaling and evolving PD practices. In this thesis I aim to explore how researchers can support those four forms of sustaining PD practices and experiences by designing a toolkit for teachers. The toolkit is aimed at sustaining PD practices and experiences of the initial SPT project for participating teachers and children and teachers not involved in the initial project.

When aiming for embedding PD practices and experiences in a school context, this context usually creates challenges for PD researchers: Rigid structures and power relations between pupils and teachers impact design sessions (Iivari et al., 2018, Iivari & Kinnula, 2016), and classes have a high teacher-pupil ratio (Bødker et al., 2017). Hence, I argue for exploring the characteristics of a school context as a next step, learning more about constraints, requirements and needs of teachers who might be able to support sustaining our project’s practices and experiences for similar audiences in the future. I introduced infrastructuring as a lens to inform processes which might help to sustain practices and experiences of PD project and illustrated how researchers in the field of PD with children have used infrastructuring. This could be implemented by developing a socio-material toolkit.
Finally, I have presented an overview of existing toolkits and discussed how they can enable children to engage in technology design activities. However, the majority of existing toolkits are 'stand-alone' materials and might benefit from social infrastructures that support their use. Future research will also be necessary how a toolkit that supports teachers with empowering children to engage with technology in creative and critical ways and to create their own technologies could be tailored to a school context.
CHAPTER 3

Methodology and Research Context

This chapter provides the methodology and research approach used in the research projects (the SPT project and the research conducted to design and evaluate the toolkit) leading to this thesis. First, I set up the context for my research - the Social Play Technologies (SPT) project. I present three case studies of the SPT project (LightSpaces, MusicPads, PictureStage) and the design process to give an overview about the project context and the way we engaged together with the children and teachers in technology design activities. In the second part, I explain how the knowledge of this thesis is constructed and why I have chosen an interpretivist/constructivist approach. In the last part of this chapter, the methods are presented which were used to 1) collect the data, 2) analyse the data and 3) evaluate the research approach. Finally, I reflect on the impact of COVID-19 on the chosen methods and the underlying ethical guidelines of this thesis.

3.1 Setting the research context - The three SPT case studies

The work reported in this thesis took place as part of a broader research project called “Social Play Technologies” (SPT), during which we collaboratively designed interactive technologies, supporting social play experiences, with neurodivergent children. During this project, we identified the challenge of sustaining the positive experiences and practices of PD projects like the SPT project for the participating teachers and similar audiences not involved in the initial project. My thesis addresses this challenge and reports on the pathways I explored to sustain particular project practices and experiences.

In the SPT project, we explored how digital technology can scaffold and mediate social play activities in three co-located groups of neurodivergent children, consisting of five
to six children, aged six to twelve years. We co-created three interactive play things, LightSpaces, MusicPads and PictureStage, that supported children in engaging with each other in meaningful ways during play activities. All play things were designed to be open ended in their interpretation and embedded in the social play contexts of the participating children (see Table 4.1). We conducted in total 50 design workshops, one hour each, with the children at their schools. The SPT project was the starting point for my own work presented in this thesis: The positive experiences of the children and teachers involved (as illustrated in Chapter 4) motivated me to explore how positive experiences and practices of the SPT project could be sustained for participants and similar audiences beyond the project’s end. I present here the three case studies of the SPT project to set up the context for my thesis.

3.1.1 Social Play Technologies cases

In three co-located groups of children, we collaboratively designed with the children the social play technologies. The SPT included three cases: LightSpaces, MusicPads and PictureStage. The names for the cases are chosen based on the social play technologies which were designed in each group.

The case studies presented in this chapter were part of the research project ‘Social Play Technologies’ led by Christopher Frauenberger, conducted at the TU Wien. Christopher Frauenberger, Irene Posch, Johanna Pichelbauer, Katharina Werner, Katta Spiel and Kay Kender were involved in this project. I use the pronoun ‘we’ when reporting on the SPT project in recognition of the contributions of my colleagues of the SPT team. My contribution in this project was to organise and run, together with my colleagues, the co-design workshops with the children. I was also involved in building and evaluating the prototypes. The findings from the case studies have been published in (Scheepmaker et al., 2018), (Frauenberger et al., 2020), (Frauenberger et al., 2019) and (Kender et al., 2020).

LightSpaces

Six children (see Table 4.1), who were in the same class and knew each other well, participated in the design process of the Lights Spaces.

The LightSpaces (LS) were a collection of coloured fabrics, three of them with an embedded interactive lighting system. The children who co-created the LS used the fabrics to connect them with furniture in the room, using integrated magnets in the edges of the fabrics, to create their own ‘play spaces’. In those created play spaces, the children engaged in role-playing games and pretend play. Three squeezable objects in different shapes and colours (see Figure 3.1) were attached to the fabrics and used to control the lightning system.

MusicPads

Five children (see Table 4.1) participated in the design process of the MusicPads.
3.1. Setting the research context - The three SPT case studies

Figure 3.1: A picture of the LightSpaces prototype. The hand in the middle presses two colour coded pieces of fabric (yellow and blue) causing all lights to shine in green. All fabrics incorporate magnets to be easily attached to furniture in the children’s environment (e.g. tables).

The MusicPads (MP) (see Figure 3.2) consisted of ten interactive pads that played sounds or sound effects when stepping on them. They could be placed or moved anywhere in the room. When stepping on a pad, the embedded sensors reacted and gave feedback by activating the embedded LED strip and sound. The base station was connected wirelessly to the pads and played the sounds and effects. When the red button was hit, the sound and effects were re-assigned to the pads.

The MP were used by the children to play music together, and also to collaboratively identify sounds and effects. The children frequently negotiated rules for how to interact with the pads and invented their own games with the MP. They also enjoyed drawing on the pads with a whiteboard maker, to individualize them.

PictureStage

Four children (see Table 4.1), who were in the same class and knew each other well, participated in the design process of the PictureStage.

The PictureStage (PS) (see Figure 3.3) consisted of a tabletop reading lamp with an
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Figure 3.2: Picture of the MusicPads prototype. The speaker system was on the left, the muscipads on the right. The musicpad in the middle shows the LED stripe which lighted up when stepping on the pad.

embedded Raspberry Pi, running OpenCV and a camera which captured the illuminated area. The output was projected with a projector, aimed at a wall or the floor. The children drew underneath the lamp or used squares with RFID tags with visual effects.

The children used PS to negotiate what they project and draw under the lamp. They interacted with their drawings using PS and created games around it. They also created a story out of cut-out drawings and performed it to the researchers.

3.1.2 Design process of the three cases

The design process was conducted iteratively. Concepts were refined many times and with the PS group, we even threw out a concept half way through and started from scratch.

To give an overview of the different phases in a design process, I list six important stages we passed through with each design team:

1. Bonding: During the first workshops, we focused on getting to know the children and to form bonds with each other, for instance, by collaboratively crafting tokens.
3.1. Setting the research context - The three SPT case studies

2. Technology Immersion: We introduced different kinds of technologies to the children, for instance littleBits[1] or Calliope. While exploring the possibilities of the technologies, the children learned how to combine, for instance, inputs and outputs, and embedded them in their own play.

3. Generating ideas and concepts: After the children came up with ideas or we observed them engaging with technologies which supported their play, we generated and iterated ideas and concepts during regular team meetings.

4. Low-tech prototyping: Especially during early design phases, we engaged in low-tech prototyping activities using no technology or low-tech materials the children were

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[1] LittleBits are electrical building blocks developed for children to build prototypes: https://sphero.com/collections/all/family/littlebits
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already familiar with. We also used Wizard-of-Oz approaches.

5. High-tech prototyping: When we had a more refined idea for a concept, we built stable prototypes to test with the children.

6. Testing prototypes: We iteratively tested prototypes at every stage of the process to see how the children engaged with them, how they embedded them in their play and what we needed to improve in terms of usability, engagement and stability.

3.1.3 Methods applied in the SPT project

The SPT project was deeply rooted in PD practices. Methods and approaches from the field of PD were chosen to empower neurodivergent children to actively co-create and re-think the technologies they play with (Frauenberger et al., 2019, 2020). PD projects succeeded in the past to actively involve neurodivergent and neurotypical children in design projects, to empower them (Wilson et al., 2018) and create meaningful experiences with children (Iivari & Kinnula, 2016; Spiel et al., 2015), and resulted in valuable gains for children (Barendregt et al., 2016; Börjesson et al., 2019; Dressen & Schepers, 2018; Franco & de Deus Lopes, 2009; Iivari et al., 2018; Iivari & Kinnula, 2016; Iversen & Smith, 2012; Iversen et al., 2017b; McNally et al., 2017; Van Mechelen et al., 2019, 2018; Melonio et al., 2020; Robinson et al., 2020; Schepers et al., 2018a, 2018b; van Rijn & Stappers, 2008). It was thus a suitable approach which aligned with the agenda of the SPT project, which was to empower children in engaging in technology design processes.

The different phases of the design processes in the SPT project were partly based on the Cooperative Inquiry framework (Druin, 1999), adapted for the specific characteristics of neurodivergent children by Guha et al. (2008). Similarly, the IDEAS framework supports involving autistic children in design processes, focusing on empowering the children by structuring the environment (for example by having consistent routines) and offered additional supports (Benton et al., 2011). We balanced carefully structured activities to maintain a secure environment and creative freedom based on the concept of a Handlungsspielraum (Makhaeva et al., 2016), empowering the children to be active participants in a design process. This was achieved by organising workshops offering recurring elements and rules, while giving the children freedom to make their own decisions and offering a diverse collection of materials and prototypes. Each workshop had for instance 15 minutes of free playtime the children could use the way they wanted. We also built on the experiences from the previous research project led by Christopher Frauenberger (Frauenberger, Makhaeva & Spiel, 2016; Frauenberger et al., 2017a; Frauenberger, Makhaeva & Spiel, 2017b; Spiel, 2017; Spiel, Frauenberger, Hornecker & Fitzpatrick, 2017; Makhaeva et al., 2016).

3.1.4 Data collection in the SPT project

We conducted in total 50 co-design workshops over 2.5 years. All workshops were video-recorded and individual researcher diaries (I refer to the diaries in the thesis using the
3.2. Research paradigm

After discussing the SPT project as context for this thesis, I discuss the methodological background for this thesis which was based on the SPT project. This thesis investigates how we can increase the likelihood of sustaining positive experiences and practices of PD projects in a school context for involved teachers and similar audiences not involved in the initial project. Hence, the context in which this research takes place plays a key role in finding the answer to the question. It is therefore necessary to gain an in-depth understanding of the context and the teachers’ practices, in which this research project takes place: schools. Together with teachers, I explored how PD practitioners could embed and sustain their practices and experiences with a toolkit in a school context.

The context in which my research is situated in, schools and the practice of teachers, is local. I investigate the challenges of sustaining SPT practices and experiences in this context (Research question 2) through engagements with teachers. However, there is not one school context, with a definitive set of characteristics. Teachers were involved from different schools with respective individual requirements, skills, needs and wishes. Hence, the knowledge created from the engagements with teachers is situated in the local context of the teachers involved in this research and influenced by the teachers’ own personal experiences and values.

To address the challenges of sustaining practices and experiences of a PD project, I developed a toolkit collaboratively with teachers. The insights from the design process also enabled me to explore the contextual characteristics of a school context and opportunities for sustaining SPT practices and experiences.
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how to support teachers to enable children to design technologies. During the interactions with the teachers, the toolkit prototype and my understanding of the school context characteristics evolve and knowledge is created. Hence, those researcher-teacher-toolkit interactions are a central element in the process of knowledge creation.

The approach in this thesis aligns with an Interpretivist/Constructive research paradigm (Mackenzie & Knipe 2006). This approach seeks to build an understanding of human experiences, relying on the views of the participants that are involved in the research (the teachers in this research). As argued, the interaction between researcher and participant plays a central role in thesis to explore the participant’s experiences and characteristics of the school context. Qualitative methods are applied to gain in-depth knowledge of the teachers practices and to explore opportunities for a toolkit approach to sustain the practices and experiences of the SPT project. By doing this, my role is twofold: As researcher, I ask specific questions to the participants to gather data and construct knowledge based on their answers and interactions with them. As designer, I propose a toolkit approach and iteratively design a toolkit in collaboration with the teachers. I contribute to this process with my own values, understandings and designerly knowledge and skills. Hence, I acknowledge my own role and influence in the process of data collection, analysis and interpretation and shape the research process as well as the participants.

3.2.1 Concept-driven Interaction Design Research

To integrate the toolkit design process in the overall research process, I applied a concept-driven approach to interaction design. Stolterman and Wilberg (2010) introduced a concept-driven approach to interaction design research, which focuses on theory development and builds upon Research-through-design (RtD) (Zimmerman, Forlizzi & Evenson 2007). RtD acknowledges the active role of the designer in the project, influencing process and outcomes with their special ‘designerly’ knowledge and experiences. This is inline with my constructivist perspective and role as active participant in the research process. During the research project, I followed an iterative design process of problem context exploration, ideation, developing toolkit prototypes, testing and evaluating the resulting toolkit that reflected the generated framing of the problem. RtD is conducted in design research processes where a critical understanding of design problem spaces is required (Bardzell, Gross, Wain, Toombs & Bardzell 2011).

RtD has a strong focus on creating an artifact as outcome, but has been criticized for producing less “trustworthy results” (Zimmerman, Stolterman & Forlizzi 2010). Theory development is not the main aim of RtD and often only an “afterthought”. Addressing these criticisms, Stolterman and Wilberg (2010) introduced a concept-driven approach to interaction design research, which focuses on theory development and builds upon RtD. Concept-driven interaction design is an approach that makes the existing cycle of prototyping, theory development, and user studies explicit. At the beginning of the design process, a conceptual or theoretical idea forms the basis for the design process. This conceptual idea is conceptualised and theoretically explored further through hands-on
design and artifact development. The end result is, next to an artifact, an evolved understanding of a specific idea, concept or theory.

A concept-driven approach supports the development of a critical understanding of the school context, while engaging in a design process (of the toolkit) and exploring opportunities to sustain the experiences and practices of PD projects. The design artifact, the toolkit, is used in this process to explore how teachers would evolve their practices around technology design activities. I used the toolkit prototypes as a means to deepen my understanding of the school context and re-designing the prototype collaboratively with the teachers. The design process is thus research-oriented, a combination of research and making, but the toolkit as artefact and resulting design implications play an important role in it. A concept-driven approach aligns with this work, as the main aim of this thesis is to formulate considerations for future PD practices which can help researchers to make preparations for enabling participants and similar audiences not involved in the initial project to sustain the project’s practices and experiences before the initial project ends. A toolkit approach is only one possible way to approach the challenge of sustaining practices and experiences and considering the situatedness of this work, future work must show whether this approach or the resulting toolkit could indeed lead to sustained practices and experiences of PD projects in a school context. Hence, an important contribution of this thesis is not only the resulting artifact (the toolkit), but also an evolved understanding of the school context and conceptual approach of a toolkit as pathway to create sustainable practices and experiences in this specific context. The quality of the toolkit is a reflection on the concept and supports the argument.

3.3 Methodological approach

Here, I give a brief summary of all methods applied during the studies and how the data was collected and analysed. I have conducted a total number of four studies: A semi-structured interview, a co-design workshop, an online-survey and an evaluation study (including an assignment for teachers to plan a teaching unit and three lessons, and two focus groups and a semi-structured interview to discuss the results).

3.3.1 Overview of studies

These methods helped helped me to answer the RQs two, three and four. Table 3.1 shows the studies with the teachers I have conducted during the design process of the toolkit.

To gain initial insights in the practice of teachers and the school context, a semi-structured interview was conducted with two teachers who participated in the SPT project. The interview resulted in an overview of challenges their school context presents and first ideas on how to address them. After the interview I decided to create a toolkit, a collection of tools that could support teachers to enable children to engage in technology design activities. Based on the characteristics of the school context which were discussed during the interview, results from the literature review and our own experiences stemming from
the workshops conducted in the SPT project with the children, I designed a first toolkit prototype.

To deepen my understanding of how a toolkit could support teachers with their practice, what kind of tools such a toolkit could contain, we conducted a co-design workshop with two teachers. During the workshop, the teachers explored the materials of the toolkit and re-designed alternatives for each one by actively engaging with them. The co-design workshop resulted in additional insights into the characteristics of the school context, the teachers’ constraints and wishes, and design insights into how to re-design the first toolkit prototype.

To initially evaluate if the second toolkit prototype would meet the constraints and needs of teachers not involved previously in the SPT project or a PD project in general, I conducted an online survey with five teachers. The different tools were presented on a website and the survey consisted of a mix of 21 questions about the respective parts of the toolkit. The online survey resulted into first insights about how teachers who did not participate in the SPT project or toolkit design process would interpret the different tools. Based on these results, a third and final version of the toolkit prototype was developed.

To evaluate if and how a toolkit could work as an approach to sustain SPT experiences and practices for teachers not involved in the initial project and how teachers would appropriate the toolkit to embed it into their own practice, an evaluation study was conducted. Five teachers from Austria and Germany were recruited online using social-media. They were asked to write lesson plans where they describe how they would use and appropriate the toolkit in their class. Next, I discussed with them their experience with the toolkit and how they would appropriate it via two focus groups and one semi-structured interview.
3.3.2 Data collection

The semi-structured interviews, the focus groups and the co-design workshop were audio-recorded. During the first semi-structured interview and the co-design workshop an assisting researcher took notes. The online survey was conducted using limesurvey\(^3\) and the results collected in excel tables. The data of the lesson plans and teaching units was digitally collected using interactive pdfs, one teacher printed the form and handed in her data on paper which was digitalized afterwards.

Next to the data which was collected during the studies, I wrote a researcher diary. The diary contained reflections on studies, design and methodological insights, and helped me to scaffold the knowledge during the thesis writing process (Engin & Assistant, 2011).

3.3.3 Data analysis

All data was analysed using Thematic Analysis (TA), based on the approach of Braun and Clarke (Braun & Clarke, 2006, 2020). TA is qualitative method to analyse data such as transcripts from interviews or workshops, aiming to find patterns or themes within the data. I used TA mainly inductively by looking for patterns of meaning in the data and codes. Coding is not a method for searching evidence for already defined themes (Braun & Clarke, 2020), but requires an active and reflexive engagement with the data, by reading, reflecting, questioning, iterating, writing it. The data was analysed for multiple purposes, dependent on the study: to explore the situated context (schools) and its characteristics, the needs and wishes of teachers and to explore how teachers would use and appropriate the toolkit. I used infrastructuring as lens in the toolkit design process, as motivated in Chapter 2. To analyse relevant data in relation to infrastructuring, I used TA deductively (informed by infrastructuring as a lens). Hence, I paid special attention to the socio-material relations discussed in the data sets.

For analysing the data from the semi-structured interview, the co-design workshop and the online-survey, my TA approach was informed by the first article of Braun and Clarke (2006) about TA. At this point, they had not defined a specific approach to TA. When analysing this data, I used the guidelines from Braun and Clarke as a ‘recipe’ I could follow step-by-step. Since their first work in 2006, their understanding of TA has evolved (similar to my own understanding of TA which has changed during the research process of this thesis). Braun and Clarke now refer to way they approach TA as reflexive TA. Reflexive TA values the subjective, situated, aware and questioning researcher, hence: A reflexive researcher. This aligns with the research paradigm I operate in and my own understanding of my role as researcher: As active and subjective actor in the creation of knowledge, using my knowledge and understanding as resource rather than fearing bias. Reflexive TA is informed by a qualitative paradigm: the Big Q framework. Big Q or ‘fully qualitative research’ refers to qualitative research which builds on qualitative tools and techniques within a qualitative paradigm (qualitative values, norms and assumptions) (Braun & Clarke, 2021).

\(^3\)An online survey tool: \url{https://www.limesurvey.org}
To analyse the co-design workshop, the data was coded separately by two researchers (me and a colleague who was also present during the workshop) and we discussed the themes afterwards to get a broader perspective on the design insights resulting from this study. The other data was analysed by me alone. I followed the six steps as outlined by Braun and Clarke: First, I familiarised myself with the data. This happened already during the transcription of the audio or video records, which was done manually by myself as a first and important step to inform further analysis [Lapadat & Lindsay 1999]. Next, I generated initial codes and searched for themes while paying special attention to those themes which could be relevant for the research question. I first highlighted parts of the text, ranging from single words to sentences, which seemed relevant for my research questions, or caught my interest in other ways without being able to name a theme yet. Based on the initial codes, I read through the data again and searched for themes. I assigned different colours to each theme and highlighted the extracts accordingly. To review themes and refine them, I used a word document with all initial main- and subthemes and sorted the highlighted extracts iteratively. On a notepad, I kept record of this process and played with different themes and names by drawing a mind-map. This allowed me to more flexibility and visually supported the process. When I was satisfied with the themes, I re-arranged the document and made an overview of all themes and codes. An example of this process is pictured in Appendix D [8.3.6] Based on this document, I wrote a summary of the results.

The researcher diaries from the first semi-structured interview and the co-design workshop informed my analysis. I also used the diaries to retrace the process of knowledge construction [Engin & Assistant 2011].

3.3.4 The impact of COVID-19 on the chosen research methods

After conducting the co-design workshop with the teachers, I was facing restrictions caused by the COVID-19 pandemic. External people (such as researchers) were not allowed to enter schools in Vienna and during each lock-down the children were home-schooled. This led to an increased workload for teachers, which had a negative impact on their availability and motivation to participate in my research project.

Hence, I chose my research methods not only based on the most suitable approach which would have helped me the best to answer my research questions, but also by considering the feasibility in line with the current COVID-19 restrictions and resulting challenges. I initially planned to conduct a series of co-design workshops with teachers to collaboratively iterate the toolkit concepts during hands-on activities. My evaluation study was conducted remotely and without the involvement of children, however, I originally planned to evaluate at least parts of the toolkit during a workshop with children.
3.4 Quality criteria

This thesis sets out to address a challenge in a situated, complex context (schools and their respective inherent structures). As illustrated in Section 3.2, my research approach builds on gaining an in-depth understanding of local context. In this thesis I decided to approach the challenge of sustaining practices and experiences of a PD project with a toolkit approach, but I acknowledge that there is an unlimited potential for possible solutions (some other pathways to sustainability are presented in Chapter 2). Hence, ‘traditional’ scientific quality criteria such as generalizability, objectivity, reliability and validity do not apply for this thesis. Instead, this thesis I applied the six quality criteria for rigor as defined by Meyer and Dykes (2020): informed, reflexive, abundant, plausible, resonant and transparent.

The knowledge base informing this thesis is partly presented in Chapter 2, consisting of existing literature about technology toolkits for children and opportunities, sustainability aspects in PD projects with children, and theories informing this thesis. Besides existing work, my experiences during the SPT project and being part of an HCI group have shaped my theoretical and methodological understanding and skills. I embraced the reflexivity of my work and was aware of my own bias and active role in the research and design process, and as previously argued, as aligning with an interpretivist approach. I aimed to explore new perspectives different from my own during the engagements with children in the SPT projects and the teachers who were involved in the design process. I shared and discussed my learning outcomes with colleagues and supervisors, helping me to reflect on my research outcomes and to spot potential assumptions or biases of my work. Peer-reviewed publications and peer-reviewing this thesis further supported me to be a reflexive researcher. This thesis is based on abundant data from interviews, focus groups, workshops and online studies, which present the different voices from co-located teachers and helped me to provide rich evidence and descriptions (for instance by using quotes). By abstracting from this specific, situated details and analysing them using reflexive TA (Braun & Clarke, 2006, 2020), I developed concepts and made plausible, more general claims. Keeping a researcher diary supported me to critically reflect upon my findings (Engin & Assistant, 2011). I aim for my work to resonate in the fields of HCI and PD. In Chapter 7, I position this thesis in existing work and suggest considerations for future work which can inspire researchers to increase the likelihood that the participant’s positive experiences and PD practices can be sustained for participants and similar audiences not involved in the initial project. The previously mentioned rich data underpins this thesis, making it resonating with and transferable into different contexts. By explaining how my work resonates with the previous criteria as defined by Meyer and Dykes (2020), I contributed to the transparency of the methods which led to generating knowledge presented in this thesis.
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3.5 Ethical considerations

The University, where this research was conducted, had no ethical committee and I did not need ethical approval to conduct my studies. This required a pro-active engagement with ethical guidelines. The SPT project followed guidelines formulated by the project leader Christopher Frauenberger (Frauenberger, Rauhala & Fitzpatrick, 2016), which formed the basis for my own ethical understanding. The ethical guidelines for the SPT project and this thesis are presented in Appendix B 8.3.6. I also discussed decisions related to ethical considerations with the project team.

I collected informed consent forms (see Appendix B 8.3.6) prior to the first engagement with all participants. They were informed about the project context and the data collection and protection process with a written letter. All informed consent forms and letters were reviewed by my supervisors Christopher Frauenberger and Geraldine Fitzpatrick.
In the previous chapter I presented three cases and the design process of the SPT project. In this chapter I reflect upon the SPT project which motivated my own work and informed the toolkit development process. The SPT project included three cases: In three groups of children, we collaboratively designed three social play things that support children to play together.

This chapter has three parts: First, I motivate why we aim to sustain practices and experiences of the SPT project for teachers involved in the SPT project and similar audiences (children and teachers) not involved in the initial SPT project. Second, I present the different experiences of the children involved in the SPT project which we aim to sustain for children not involved in the initial project, the sustainability targets. I reflect upon the ways we enabled the children to engage in technology design activities and achieved the sustainability targets: the enablers. The defined sustainability targets form the goals for the toolkit, the defined enablers form the input for the toolkit design process (as further illustrated in Chapter 5), by giving first insights into what might be necessary to sustain similar experiences and practices for teachers and children not involved in the initial project. Third, I reflected upon the challenges a school context holds for design activities, for instance teacher-children power relations or rigid structures.

This chapter answers the subquestion of the first research question: What does sustainability mean in the context of the SPT project and what could be possible targets and enablers to sustain?. With the term sustainability, I refer to efforts which have “the quality of being able to continue over a period of time”. In terms of sustainability, I was particular interested in sustaining SPT practices and experiences for the participating teachers and similar audiences not involved in the initial SPT project in a school context.
4. Defining Sustainability Targets and Enablers

4.1 Motivating why we want to sustain practices and experiences of the SPT project

Before stepping through the specific practices and experiences of the SPT project, I motivate the decision to explore pathways to sustain the project’s practices and experiences for the participating teachers and teachers and children not involved in the initial project. Over the three year timespan of the SPT project, we observed the children engaging critically with existing technologies, discussing and negotiating together new concepts and visualising their ideas with different kind of materials (electrical components or simple pen and paper prototypes).

Nearing the SPT project’s end, we realised the effects of the positive experiences the participants involved in the project had, as this vignette from the my thesis researcher diary illustrates:

*I conducted a game-design workshop with the MP group in collaboration with a company during which the children were asked to re-design a game the company developed. Two children felt immediately inspired and sat together to draw a planning for the new game. They drew different levels with varying levels of difficulty, obstacles which grow if the level is getting harder. They criticised the existing boundaries in the game: “Brainhero (the protagonist) should be able to fly in both directions, not only from front to back!” They were also considering to have a villain in the game, but after discussing with each other, they agreed to cross out this idea. Instead, they suggested new characters: “What about switching characters? I want a spider, or a UFO!” (Figure 4.1 shows the drawings of the children they made when negotiating the details for the re-designed game). Two designers working for the company were observing the children during the workshop, and stated afterwards how impressed they were from the way the children approached the re-design challenge and the ideas they suggested.*

This vignette illustrates how confidently the children took the lead in a design process and re-designed - with the designers of the game sitting silently next to them - the company’s game. The children analysed critically the existing game and suggested ideas for improvements, without any guidance from the researchers or designers from the company. At this point, I realised that the experiences from being involved in the SPT project had broader effects on the children and the children benefited from their experiences in the SPT project. This motivated me to explore how we could sustain similar, SPT experiences and practices for children not involved in the SPT project. Other vignettes illustrating the positive experiences of the children involved in the initial SPT project are presented in Section 4.3.

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1. We certainly cannot, and do not want to claim that this is (only) the result of their participation in the SPT project. However, we hope that their collaboration with us has supported them to become those confident and creative designers they are now.

2. https://brainhero.life
4.2 Research approach

The research approach of the SPT project, including the process and data collection for the SPT project, was described in Chapter 3. Here, I illustrate how I used the researcher diaries from the SPT project and my own notes to reflect upon the cases, leading to defined ‘sustainability targets’ and a list of ‘enablers’ which enabled children to participate in technology design activities. Next to the collected data in the SPT project (video-records of the workshops and researcher diaries), I discussed with the SPT research team what their experiences were during the project, which positive experiences of the children they could identify, and how we enabled those experiences. As mentioned in Chapter 3, I had also frequent discussions with the teachers of the children, which were not recorded, for instance when we picked up the children for the workshop or brought them back to their classroom. We also had irregular meetings with the two teachers of the LS group and the PS group who were not present during the workshops (the roles of the teachers are explained more in detail in Section 4.4.1). I used my own researcher diary for note keeping insights from those discussions. I kept all notes relevant
4. Defining Sustainability Targets and Enablers

for my own research reported in this thesis in this separate diary. I also captured my own reflections about my work and experiences in the SPT project and the toolkit design process in this diary.

4.2.1 Data analysis

I conducted a Thematic Analysis of my own notes and the SPT researcher diaries, following the steps as outlined by Braun and Clarke (2006) and explained in Chapter 3. I used TA mainly deductively, searching for all data which might be related to ‘experiences’, ‘design process insights’ and ‘methods applied’ in the project. Hence, I focused during the coding process on positive experiences of the participating children and practices which enabled those experiences. Figure 1 and 2 in Appendix B 8.3.6 show examples of my notes I took when searching for initial themes. When I started coding, I realized that my own notes do not give a full picture of the data. I was missing the perspective of the children who participated in the cases. Hence, I added parts of the researcher diaries from the SPT project (as the researchers captured aspects of the children’s perspectives, mainly in their role as playpartner) to my notes. Since we had collected 50 researcher diaries during the SPT project, I coded the diaries partially. I first read the diary and highlighted possible relevant parts for the analysis. Next, I coded the highlighted parts deductively, based on the previously defined initial themes of experiences, design process insights and methods applied. One SPT researcher diary entry is included as example in Appendix B 8.3.6 and Figure 4.2 shows a screenshot of a partly coded researcher diary. Where quotes from the children were missing, I listened to the video-records and partially transcribed conversations with the children. Then, I compared and re-arranged the themes found in the SPT researcher diaries with the themes from the video-recording transcripts and the themes which I generated from my own notes. Those resulted in two final sets of themes, one related to the ‘sustainability targets’, one related to the ‘enablers’.

4.2.2 Participants of the SPT workshops

Table 4.1 shows all the child participants (15 in total, all names changed) of the SPT projects.

4.3 Results: Presenting the SPT project sustainability targets and enablers

Here I present the results of the analysis process of the sustainability targets and enablers to map out which experiences we might want to sustain for children not involved in the initial SPT project and how we enabled those experiences in the SPT project. I use the term ‘sustainability targets’ to refer to the positive experiences the children had during the SPT project. Sustaining means in this context that children not involved in the initial SPT project have SPT experiences, but without researchers being present. Instead,
4.3. Results: Presenting the SPT project sustainability targets and enablers

Figure 4.2: Screenshot from coding process of the researcher diaries.

teachers enable the children to have similar, SPT experiences, by applying SPT practices (based on the enablers).

A cornerstone in the SPT project and the overarching sustainability target was the empowerment of children in technology design processes and the project was grounded in the democratic values and ideals of PD [Iversen et al., 2010]. Having those experiences around empowerment and technology design activities can contribute in a positive way to the children’s personal development, as skills such as creativity, autonomy and problem-solving are supported [Iversen et al., 2017a; Skinner, 2020]. Hence, when looking at the positive experiences of the children, I defined those experiences centering around empowerment in technology design processes as *sustainability targets*. As argued in Section 2.1.3 and 2.2, the SPT project and the toolkit presented in this thesis builds upon three aspects of empowerment, as defined by [Kinnula et al.]

1. Educational/competence view: Empowering children through offering them important skills and competencies.

2. Democratic view: Empowering children to participate in decision-making processes through giving them a leading role in design processes.

3. Critical view: Empowering children through encouraging them to critically engage with, and re-think (existing) technologies.
4. Defining Sustainability Targets and Enablers

<table>
<thead>
<tr>
<th>LightSpaces</th>
<th>MusicPads</th>
<th>PictureStage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leyla 8, protects Attila, low frustration tolerance, learning differences</td>
<td>Tony 7, thoughtful, interested, left after year one, learning differences</td>
<td>Aisha 9, kindhearted, easy-going, creative</td>
</tr>
<tr>
<td>Leo 7, left after year one, sensitive, attentive, ADHD</td>
<td>Timur 8, kindhearted, easily frustrated, learning differences</td>
<td>Elli 9, creative, calm, shy, needs encouragement</td>
</tr>
<tr>
<td>Asa 7, loves drawing &amp; the city’s underground system, autism</td>
<td>Emir 8, enthusiastic about maths, differences in social interactions, autism</td>
<td>Jason 12, left after year one, English speaking, imaginative, autism</td>
</tr>
<tr>
<td>Attila 7, friendly, sensitive, optimistic, self-blaming, autism</td>
<td>Deniz 8, full of ideas, dominating, autism</td>
<td>Valerie 11, active, strong sense for cooperation</td>
</tr>
<tr>
<td>Link 10, joined in year two, interested in Super Mario, easily distracted, autism</td>
<td>Louisa 9, avid reader, gets tired quickly, Down syndrome</td>
<td>Asa 8, switched from <em>LightSpaces</em> to <em>PictureStage</em> group in year two</td>
</tr>
<tr>
<td>Jamila 9, creative, self-confident, learning differences</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.1: Child participants (all names changed) in each of the three groups including age, characteristics and diagnosis where available.

While researchers in the past have succeeded in involving children in design projects (Druin, 2001), a more recent focus in the field of PD with children is the inclusion of neurodivergent children (Wilson et al., 2018; Benton et al., 2011; Malinverni et al., 2014; Guha et al., 2008; Spiel et al., 2018). With the SPT project, we contributed to this body of work by empowering neurodivergent children to collaboratively design social play technologies. Therefore it was important that the children experienced their collaboration as meaningful and that we created technologies as design partners. Hence, we considered experiences which contributed to the empowerment of children crucial sustainability targets, as they enabled the children to take a critical, reflexive stand in the design process. In the SPT project, the children were actively involved in each stage of the design process and contributed to it. Looking at the results of the analysis and the presented vignettes and quotes from the children, we saw different forms of empowerment evolve during the SPT project, which are part of the below illustrated sustainability...
4.3. Results: Presenting the SPT project sustainability targets and enablers

targets. For each sustainability target, I explain the enabler(s) which enabled this target.

I motivate based on the results of the analysis and reflexive discussions with the SPT project team why we chose those experiences as ‘sustainability targets’. All sustainability targets are listed in Table 4.2 and visualised in Figure 4.3, showing the experiences we identified.

<table>
<thead>
<tr>
<th>Sustainability targets</th>
<th>Themes from the analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children take a leading role in design</td>
<td>Children were empowered to design technologies as design partners and decision-makers</td>
</tr>
<tr>
<td>processes</td>
<td></td>
</tr>
<tr>
<td>Critical engagements with technologies</td>
<td>Children engaged critically with existing technologies</td>
</tr>
<tr>
<td>Creative engagements with technologies</td>
<td>Children engaged in creative ways with new technologies and developed new ideas or concepts for future technologies</td>
</tr>
<tr>
<td>Technical explorations</td>
<td>Children acquired technical insights and understandings</td>
</tr>
<tr>
<td>Fun</td>
<td>Children enjoyed their participation in technology design activities</td>
</tr>
</tbody>
</table>

Table 4.2: Overview of sustainability targets.

As next step, I present the results of the analysis related to the design process and what helped the researchers to achieve the resulting targets (see Figure 4.3 for a list with all targets and enablers). I refer to the practices we used to enable the children to engage in design processes using term enablers. The enablers are at this point only from the perspective of the researchers (not the teachers), I cannot determine at this point what kind of enablers would be needed if teachers (not involved in the initial SPT project) would like to sustain similar targets in a school context.

4.3.1 Sustainability target 1: Children take a leading role in design processes

The empowerment of children as leaders of the design process was an important experience the children had during the project (relating to Kinnula’s et al. democratic view (Kinnula et al., 2017)). As design partners, the children took a leading role in technology creation processes, during which they used and evolved their creative skills (relating to Kinnula’s et al. educational/competence view). Even with new materials, they felt confident to explore the design space (see Figure 4.4). Children were empowered to critically engage with technologies as illustrated in Section 4.3.2 and took the lead in design activities with professional designers from a company as presented in Section 4.1 (relating to Kinnula’s et al. critical view). During the SPT project, the children created their own technologies or their own versions of prototypes, as illustrated in Section 4.3.4.
We supported their empowerment by loosening up traditional adult-child relationships, building on the work of Druin (Druin, 2001), and let the children support each other in design teams. This target was enabled in the SPT project in two ways: by balancing adult-child relationships and enabling children to collaboratively create concepts and solve problems in design processes.

To balance adult-child relationships, one researcher teamed up with the children as their playpartner. The playpartner engaged in the activities during the workshop and supported the children when necessary, for instance, by expressing their ideas and crafting activities. We hereby challenged the inherent power imbalances between (adult) researchers and children, but also in traditional teacher-pupil relationships in a school context (Iivari et al., 2018; Iivari & Kinnula, 2016). This vignette from the SPT researcher diary from the MP group illustrates how a playpartner supported Timur to engage in a crafting activity:

"Timur wanted to swap his object with Tony, because he liked his interpretation better. He started to cry and it took me a while to motivate him to continue working on his object (...) I made different suggestions which he initially refused, but eventually he started crafting (...) During the construction (of the object) he used me as playpartner and 'extended tool', I did the things he could not do, so I could support him in realizing his vision."³

In this vignette the playpartner plays two roles: Timur’s playpartner is a comforter to the

³The original vignette in German is: “Dort wollte Timur erst sein Objekt mit Tony’s tauschen, anschienend weil er die Interpretation von der Gruppe ziemlich cool fand (Buchstabenberg). Er hat dann erstmal geweint und war nur langsam dazu zu bringen, an dem Objekt weiterzuarbeiten (...) Ich habe Timur dann verschiedene Angebote gemacht, die er alle ausgeschlagen hat, aber dann doch auch selber angefangen, daran herumzuarbeiten (...) In der Konstruktion hat er mich als Spielpartner*in und extended tool benutzt, damit ich die Sachen machen könnte, die er nicht so gut kann und ihn dadurch in
him and supports him to engage actively in the design process by suggesting alternatives, without trying to enforce actions. Second, Timur’s playpartner supports him during the activities as ‘extended tool’, by helping him with crafting activities he cannot accomplish and by doing so, realising his ideas.

In other workshops, the playpartner becomes a peer to the children who is engaged in their play. A vignette from the SPT researcher diary from the LS group shows how their playpartner supported Asa to collaboratively play with the other children: “I (the playpartner) play with Leo and Asa (...) Asa invited me into his metro cave. I try out the lights and motivate Asa to do the same (...) We play that we are a metro, hence, we move between two caves. When Leo throws us out of ‘his’ cave, because I want to play with two lights, Asa explains, that we could continue playing outside the cave (...) Now Leo is getting interested in the lights (...) and uses the blue controller (for the lights). Asa does not see that Leo has the controller and is wondering why his light changes colours. Leo thinks that that is funny (...)”

Asa, who is part of the LS group and the PS group, preferred most of the time to engage in his own play and found it challenging to join in the social play of the group. Hence, the playpartner tried to support him as his peer who shares his interest in the metro system. The playpartner showed Asa and Leo opportunities to play with each other, by using the lights. At this point, the children started to use the lights to communicate with each other at separate places in the room and the playpartner did not need to scaffold their interaction anymore. This was a key moment in the design process of the LS group during which we realized that an interactive, co-located lighting system (which became the LightSpaces), could support children to play with each other.

The empowerment of children and loosening up traditional power imbalances between adults and children enabled the children to engage with us on a different level: They involved the playpartner in their activities and let us ‘in’, sharing for instance their ideas and perceptions of play. However, this approach was not in line with the traditional structures at the schools. Once, we were playing dragons with the children under the tables and at this moment, a teacher came in and asked if we needed help with reinforcing the classroom rules. The way we interacted with the children seemed to be different from the existing teacher-children relationship and teaching practices. The aim of this thesis is not to change school structures or classroom rules, but if we aim to sustain SPT practices and experiences, those moments made us aware that the enablers which worked well in the SPT project might need to look different for teachers which are bound to these structures and rules.
The children are not only enabled to collaborate with adults, but also to collaborate with each other in design teams, working either as a whole group together or by being split up in teams of two. Those team activities resulted often in constructive disagreement [1], children started to dispute and eventually quarreled among themselves. We explicitly did not immediately try to solve their conflicts (but sometimes we tried to mediate the situation, in case the conflict got physical). Those disagreements often led to insights in the childrens’ different, and often conflicting perspectives, informing the design process in ways that a technical artefact can embody different perspectives. To illustrate this process, I give a vignette from the SPT researcher diary MS group. We had brought abstract shapes created from blue foam to the workshop and asked the children to re-design those shapes. “Emir and Deniz struggle to cooperate, everyone wants to realize their own ideas. They do not negotiate or try to find a compromise and work next to each other, working on an individual artefact. Emir tells Deniz about his ideas, but Deniz is crafting a ball of whool he connects afterwards to the artefact Emir crafted.”

Deniz and Emir were not interested in working collaboratively on the object, but decided to work separately with the object. They brought their individual agenda and intent into the design in parallel. At the end of the workshop, they presented a coherent story and one object - representing both perspectives. Hence, we did not aim to solve conflicts within the design process, but tried to enable the children to incorporate them into their ideas or concepts. Working in pairs or teams also challenged the children to share resources (for instance crafting materials) and to collaborate with each other on the same project. With some practice the children managed to share their ideas with each other and eventually agree on a concept they developed collaboratively further.

In the LS and PS groups, the childrens’ disagreements often resulted in interesting design triggers and enabled us to explore ways how technology could be used to scaffold and eventually support the children to mediate those situations. In the MP group, the teacher often intervened when she had the impression that the situation was getting out of hand.

4.3.2 Sustainability target 2: Critical engagements with technologies
The children critically engaged with technologies during the SPT workshops. As the anecdote in Section 4.1 illustrates, the children from the MP case embraced their new role as designers and shared confidently their feedback on an interactive game. They immediately engaged in a re-design process and brainstormed about new ideas the designers working for the company could implement.

5The original vignette in German is: “In der Deniz-Emir Gruppe ist Kooperation schwierig, jeder möchte alleine seine eigene Ideen verwirklichen. Absprachen untereinander machen sie nicht und verhandeln auch nicht. Dadurch behindern sie sich gegenseitig beim basteln. Es fällt auf, dass Emir und Deniz in ihrer eigenen narrative festhängen. Emir hat, basierend auf einem Erlebnis in der nahen Vergangenheit, das Artefakt mit dem roten Gitterstoff geschmückt und sticht Nadeln in das Objekt. Dazu erzählt er, wie das Objekt operiert wird und das ihm Blut abgenommen wird. Deniz geht nicht darauf ein, er beschäftigt sich intensiv mit dem Wollknäuel welches er am Ende am Objekt befestigt.”
4.3. Results: Presenting the SPT project sustainability targets and enablers

In the second year of the design workshops with the PS groups, the children frequently gave critical feedback on the prototypes we brought to the workshop, as this vignette from the SPT researcher diary illustrates: “Feedback (from the children): Elli prefers to draw and write on the blackboard, she asked if we could draw on the camera instead of in the air, she feels disturbed by the video image.” We observed similar developments in the other two groups: Across the timespan of the project, the children got more and more comfortable to criticize the technologies or prototypes we brought to the workshops. As the vignette from Elli illustrates, this often led to ideas for improvements of the prototypes. Hence, we concluded that empowered children in a design process were able to engage critically with existing technologies, and by taking a critical stance, they were able to generate ideas for different, possible better technological solutions.

We considered critical engagements with technologies a sustainability target, as it opened up a solution space for new ideas and relates to Kinnula’s et al. critical view. By engaging critically with existing technologies, children felt the need to search for other better solutions.

To enable critical engagements, we asked the children about their opinions of technologies and let them critique technologies (either existing technologies or prototypes we developed during the design process). We then reacted based on their feedback, by adjusting for instance the prototypes or concept. We considered critical engagements with (existing) technologies as a first step to open up the design space and to explore new opportunities for technologies, or re-design existing technologies. In the MP group, we introduced a new microcontroller developed for children (Calliope) that we were enthusiastic about, because it had built in sensors and LEDs and was easy to programme. We let the children explore the microcontrollers on their own (without telling them how they work or sharing our perspective with them), and asked them to develop ideas for wearables using the technology. After initial exploration (and disassembling the microcontrollers to explore the hidden working mechanisms), Deniz criticized the features (“They can only play tones, that’s no music!”) and decided not to use them for wearables (against our suggestion to make wearables during the workshop). We reflected on this moment in the SPT researcher diary: “Finally the children engaged in ‘design critique’, talking about the objects. They argued that the sound is too low/bad quality, that the battery should be attached to the object so that it could be attached directly to the body.”

This vignette illustrates how we enabled the children to critically engage with (existing) technologies, for instance by letting them freely explore technologies before giving our perspective, collaboratively discussing our experiences with the technology and whether technologies should be implemented in prototypes, or not, like in this example.

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6 The original vignette in German is: “Feedback: Elli malt und schreibt lieber an der Tafel, wünscht sich auch, dass wir ‘auf’ der Kamera malen anstatt ‘in der Luft’; sie stört das Videobild beim Malen.”

7 The original vignette in German is: “Letztlich konnten sie dann relativ gut über die Objekte reden in der Form von ‘Design Kritik’. Sie meinten u.a., dass der Ton zu leise/schlecht sei, dass die Batterie am Objekt befestigt sein solle, dass es gleich an den Körper gebunden werden kann.”
4.3.3 Sustainability target 3: Creative engagements with technologies

The children engaged in diverse creative ways with technologies in the SPT project. The LS group engaged frequently in role-playing activities, which were later supported with the LightSpaces. Whenever we brought technologies to the workshops, for instance the Philips Hue lamp which can change colours, the children used them as part of their role-playing games. The lamp, when turned red, became a lava flow inside a dragon’s cave.

The analysis of the researcher diaries from the PS group showed a learning curve of creative engagements with technologies. When we started the technology immersion phase (Druin, 1999), we brought littleBits to the workshop. The topic of this workshop was superpowers. After an open round of exploring the littleBits, we asked them to make mock-ups for superpowers using littleBits and crafting materials. The children tried out different combinations of sensors and actuators, but struggled to imagine what kind of superpowers their mock-ups could demonstrate. Elli crafted a superhero she knew from a TV show, but without using the littleBits. Hence, the children found it difficult to imagine new functions for technology and engaging with technologies did not support them sufficiently in this process.

One year later, we brought first mock-ups and prototypes of the PS to a workshop. The PS prototype was based on paper-based cubes with RFID tags with triggered visual effects of the projected drawings of the children. At first, the children engaged in re-designing the cubes. A vignette from the SPT researcher diary illustrates this process: “We give Valerie the cube which quadrupled an image section and draws mirrored flowers, triangles and other symbols following the center line in the middle of each side (of the cube). Aisha decorates the black and white cube, drawing the sides black and white. Asa puts two cubes under the camera and wonders how those cubes could have a double function. After the children re-designed the cubes, they used them in their play: “Valerie takes the cube and plays (...) that you have to hit a field (on the drawing) with the cube and then you jump to this field (to the projection of the drawn field) (...) Elli lies in the projected drawing and the other children try to put the smiley-face (the smiley-face is a visual effect triggered with a cube) on her face.” This vignette from the SPT researcher diary illustrates that the children of the PS group engaged more creatively with technologies over the time. At first they were hesitant to use technologies or imagine new functionalities (as the first

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8Smart light bulbs or LED strips which can switch colours: https://www.philips-hue.com/en-us/products/all-products
9Electrical building blocks developed for children to build prototypes: https://sphero.com/collections/all/family/littlebits
10The original vignette in German is: “Wir geben Valerie den Würfel, der einen Bildausschnitt vervierfacht, und sie zeichnet sich spiegelnde Blumen, Dreiecke und andere Symbole mit einer langen Achse in der Mitte auf jede Seite. Aisha darf den Schwarz/Weiß-Würfel verzieren und malt ein paar der Seiten schwarz an, läßt die dazwischen weiß (...) Asa hält zwei Würfel hinein und überlegt, wie man sie für Doppelfunktion hineinhalten sollte.”
11The original vignette in German is: “Valerie kommt sofort mit dem Würfel und spielt (...) dass man mit dem Würfel ein Feld treffen muss, um bis dorthin hüpfen zu dürfen (...) Elli liegt in der Projektion und die anderen versuchen, das Smiley-Gesicht über ihr Gesicht zu legen.”
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vignette showed), later they re-designed the technologies and imagined new, creative ways of engaging with the mock-ups and prototypes.

We considered **creative engagements with technologies** a sustainability target, as it enabled children to re-think existing technologies and looking for ways to improve their play and relates to Kinnula’s et al. educational/competence view.

To enable children to engage in creative ways with technologies, we aimed to open up the design space and **explore possibilities beyond the limitations of existing technologies**. We offered for instance activities for stimulating creativity. Some children did not need to be stimulated explicitly to engage in creative activities - the LS group was role-playing fantasy narratives at any given opportunity. This vignette from the researcher diary shows how the LS group engaged in one of their role-playing scenarios, while drawing caves: “**Link draws a cave with bats, Jamila a dark cave and asks Leyla if she wants to add something to it. Leyla does not want to have light in the cave, but a lava lamp would be fine. But ideally she would like to have a vulcano. Attila draws a cave with a vulcano. Then Leyla and Attila connect their caves with a passage. Interestingly, the lights are less important for them. Their pretend play scenarios are more important, for instance, that Attila is a dragon in a cave and surrounded with lava.**”

For the LS group, lights, caves and role-playing are the central elements in their social play. While engaging in story-telling and role-playing, the children negotiated what kind of elements were important to them and what kind of technology (a lava lamp) would contribute to their role-playing games.

Other groups needed to be supported with storytelling and probes to stimulate creativity. With the MP group we had an alien narrative. We imagined that aliens were real and sent us materials that the children could manipulate and send back to the aliens. To support the narrative, we brought to the session a silver blanket and pictures from outer space. Figure 4.4 shows a picture of the objects after they were re-designed by the children. We reflected on this workshop in the SPT researcher diary: “**The alien narrative worked well to get children out of their life-world. Earlier ideas were framed (by existing games) and the children influenced each others ideas. Today every child had their own interpretation of their foam object.**” Hence, the children felt inspired by the narrative and were enabled to think beyond ‘what’s possible’ and existing technologies. They created novel objects and realized their individual ideas.

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**13** The original vignette in German is: “Die Alien Narrative hat gut funktioniert, um die Kinder aus ihrer gewöhnlichen life-world heraus zu holen. Während frühere Ideen sehr geframed waren und sie sich gegenseitig beeinflusst haben, hat jedes Kind eine eigene Interpretation ihres Blauschaum Objektes entwickelt.”
4. Defining Sustainability Targets and Enablers

While the majority of the children enjoyed role-playing and activities embedded in fantasy narratives, there were often one or two children in each group who did not engage as enthusiastically as the rest of the children in the activities or would have preferred a different theme for the narrative. In our relatively small groups (five children), the children or we as researchers were able to find themes the majority was interested in and considered engaging.

To support the children in the design process and to help them explore ideas, we aimed to balance openness and structure. Based on the concept of a Handlungsspielraum (Makhaeva et al., 2016), which applies to the organisation of the workshops, workshop elements, rules, materials and prototypes as explained in Chapter 3, we offered the children certain structures for guidance, and freedoms to explore their creativity. Here, I will illustrate how we have applied the concept of a Handlungsspielraum based on workshop structures and elements.

To give the children structures, each workshop started and ended with a start and end ritual (as suggested by Benton et al. 2011). At the beginning of each session, we presented the plan for the day. We also printed a collection of pictures from the previous session and handed them out to the children, to stimulate a discussion about what happened the last time we met. At the end of each session, the children could play freely. Another repeatedly used element was the opportunity to take pictures during the workshop. We gave each group of children their own camera, which they shared and used to record the process.

While the rituals offered the children structures, the middle part of the sessions varied and we gave the children the opportunity to explore technologies and engage in design activities. We brought for instance littleBits to the workshop and let the children first explore on their own how they work and what do do with them. The MP group explored the littleBits in an open-ended setting, without any instructions or additional material to explain their functions. The vignette from the SPT researcher diary illustrates our reflections on this workshop: “They (the littleBits) were a hit. All children and their teachers constructed eagerly. Laura (researcher) first gave the children one type of littleBit
4.3. Results: Presenting the SPT project sustainability targets and enablers

(energy, sensor, output) after the other so they started with simple constructions which got more complicated (...) Timur became a DJ, Tony used the noise output and Emir and Deniz worked together on the keyboard and used LEDs. They experimented a lot and were very creative with in- and outputs. Tony and Timur constructed collaboratively. To sum up, this session was the most engaging and enthusiastic one.\textsuperscript{[14]} The children used the littleBits without any instructions or assignments from us. They first explored their functionalities and then started to realise their ideas with the littleBits. Four children worked in pairs (without any scaffolding from the researchers or their teacher to motivate them to collaborate) to build a shared concept, which has been a challenge in this group so far. After discussing this session with the SPT team, we concluded that this was the most successful session in terms of engagement in design processes and creative idea exploration. This shows how children benefited from the freedom to explore and experiment with materials, leading to unexpected and creative experiences.

As explained in Section \[4.3.3\] the PS group struggled to find meaningful combinations of littleBits when we offered them a similar setting as to the MP group. Hence, we gave them more structure by assigning them tasks about what to build (for instance, superhero equipment) and visualised the different types of littleBits with input and output cards: \textit{“Katta (researcher) hands the children input and output cards which visualise (super)powers and outputs (for instance water, wind, sound, movement, light...) which can be realised with the littleBits. We discuss if he (Asa’s sidekick) should have superpowers (...). Asa grabs the sound- and movement card. Elli is representing the superpowers already with the littleBits (movement and light). Asa is exited and wants to play with the littleBits, too.”}\textsuperscript{[15]} Hence, the PS group needed a more structured approach with clear instructions and supporting materials (like cards) to be able to use the technologies in their design process and to explore them in meaningful ways.

The examples show that the two groups of children needed different levels of structures and scaffolding to be enabled to engage in technology design processes. Hence, balancing openness and structures and adjusting them if necessary was crucial in the SPT project.

\textsuperscript{[14]}The original vignette in German is:”Die waren überhaupt der Hit. Alle Kinder und ihre Lehrerin haben fleißig gebaut. Laura hat auch gut eingeführt indem es erst eine Modalität (Energie, Sensor, Output) nach der anderen gab und sie von einfacheren auf komplexere Einheiten gegangen sind (...) Timur hat sich als DJ bemüht, Tony hat den Lärmacher benutzt und Emir und Deniz haben zusammen das Keyboard und Lichter benutzt. Währenddessen haben sie viel experimentiert (...) Die beiden waren auch echt kreativ mit den Ein- und Ausgaben und haben viel experimentiert. Tony hat sich dann auch mit Timur zusammen geschlossen und da was gebaut. Insgesamt war es bisher die engagierte und enthusiastischste Session (...)”

\textsuperscript{[15]}The original vignette in German is:”Katta verteilt währenddessen Input und Output Karten, auf denen (Super)Kräfte und Aktionen abgebildet sind (wie Wasser, Wind, Geräusche, Bewegung, Licht...) die mit den littleBits nachempfunden werden können. Wir sprechen darüber, ob er Superkräfte haben soll (...) Asa nimmt sich die Geräusch- und Bewegungskarte (...) Elli hat währenddessen schon mit den littleBits die Superkräfte visualisiert (Bewegung und Licht). Asa findet das sehr spannend, und möchte auch mit den littleBits spielen.”
4.3.4 Sustainability target 4: Technical explorations

The children engaged during the design workshops in technical explorations. The MP group, for instance, built their own pressure sensors which were part of the MusicPads and gained insights in the working mechanisms of sensors. Sensors or other electrical parts are part of the children’s daily life (as part of smartphones or interactive toys for example), however, they are often hidden in technologies. Through the design process and active engagements with technologies, those parts and working mechanisms were uncovered by the children, resulting in technical insights and knowledge. Emir described the function of the sensors in the MusicPads in his own words: “It (the MusicPad) can feel itself!” 16 He commented the built in springs with: “Ah, like in a couch!” 17 Hence, the children were able to describe technical parts (physical and electrical) using their own words, showing that they understood how they work. After the children of the MP case built their pressure sensors, they wanted to individualise them by painting on them and giving them individual shapes (see Figure 4 in Appendix B 8.3.6 for a picture). Afterwards, the children played with the sensors and invented new games in which they used their sensors in combination with the MP installation.

We considered technical explorations a sustainability target, as it enabled children to create new ideas and led to creative engagement with technologies and relates to Kinnula’s et al. educational/competence view since the children acquire technical competences through the technical explorations. As the MP case shows, the children used their new understanding of sensors and resulting prototypes to create new games and to express themselves by individualising their sensors. Learning outcomes resulting from for instance technical explorations in PD projects are discussed frequently in the literature as well (see for instance (Barendregt et al., 2016)).

To enable the children to gain technical knowledge, we gave them high-tech materials and let them explore technologies and prototypes. As researchers, we had access to various (technological) materials teachers usually do not have access to. In our workshops we used various materials - ranging from simple crafting materials the children were already familiar with (paper, pencils etc), to low-tech electronic building blocks designed for children to use (the littleBits), and ‘high-tech’ prototypes built with microcontrollers. Next to materials we brought to the workshops, the children used materials which were available in the classroom, for instance furniture or games. In the MP group, the children even used materials the brought from home, for instance a card game.

The children were able to build first prototypes using materials they were familiar with, or combined low-tech with high-tech prototypes. With the MP group the children designed their own sensors using cardboard and conductive materials. During the making process they learned how sensors work and why they are useful for technologies.

The LP group integrated the high-tech prototypes in the caves they built from furniture, as this vignette from the SPT researcher diary illustrates: “We built from the stitched

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16 The original quote in German is: “Es spürt sich!”
17 The original quote in German is: “Ah, wie im Sofa!”
4.3. Results: Presenting the SPT project sustainability targets and enablers

together fabrics a cave (...) The children wanted to use tape to attach the fabrics to the cupboard and the tables (...) Leyla was fascinated by the lightball\(^\text{18}\) and wanted to hatch it as an egg (while sitting in a cave). She imagined that she is a bird (...) When the different lights appeared, they were fascinated and explored the objects. Asa wanted to know how the lightball works and why it can change colors. He also asked me (the playpartner) why and how it can make sound. To explore this, he opened the ball.\(^\text{19}\) The children started the cave design process with no-tech materials (fabrics, tapes and furniture) and integrated during the process technologies (the lightball in this example), giving it a role in their pretend-play (as egg which needs to be hatched). While engaging with the ball, they got curious how the ball might work and opened it and asked questions about its hidden working mechanisms. This vignette shows two insights: First, by combining no-tech materials with technologies, the children could naturally integrate technologies in their design process. Second, by engaging with the technologies, they were motivated to explore hidden working mechanisms and to extend their current knowledge about technologies.

Hence, this mix of materials enabled children to actively participate in every step of the design process and explore technologies. We also learned from our experiences, that the children were able to build first prototypes using materials which were available to them. This enabled them to actively learn about technology related subjects and gaining insights in technical working mechanisms which are usually hidden in products in their daily life (for instance sensors).

4.3.5 Sustainability target 5: Fun

Fun was a frequent experience during our engagements with the children. I used the word ‘fun’ as the children frequently used this term when describing their emotions and to build upon the work of Schepers et al. (2018b) who argued that fun is an important experience for children in PD projects. With the PS group, it took us a while to find pathways for social play technologies every child enjoyed to play with. When the final prototype of the PS was developed, we had a workshop where all children engaged with PS at the same time and repeatedly mentioned how they had fun during the workshop, as this vignette from the SPT researcher diary illustrates: “Asa is amazed. The time is up and we pack up and sit together. Everyone says that they had a lot of fun today.”\(^\text{20}\)

\(^{18}\)Hackaball, a programmable ball which can switch colours and make sounds: \[\text{http://www.hackaball.com}\]

\(^{19}\)The original vignette in German is: “Danach durften wir uns erst aus dem zusammengenähten Stoffen eine Höhle bauen (...) die Kids wollten lieber Tape benutzen und die Seiten auch am Schrank und an den Tischen festtapen (...) Leyla war besonders fasziniert von dem Lichtball, den sie als Ei ausbrüten wollte. Sie hat sich vorgestellt, dass sie ein Vogel ist der brüetet. Als dann die Lichtvariationen dazu kamen, waren Asa und Leyla fasziniert und haben die Objekte erkundet. Asa wollte herausfinden, wie der Ball funktioniert und warum er seine Farben wechseln kann. Er hat mich auch gefragt, warum und wie er Geräusche macht. Um diesen Sachen auf den Grund zu gehen, hat er den Ball geöffnet.”

\(^{20}\)The original vignette in German is: Asa ist begeistert. Die Zeit is abgelaufen, wir packen zusammen und setzen uns kurz zusammen. Alle sagen, dass es ihnen sehr viel Spaß gemacht hat.”
One participant, Asa, had a special interest in the city’s underground system, but the other children did not share this interest. During the first workshops, he sat aside from the rest of the group and drew metro plans on his own. We observed frequently that he found it challenging to engage in design processes as the rest of the group was usually interested in different topics. At the end of the second last workshop of the SPT project, he brought in his interest and drew the underground system using the PS prototype. The other children joined him and invented a game based on his drawings: “Johanna (researcher) asks him (Asa) if they are allowed to use his metro plan for the game. The girls are not immediately enthusiastic about this idea, but throw sponges at the metro station (which was the game). Asa does not want to call the metro stations (the girls hit with their sponges) at first, but when they hit the station where he lived, he takes control of the game (and starts calling stations). The game becomes challenging, but all enjoyed playing it.”

As this vignette from the SPT researcher diary illustrates, fun was an important factor for the children’s engagement in design processes.

Reflecting on the results of the analysis, fun was an experience reported in all groups. During the final workshops the children engaged happily with the final SPT prototypes. The children of the MS group considered fun an important experience, too, as this vignette from the SPT researcher diary shows: “During the round of questions, the children mentioned that they wished that all children would enjoy playing with the (Music) pads. They want that it is fun for all.”

We considered fun a sustainability target because having fun enabled the children in the SPT project to engage in the design process and to bring in their perspective and interests. Recent work echoes the importance of fun as experience during a PD process with children (Schepers et al., 2018b).

To enable fun, we offered children ‘fun’ design activities. The SPT project aimed to develop ‘play things’ and support social play among children. Fun was thus a crucial element for us, during the design process and for the resulting prototypes. We did not always succeeded to offer ‘fun’ activities, and recent work shows that organising PD workshops in a school context sometimes result in ‘school fun’ instead of ‘just fun’ experiences (Dreessen & Schepers, 2018), considering the rigid school structures and the focus on learning. To enable the children to have fun, while being in a school context, we always included ‘15 minutes of playtime’ in our workshops. At first, the children engaged in free play using the objects and toys which were available to them in the classroom. Later, they engaged with the technologies we collaboratively designed with them. The LS group, for instance, immediately embedded the LS play things in their role-playing games.

21The original vignette in German is: “Johanna fragt ihn, ob wir inzwischen seinen U-Bahnplan verwenden dürfen für ein Spiel. Die Mädchen sind nicht sofort begeistert, aber dann werfen sie mit den Schwämmen nach U-Bahnstationen. Asa liegt nicht viel daran, eine U-Bahnstation anzusagen. Als jemand einmal zu weit wirft, sagt er, dass der Schwamm jetzt beim Elterleinplatz liegt (dort wohnt er) (...) Asa übernimmt, und das Spiel wird sofort sehr herausfordernd bis unmöglich, aber es macht trotzdem allen Spaß.”

22The original vignette in German is: “Vereinzelt kam in der Fragerunde auch auf, dass sie sich wünschen dass die Platten “allen” Spaß machen, dass sie wollen dass es für “alle” lustig ist.”
4.4 Reflections on the role of teachers and researchers in the design process

they engaged in during each workshop, as previous vignettes from the SPT researcher diaries illustrated, for instance in Section 4.3.4.

Interestingly, the children did not always experienced this ‘free playtime’ as play, as this quote from Leyla illustrates: “We never have time to play! We finally managed to build the caves and now we are not allowed to play!” In this workshop with the LS group, the children spent the majority of the time to build caves and Leyla was frustrated that they had no time left to play in the caves afterwards. Since building caves was the activity the children suggested during each workshop (and they built caves in the majority of the workshops), we considered the building process (the design process) as part of their play. Hence, when aiming to enable fun, it is important to consider the perspective of the children and eventually discuss with them if they had indeed fun.

Next to giving children free playtime, their active role as design partners and having the freedom to steer activities enabled fun. As the microcontroller example from the MP group (see Section 4.3.2) illustrates, they had no fun to continue working with the microcontrollers any longer or to engage in the next planned activity, so we adjusted adhoc the plan based on what the children wanted to do.

4.4 Reflections on the role of teachers and researchers in the design process

Next to the ‘enablers’ which supported the children in the design process, it was also the effort of the people facilitating the workshop which supported the children. Here, I reflect upon our roles (as researchers and designers) and the roles the teachers played in the design processes of the three social play technologies. Those reflections help to identify the differences between researchers and teachers and their respective roles in the design process.

4.4.1 Role of teachers

In two cases, the LS and PS, the teachers were not present during the workshops. However, they were enthusiastic about the activities we conducted with the children and asked frequently for updates and gave us feedback on the learning outcomes of the children. Stephanie, the teacher from the LS group, expressed her happiness at being chosen to participate in our research project. She told us that, usually, her school is not asked for collaborations with research institutes. When picking up the children or bringing them back to their class, the teachers frequently reported what the children told them about the workshops. When Stephanie was picking up the children from a workshop with us, she mentioned that the children started to build ‘caves’ in the classroom. During our workshops, we repeatedly build caves with the children, using tables, chairs and fabrics, which were later technically enhanced with the LS prototype. The caves helped the
children to get into their role-playing and were also a 'safe place' where they could hide from other children when feeling overwhelmed. Stephanie told us that she liked the cave concept and let the children build caves in their classroom, too. This example illustrates how the teachers used inspiration they got from our collaboration for their own practice.

In the MP case, the teacher chose to be present during the workshops and had an important role in mediating the group and understanding their reactions by providing us with the appropriate larger context. The teacher offered confidence and stability to the children and mediated the activities, mainly by enforcing social norms. While the children benefited from their teacher’s support in terms of stability, we frequently had to ask the teacher to refrain from overriding the children’s opinions. In the other two groups, the workshops were less structured and we had to mediate social interactions among children. The children expressed their opinions, without being or feeling observed by their teachers.

We learned from our collaboration with the teachers, that they valued what the children learned from our project (for instance technical insights, social and creative skills) and that they enjoyed being part of a collaboration with a University. The teachers gave us a free hand in how we wanted to set up our workshops. In the MP case, we realised that our methodological approaches were not always in line with the teacher’s approaches. While we aimed to empower the children to explore different directions, voicing and negotiating their ideas, their teacher sometimes tried to guide discussions by aiming to find consensus or overriding the children’s opinions. We had no educational agenda or learning aims defined by a curriculum we needed to meet, which gave us freedom and time to explore different pathways with the children and let the children explore different directions they wanted to go with the technologies without finding immediate consensus or choosing a direction. Another importance difference between the SPT project workshops and traditional classroom situations is that we worked with small groups of children and that at least two researchers, sometimes three researchers, were present during the workshops. These settings opened up opportunities for having close and different relationships with the children and allowed us to apply methods and use practices which require more (adult) support. Similar practices and methods might be harder to apply in a traditional classroom setting when only one teacher is present and the group of children is bigger.

During the SPT project, we did not actively enable teachers to evolve their practices around their experiences with us. Reflecting on our engagements with the teachers during the project and their feedback on our work with the children, we realized that they felt inspired and even tried to incorporate insights from us in their own practice, as Stephanie’s cave story illustrates. In the SPT project, we offered the teachers the option to join the workshops if they wanted to, but only the two teachers from the MP group had sufficient time to attend them. The teachers from the LS and PS group were frequently updated from us and we briefly talked with them when picking-up or bringing back the children to their classroom. In hindsight, we missed opportunities to more actively share our experiences with the teachers who were not present during the workshops and to schedule designated moments for sharing experiences. Hence, we struggled to actively
enable teachers to gain inspirations from our work.

4.4.2 Role of researchers

Our roles as researchers had multiple facets. Our main aim was to empower children to engage with technology in creative and critical ways and to create their own technologies. Hence, we organised our roles in ways to support this aim. Two researchers ran the workshops, playing two roles: One researcher was the active observer, responsible for the planning and instructions during activities. The other researcher was the playpartner of the children, forming a close-knit relationship with the children and supporting them during activities with idea expression and realization. As researchers we were also responsible for meeting the SPT project’s aims, for instance: Exploring methodological pathways for how to actively involve neurodivergent children in technology design processes and finding new roles of technology to scaffold social play among children. Once in a while, we had brainstorm meetings with the team to discuss the process of each design team, formulated new insights and planned how to move forward in terms of iterating the concepts. Hence, the methodological experiences of the researchers and experiences with PD practices with children played an important role in enabling the children to engage in the design processes.

Another role we played during the workshops was the ‘technical expert’: We brought the technological knowledge and skills to the workshops and built the prototypes for the children. We had access to technological resources, for instance electronic components and machines like 3D printers, to help the children explore technologies and to realise their ideas.

In line with our aim to empower children, we wanted the children to have meaningful experiences, our agenda included exploring methodological approaches for how to involve children in design processes and new roles of technologies. We also had resources such as technological equipment we either brought to the schools or used to build prototypes. After we left the schools, teachers lost access to those resources.

4.5 Discussion

Having identified sustainability targets and enablers, I discuss the relevance of the sustainability targets and enablers in the school context. I further discuss possible challenges we discovered in the SPT project when aiming to sustain targets in a school context for teachers and children not involved in the initial PD project and which possible support might be needed.

4.5.1 Relevance of experiences and enablers

From a researcher perspective, the experiences of the children during the SPT project led to an empowerment of children in the design process and thus, enabled, to engage in technology design processes. As a PD project, the SPT project was based on values
that are considered to be important within the PD community: The empowerment of marginalised groups, such as neurodivergent children, for instance (Malinverni et al., 2014; Wilson et al., 2018; Druin, 2001). Grounding a project in PD inspired values gave us guidelines for the involvement of the children and supported us when we needed to make decisions. For instance, when we had a concept in mind but the children chose a different direction, we re-considered design decisions. We further aimed to build upon the notion of democratising technology innovation, for instance by giving children access to production tools and electronic components they usually do not have access to. Having access to technologies was another key in supporting children to imagine the opportunity to explore new roles of technologies. Hence, we identified PD values as main underlying element for the enablers we presented in Section 4.3.

The question remains which experiences are considered to be important from a teacher perspective. As discussed in Chapter 2, related work explored which gains teachers experienced from their participation in a PD project with their class (Börjesson et al., 2019). They reported multiple perceived gains, such as learning new skills related to technology design processes, new ways of teaching and creating educational and fun experiences for children. As technology education as part of the new STEM curriculum is advancing in the local context of the SPT project, participating teachers and teachers not involved in the initial SPT project might benefit from engaging in SPT practices with their pupils. This indicates that supporting teachers to evolve their own practice around SPT practices might be a promising lead towards sustaining the sustainability targets and enablers.

Taking into account the perspective from the teachers will be necessary to determine which sustainability targets they would be interested to sustain in the school context.

4.5.2 Scope of enablers

As argued in Section 4.3 and Chapter 2, the SPT practices were grounded in PD practices and enabled the empowerment of children in design processes. However, not only the enablers as mentioned in Section 4.3 enabled the children to engage in technology design processes. Other enabling factors where the experiences and skills of the researchers as elaborated in Section 4.4.2, the technological artefacts (prototypes) and the low-tech and high-tech prototyping materials the researchers brought to the workshops. The scope of the presented enablers is limited to practices which enabled the positive experiences of the children we aim to sustain for children not involved in the initial project (the sustainability targets). The combination of choosing the enabling practices and having access to enabling materials, skills and knowledge related to PD practices and technology design processes resulted into the positive experiences of the participating children.

I chose as scope for the presented enablers in this thesis the practices which:

- could be potentially embedded in a toolkit which can support teachers to enable children (not involved in the initial SPT project) to engage in PD technology design
activities

- could be realistically be adopted and evolved by teachers to conduct SPT activities with their pupils to enable SPT experiences
- are unrelated to specific artefacts designed during the SPT project

Regarding the first scoping point, enablers related to technical skills of the organizers, (previous) experiences in PD or similar enablers which were relevant in the SPT project were not included in the list of enablers. Enablers which require a specific background (in PD or technology (design) could probably not easily be sustained with a toolkit for teachers without knowledge of PD/technology (design).

Regarding the second scoping point, practices which would probably not be realistically feasible to be adopted and evolved by teachers without knowledge of PD/technology (design), were not included in the list of enablers. For instance, we balanced adult-child relationships in the SPT project by running the workshops with two researchers with different roles (active observer and playpartner). If teachers would like to adopt this practice, this would require (at least) two teachers who are present during the activities/ are teaching one class together. For in classes in which only one teacher is present, this practice would not be easily adoptable. Hence, I generalized this enabler to “balance adult-child relationships.”

Regarding the third scoping point, we co-designed with the three groups of children three different interactive playthings which resulted in three artefacts at the end of the project (see Section 3.1). Those artefacts - and the low-tech and high-tech prototypes built during the design process - enabled the children to playfully engage with the current concept and to iteratively generate ideas how to improve the current concept. Physical prototypes or artefacts which were developed during the SPT project were not included in the list of enablers for two main reasons: 1) To allow teachers and children not involved in the initial SPT project to work on their own ideas/concept and which topics are meaningful to them, not necessarily social play related technologies, and 2) to be able to scale the toolkit for a bigger group of teachers and children not involved in the initial project. All prototypes and artefacts developed during the SPT project are unique and require technical maintenance.

4.5.3 Possible challenges when aiming to sustain targets of the SPT project in a school context

As related work (see Chapter 2) and experiences from the SPT project showed, PD approaches and underlying values sometimes collide with practices at schools [Iivari et al. 2018; Iivari & Kinnula 2016]. We were able to balance adult-child power relations, for instance, be forming design teams with the children and working as design partners during our workshops, as illustrated in Section 4.3.1 and Section 4.4.2. Teachers already have built close relationships with children and established routines of teaching and
4. Defining Sustainability Targets and Enablers

working together. Those routines might not be in line with the approaches we used during the SPT project, for instance, being a playpartner of the children. As discussed in Section 4.4.1, the children benefited from their teachers support in terms of stability, but we frequently had to ask the teachers to refrain from overriding the children’s opinions. Hence, while teachers might thus be in favor of sustaining similar design activities with the children as they valued the learning outcomes, they might find it challenging to set up similar activities with children. They have a focus on valuable learning outcomes and an educational agenda they need to meet. Related work reported similar challenges with PD activities in a school context, as illustrated in Chapter 2.

Teachers and researchers also have different skillsets: Our design team was, next to other various skills, trained in designing technological artefacts. We were able to choose appropriate technological materials for the children, explaining technologies to the children and creating working prototypes. The majority of teachers are not trained in design or engineering. Hence, after the SPT project ended, their technological and designerly expertise is hard to replace and we might need to find other ways to access technical resources.

Teachers and researchers have also different resources in terms of access to technologies or production machines (for instance 3D printers): Sustaining this access after researchers have left the field might be challenging, and related to the previous point. Further, if access would be granted teachers might lack the skills to introduce technologies to children.

When aiming to support teachers to enable children to engage in technology design processes, we thus need to explore ways in facilitating those processes and providing resources for the teachers. Reflecting on the experiences with a PD project in a school context, I also found indicators for possible challenges when aiming to sustain enablers from a PD project and a range of other enabling factors (for instance prototypes developed during the SPT project and skills of the researchers) are unlikely to be sustained by using a toolkit. As teachers have different premises and qualifications than researchers, and schools have other structures and agendas than Universities or funding bodies, the next step in the process of my thesis is to explore the school context and the resulting requirements.

After having identified possible challenges when aiming to support teachers to facilitate similar processes and experiences, the final question which remains is what kind of support teachers might need to be able to facilitate similar processes with the children. This question cannot be ultimately answered before having explored the contextual characteristics of a school context and the perspective of the teachers.

4.6 Summary

This chapter reported on the cases of the SPT project which inform and motivate my research. I presented in the first part of this chapter the sustainability targets of the SPT
4.6. Summary

project: positive experiences of the children participating in the SPT project we aim to sustain for children not involved in the initial project. I analysed what motivated and what enabled those experiences (see Figure 4.3) and argued why those enablers might support teachers to evolve their practice around technology design processes. The *central enablers* that supported children to engage in technology design activities are:

- Balancing adult-child relationships
- Collaboratively creating concepts and solving problems in design processes
- Critiquing existing technologies
- Exploring possibilities beyond the limitations of existing technologies
- Balancing openness and structures
- Using high-tech materials and building prototypes
- Fun design activities

I reflected on the roles of teachers and researchers in the SPT project, concluding that for instance the different skillsets and available resources of teachers, or existing power imbalances between children and teachers, are different from researchers. Hence, our enablers in the SPT project might not work when teachers conduct the activities and the enablers need to be tailored to the specific contextual characteristics of a school context and the teachers’ needs and wishes. I argue that, if I aim to support teachers to enable children in participating in technology design processes, I first need to learn more about the school context and the specific needs of the teachers who would need to replace our role as researcher in terms of organising design workshops for the children. In Chapter 5, I will further explore what might be needed to support teachers to enable children to actively engage in technology design processes, and identify possible challenges of a school context.
In the previous chapter I presented the sustainability targets (positive experiences of the children participating in the SPT project we aim to sustain for children not involved in the initial project, see Figure 4.3). Based on sustainability targets, I reflected upon the enablers (SPT practices which enabled those experiences) to achieve those targets. Aiming to sustain those targets in a school context, however, poses challenges. Teachers not involved in the initial SPT project would need to take over our role as facilitator for technology design processes. The teachers who were involved in the SPT project reacted positively to this suggestion, but after discussing with them the opportunities to facilitate technology design activities with children and engaging with related work, it became apparent that a school context poses specific challenges. As our experiences from the SPT project and related work have shown (Iivari et al., 2018; Iivari & Kinnula, 2016), teachers and researchers have different skillsets and power relations with children and are bound to the schools curricula and rigid structures. Hence, in order to support teachers to enable children in participating in technology design processes, I first needed to explore the contextual characteristics of a school context.

In this chapter I explore the characteristics of the school context and the teachers’ needs. I conducted three studies: A semi-structured interview with teachers, a co-design workshop with teachers and an online survey with teachers. I report on the findings from the interview which relate to the school context. Based on those findings and motivated by my literature reviews in Chapter 2, I argue why I have chosen a toolkit as approach to enable participating teachers and teachers not involved in the initial SPT project to evolve their practices around PD practices and technology design activities with children. In the co-design workshop, I introduce the first toolkit prototype, based on the enablers (Chapter 4) to engage teachers in a re-design process and learn about their particular context, to then co-design with them the second toolkit prototype. I refined the first toolkit prototype after the co-design workshop and tested the second prototype with an online survey. Finally, I present design implications and the final toolkit.
This chapter answers the second research question: *What makes it challenging to have sustainable PD practices and experiences in a school context?* and gives first insights for answering the third research question: *What does a toolkit need to contain to support teachers to evolve their own practice around technology and participatory design?* This chapter is based on [Scheepmaker, Kender, Frauenberger & Fitzpatrick, 2021].

5.1 First study: Interview

To gain insights into the practice of teachers, their challenges and requirements to evolve their practices around SPT practices and experiences, my co-researchers from the SPT project\(^1\) conducted a semi-structured, qualitative pair interview with two special-needs teachers. During the interview my co-researchers also explored how interested teachers were to evolve their practices around the SPT project practices and which aspects of our work they considered to be relevant for their own practice.

5.1.1 Research approach

**Participants**

The two participating teachers for the interview (Beatrice and Stephanie) were recruited via the ongoing SPT project, since we conducted design workshops with their classes. Beatrice was present during the SPT workshops (MP case) and scaffolded our activities as ‘anchor’ for the children. Stephanie was not engaged in any of the workshops (LS case), but was frequently updated by us and the children about the design workshops and our progress. Hence, both participating teachers in the interview were familiar with the SPT project, our work and the outcomes.

Table [5.1] shows an overview of the participants of the interview.

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Discussion Setting</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beatrice</td>
<td>Interview</td>
<td>90 minutes</td>
</tr>
<tr>
<td>Stephanie</td>
<td>Interview</td>
<td>90 minutes</td>
</tr>
</tbody>
</table>

Table 5.1: Overview of the participating teachers of the interview (all names changed), their profession and study setting.

**Process**

The interview was based on an interview guideline prepared by my co-researchers. They formulated two main questions: *What do teachers require in terms of resources to be able to evolve their practices around technology and participatory design?*

\(^1\)I did not participate in the interview myself due to personal reasons, but I was involved in the setup of the interview and conducted the analysis.
5.1. First study: Interview

to evolve their practices around technology design activities with children?” and “What are their constraints when aiming to evolve their practices around technology design activities with children?” The interview guide was loosely structured and started with questions about their current practices related to designing technologies (for instance: “Which educational or technical resources do you use already?” and “Which additional resources would you need to conduct technology design activities with your class?”), followed by a discussion around challenges the teachers experienced so far using technologies in class and requirements for educational resources related to technology design activities.

Data collection and analysis

The interview was audio-recorded. Two researchers were present during the interview. The audio data from the interview was fully transcribed and analysed using TA, based on the approach of Braun and Clarke (Braun & Clarke 2006), as explained in Chapter 3. The data was analysed by me, and I discussed my findings afterwards with my co-researchers who were present during the interview in case I missed anything which was not captured by the audio-records. I familiarised myself with the data by listening to the interview and during the transcription process, which was done manually by myself as a first and important step to inform further analysis (Lapadat & Lindsay 1999). Next, I generated initial codes and searched for themes while paying special attention to those themes which could be relevant to explore the contextual characteristics of schools and the needs and wishes of teachers. During the coding process I first highlighted parts of the text, ranging from single words to sentences, which fit a pre-defined lens (information which might be relevant to understand the school context, the needs of the teachers or insights for the toolkit design process), seem relevant for my research questions, or caught my interest in other ways without being able to name a theme yet. Based on the initial codes, I read through the data again and searched for themes. I assigned different colours to each theme and highlighted the extracts accordingly. To review themes and refine them, I used an excel sheet with all initial main- and subthemes and sorted the highlighted extracts iteratively. On a notepad, I kept record of this process and played with different themes and names by drawing a mind-map. This allowed me to visually support the process. When I was satisfied with the themes, I re-arranged the excel table and made an overview of all themes and codes, which is pictured in Appendix C 8.3.6.

Based on this overview, I wrote a summary of the results and selected codes which show the theme. A selection of the most relevant themes for the design process is presented in the next section.

5.1.2 Results

During the interview, we asked the teachers what they (and other teachers not involved in the initial SPT project) would need to be able to evolve their own practices around their experiences in the SPT project. They did consider the experiences of the children during the SPT project as valuable for children and were interested to engage in technology design activities with their classes in the future. However, they addressed a number
of contextual challenges which would make it difficult for them to facilitate similar technology design activities and had specific requests we should meet so they would be able to evolve their practices in a school context.

New technologies become more important in the school’s curricula

At the beginning of the interview, we were interested if the teachers would even want to evolve their practices around technology design activities with children. Beatrice told us: “Our school has as new SQA new technologies (...) and we must, we MUST do a training next year in the field of digital education. Our headmistress required this.” Hence, teaching about new technologies is becoming more and more important at Beatrice’s school. This is similar at other schools in Austria, since STEM (Science, Technology, Engineering, Mathematics) education is getting more attention and technical subjects like programming are part of the curriculum at secondary schools.

Teachers lack resources to facilitate technology design activities

A repeatedly mentioned challenge was the lack of resources to be able to facilitate technology design activities with children. Resources could be for instance money to buy materials to facilitate design processes, or time teachers need to learn how to involve children in technology design activities. Having access to relevant resources is important when it comes to sustaining PD practices and experiences (Taylor, Cheverst, Wright & Olivier, 2013), but after a project has ended, researchers can no longer support the people or offer access to resources. When we would leave something behind for teachers which should remain in use beyond the project’s end and can be used by teachers not involved in the initial project (hence teachers who are likely not or less familiar with PD practices or technology design processes), it is thus important to be aware of the existing resources, and even more importantly, which resources might be lacking and could be prepared by the researchers before the initial project ends. In this part, I will present all challenges related to the lack of resources.

An important resource which was repeatedly discussed during the interview was technical equipment and opportunities for the teachers to borrow technical equipment. Stephanie, who teaches at a school for special education, stated that there are only few toolkits for special education schools available. She does not use technological toolkits in class and (to her knowledge) her school has no technical equipment. Her school has a workshop she could use, but they have only (technical) equipment for art or sewing activities. Beatrice told as that she already used an educational robotic toolkit in class.

2SQA means quality development: In Vienna, schools have to choose a topic for each year the teachers need to acquire new skills and knowledge in the chosen area.

3The original quote in German is: “Ab nächstem Jahr ist das fix im SQA drinnen, jetzt war es noch so Schulqualität. Und wir müssen, wir MÜSSEN von unserer Direktorin aus nächstes Jahr eine Fortbildung in die digitale Richtung machen.”
(a BeeBot⁴), and combined different materials, ranging from crafting materials (wood, for instance) to Lego building blocks. She highlighted the importance of offering different materials to the children that they can creatively explore and combine, as this quote illustrates: “I am finishing my Montessori training in September and my colleague comes from a ‘Free School’. Hence, we mainly use individualized learning methods with materials which are already available in our school (...) the children can choose from and work with. For instance, a Beebot (...).” The school bought the Beebot after they collected money from the parents during their annual Christmas market, as Beatrice explained: “Usually the money we collect is donated, but this year we thought: Technology is our topic, it would be great if we could use the money for picking up the topic of digital education (...) The problem with this is, imagine we buy two tablets for the whole school, but we have 16 classes. That’s why there is only one Beebot and only one Bluebot and we have to share them.”⁵ Even at Beatrice’s school, which has chosen to focus more on new technologies in the future, the amount of technical equipment is insufficient for all classes. The school also lacks the funding to buy (more) technical materials, for instance, electrical components.

Another resource problem which was discussed during the interview was time. Beatrice introduced the concept of an “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. Beatrice told us that “Information should not be longer than an A4 page.” Stephanie adds: “That’s good advice. Otherwise it won’t be read (by the teachers).”⁶ Beatrice and Stephanie 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.

Teachers lack technical skills to facilitate technology design activities

The last constraint mentioned during the interview was the lack of technical skills and knowledge. Beatrice and Stephanie 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 Beatrice told us: “As teachers we must know everything, English, crafting... but we are also father, mother, soulmate, comforter to

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⁵The original quote in German is: “Wenn wir Adventmarkt machen und Geld einnehmen war es bست jetzt immer so, dass das zum Beispiel an eine Organisation gegangen ist (...) Und dieses Jahr haben wir gesagt, hey wir haben das als Thema, wär gut (...), wenn wir dieses Geld dafür verwenden in der Schule dieses Thema digitale Bildung mehr aufgreifen und zum Beispiel zwei Tablets kaufen. Das Problem ist, das sind dann zwei Tablets auf die ganze Schule und wir sind 16 Klassen. Und deswegen sind ein Beebot und ein Bluebot jetzt in der Montessori Klasse und die muss man sich borgen.”
⁶The original quote in German is: “Ich hätte gerne auf einer A4 Seite alle Informationen.” “Die A4 Seite ist ein guter Tipp. Tendenziell wird’s sonst eher nicht verwendet.”
the children. At some point, we have reached our limit. Electricity is not my “thing” (...) so I need someone to give me short explanations. [7]

Summary

While at Beatrice’s school teaching about new technologies becomes more and more important, Beatrice and Stephanie report that their schools, and they as teachers, lack the resources to be able to teach about this topic. Limited resources of their schools are in particular: Funding, skills, time or (technological) equipment. There might be thus a need to support teachers to enable children to learn about new technologies, for instance, by engaging in technology design processes. Hence, the next steps are to explore how such a support could be facilitated and realized in a school context. To inform this process, I build on the sustainability targets and enablers of the SPT project, and further explored the characteristics of a school context.

5.2 First toolkit concept

At the end of Chapter 4, I presented the sustainability targets and enablers of the SPT project. Reflecting on the challenges of the school context, we realised that our sustainability targets would probably neither be sustained by the teachers involved in the SPT project nor teachers not involved in the initial project. During the SPT project, we experienced the differences between the resources and methodological approaches of researchers and teachers, and the influence of the school context (rigid structures and pre-existing relationships between teachers and children, for instance) on the process and experiences (of the children). We came to the conclusion that, without planning and preparing something before the SPT project ends, we probably would not have been able to sustain SPT experiences and practices in the school context.

As motivated in Section 2.5 in Chapter 2, I chose a toolkit approach in this thesis to develop resources which could support teachers to enable children to engage in technology design processes. Toolkits can empower new audiences, enable replication and scaling of practices and experiences (which aligns with two of the four ideal typical forms of sustainability previously discussed [Iversen & Dindler, 2014]) and support the integration process with current practices and infrastructures. Educational resources have been used in the history of PD before to sustain PD practices for audiences not involved in the initial PD projects [Bjerknes et al., 1987]. The first toolkit concept is based on the results from the interview as presented in 5.1.2 and the enablers as presented in Chapter 4.

5.2. First toolkit concept

5.2.1 Implementing the enablers from the SPT project in a toolkit

In Chapter 4, I identified seven enablers which enabled children in the SPT project to engage in technology design activities and resulted in sustainability targets (outcomes we aim to sustain beyond the project’s end).

Figure 5.1: Transformation of sustainability targets to enablers in toolkit.

With this toolkit, I aim to support teachers to enable children to participate in technology
5. Toolkit Design Process

design processes. Figure 5.1 illustrates the steps taken to design the final toolkit. In Chapter 4, I presented the first two circles which summarise the identified sustainability targets of the SPT project and which enablers children not involved in the initial SPT project might need to engage in similar technology design processes and have SPT experiences, leading to similar targets as those from the SPT project.

In the SPT project, children were enabled to critique existing technologies, explore different concepts and meanings of technologies, explore technologies, collaboratively create concepts and solve problems in design processes and to have fun during the design process. We also balanced adult-children relationships to enable children to take a leading role in design processes. I refer to the enablers from the SPT project using the term SPT enabler.

Taking into consideration the challenges and characteristics of a school context in which teachers operate, I transformed those theoretical enablers into practical tools that meet the challenges and requirements of a school context and can support teachers to enable children to engage in technology design activities. The enablers included in the toolkit (I refer to them using the term toolkit enablers), as visualised in Figure 5.1, are:

1. Suggestions for methods & approaches based on PD
2. Guidelines for structuring design processes
3. Focus on groupwork and discussions led by children
4. Inventor narrative
5. ‘What-if’ games
6. Technology samples children can engage with without support from teachers

The first toolkit enabler, ‘Suggestions for methods & approaches based on PD’, supports teachers to evolve their practices around methods and approaches based on PD. PD methods and approaches were the central underlying element of the enablers in the SPT project and can support children to take a leading role in design processes (sustainability target 1). In the SPT project, we applied PD methods to enable children to critique existing technologies (during technology immersion activities, for instance, as described in Section 4.3.2). Hence, PD methods and approaches became the core of the toolkit.

The second toolkit enabler, ‘Guidelines for structuring design processes’, supports teachers to structure technology design processes. This is necessary to enable children to explore different concepts and meanings of technologies (SPT enabler 4). In the SPT project, the researchers were trained in designing technologies and structuring design processes. The results from the interview showed that new technologies is a relatively new topic in schools and teachers are not trained in designing technologies. Hence, they might benefit
from guidelines for how a design process could be structured, for instance, by passing through different design phases (idea generation, exploring technologies, prototyping).

The third toolkit enabler, ‘Focus on groupwork and discussions led by children’, supports teachers to evolve their practices around teaching methods that support an active involvement of children. By working in groups and discussion settings, children are enabled to collaboratively create concepts and solve problems (SPT enabler 2). In the SPT project, this was crucial to empower children to lead the design process together (sustainability target 1). Groupwork and discussions led by children also enable children to be decision-makers in the design process.

The fourth toolkit enabler, inventor narrative, supports teachers with a narrative which motivates children to take a leading role in design processes (sustainability target 1). It sets the context for the use of the toolkit and enables children to engage in creative processes (SPT enabler 4) as inventors who create new technical concepts. This supports creative engagements with technologies (sustainability target 3).

The fifth toolkit enabler, ‘What-if’ games, supports teachers with practical tips: To enable children to think beyond existing technologies and explore new meanings of technologies (SPT enabler 4), they could engage in ‘what-if’ games. During ‘what-if’ games, children could engage playfully in design processes, as they are not limited to technical realistic concepts, enabling fun (sustainability target 5).

The sixth toolkit enabler, Technology samples children can engage with without support from teachers, supports teachers to enable children to explore technologies and opportunities without teacher-centred teaching methods (SPT enabler 1). Instead, the children choose what kind of technologies they would like to explore, supporting their leading role (sustainability target 1).

In the following subsections, I present in detail the tools included in the toolkit and how they incorporate those enablers.

Teacher Handbook

The aim of the teacher handbook is to provide teachers methodological support and structures how to facilitate design sessions with children (Toolkit enabler 1 & 2). It guides teachers who are usually not trained in running design processes through a design process step-by-step, using a structure similar to design thinking [Plattner 2010]. The teacher handbook has two parts: In the first part, I explain the different parts of the toolkit and propose how to structure a design process with children. This structure consists of different modules, each module contains a suggestion for activities which contribute to the design process. 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 suggests an activity which takes approximately one hour. Five modules are highly recommended to do, three modules are optional, depending on the time available for the lesson. The handbook also recommends to start
5. Toolkit Design Process

a module with an opening routine (discussing what has happened during the previous module) and an ending routine (writing in the diary).

In the second part of the handbook, the modules are presented. Each module consists of two suggestions for activities: One for the whole class and one for the design teams. To support the children in this process, there are recommended questions to ask the children when they get stuck or need additional structures.

The majority of activities suggested in the toolkit are group activities and learning processes steered by the children (Toolkit enabler 3) to empower children to actively create concepts. Children work in design teams and collaboratively explore technological concepts by watching videos included in the toolkit, avoiding traditional chalk and talk techniques. The design process is framed as an invention project, the children form design teams which invent collaboratively technologies. However, the teachers will ultimately decide how they use the toolkit in class and evolve their own practices around the materials.

Cards

The toolkit contains three different card decks: Technology cards, design trigger cards and fantasy cards. The aim of the technology cards is to introduce different kinds of technologies to children and teachers, for instance sensors and outputs (Toolkit enabler 6). It shows an icon of the technology, and a short text which explains the technology. The second aim of the technology cards is to be placeholders for physical electrical parts. As schools do not have big financial resources to acquire a toolkit with physical electrical components, technology cards could be an alternative to use as placeholders in prototypes to communicate what kind of technologies that would use for their invention.

The initial prototype consisted of card decks with QR codes that would lead children to websites where they could find information about certain technologies. I used colour codes to distinguish between different types of technologies, for instance sensors/input (pink) or output (green). I used pictures of technologies on the cards to show what the technology looks like and a short explanation about how the technology works. Figure 5.5 shows the initial prototype.

The aim of the design trigger cards is to structure the idea generation process (Toolkit enabler 2). On the cards are questions which can trigger design ideas, for instance: “Imagine an invention which protects you”. They could inspire children to explore what they could invent, by giving them ideas for a problem context and how technological inventions could contribute to the children’s life. Figure 5.5 shows the initial prototype.

The aim of the fantasy cards is to inspire children to think beyond existing technologies and support them to explore novel opportunities, engaging in ‘what-if’ games (Toolkit enabler 5). The fantasy cards could also be used to structure role-playing activities. The children could use them to engage in fantasy narratives and collaboratively think of opportunities for technologies in their narratives.
Inventor diary

The aim of the diary for children, called ‘inventor diary’, is to offer children the opportunity to keep a record of their design process and to collect their experiences during this process (Toolkit enabler 2 & 4). The diaries contain short assignments which help the teachers and children to structure their work. The diary balances structured activities (for instance collecting particular cards and matching them) with open activities (blank spaces where the children can draw or take notes).

The final activity in the inventor diary is a presentation of the ‘invention’. This could be a drawing or a mock-up, depending on the materials the children used. The children are asked in the inventor diary to think of questions they could ask the groups which are presenting their inventions. This might enable them to critically engage with the inventions the other groups present.

5.2.2 Addressing the contextual challenges of a school context

I have pointed out in Section 5.1.2, that schools and teachers have limited resources. In particular: funding, skills, time or (technological) equipment or access to facilities. In this subsection, I explain how the toolkit concept addresses those challenges.

Including basic knowledge about technology and design processes

To address the contextual challenge of limited skills, I included technology card decks in the toolkit and made technology cards with a QR code leading to a video, explaining and demonstrating how specific sensors, outputs or manufacturing techniques (e.g. 3D printing) work. The aim of the technology videos is to give children and teachers brief and simple explanations about technological parts (i.e. sensors) or machines (Toolkit enabler 6). In addition, I created a booklet with guidelines and methodological tips to support teachers with engaging the students in the design process step by step.

To support teachers and children in exploring the different technologies, I suggested to use simple technical building blocks (for instance littleBits) in combination with the technology cards. LittleBits can be used without any previous technical knowledge and do not require preparation time from the teachers (because no soldering or programming is required).

A4-page rule of thumb

To address the contextual challenge of limited time, I applied the “A4-page rule of thumb” and tried to keep the information short. I also aimed to provide information about technologies in ways so 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 would not need to acquire in-depth technological skills or knowledge in advance, saving preparation time.

5.3 Second study: Co-design workshop with teachers

To deepen my understanding of how a toolkit could support teachers with their practice, how a toolkit could be designed and what tools would be necessary, we conducted a co-design workshop with two teachers. I used the first toolkit prototype as conversation starter and to give the teachers first inspirations how such a toolkit could be designed.

5.3.1 Research approach

As presented in Chapter 3, I chose a concept-driven approach [Stolterman & Wiberg, 2010] to integrate the toolkit design process in my research. The first toolkit prototype is used in the co-design workshop as a means to deepen my understanding of the school context and re-designing the first toolkit concept collaboratively with the teachers. The enablers as defined in Chapter 4 are embodied in the toolkit and iterated together with the teachers. The design process is thus research-oriented, a combination of research and making, but the toolkit as artefact and resulting design implications play an important role in it.

Participants

The participating teachers for the co-design workshop (Caroline and Petra) were also recruited via the SPT project. Caroline was the substitute teacher for Beatrice and present during the SPT workshops (MP case) and ‘anchor’ for the children. Petra was a colleague of the teachers involved in the MP case, and had not engaged in any of the workshops.

Table 5.2 shows an overview of the participants of the co-design workshop.

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Discussion Setting</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caroline</td>
<td>Primary school teacher</td>
<td>co-design workshop</td>
</tr>
<tr>
<td></td>
<td>specialised in special</td>
<td></td>
</tr>
<tr>
<td></td>
<td>needs education</td>
<td></td>
</tr>
<tr>
<td>Petra</td>
<td>Primary school teacher</td>
<td>co-design workshop</td>
</tr>
</tbody>
</table>

Table 5.2: Overview of the participating teachers of the co-design workshop (all names changed), their profession and study setting.
5.3. Second study: Co-design workshop with teachers

Materials

I printed all materials as presented in Section 5.2: The teacher handbook with methodological approaches and a suggestion for structuring design workshops, card decks (technology cards, design trigger cards and fantasy cards) and the inventor diary for the children to document the design process (see Figure 5.2). I laminated the cards and brought different sets of littleBits to the workshop as examples for electronic components.

![Figure 5.2: Picture taken during the co-design workshop with teachers, showing the inventor diary and cards.](image)

An audio-recorder was used to record the co-design workshop.

Process

The co-design workshop was held in the classroom of the MP group at a primary school in Vienna. Before the co-design workshop started, I asked the participants to sign the informed consent form (see Appendix C 8.3.6). The workshop was based on a plan (see Appendix C 8.3.6) consisting of three activities. First, we explained the different tools in the first toolkit concept and explored with the teachers what kind of tools would be useful for them and with kind of tools might be missing in the first concept. We used the
printed materials as examples of how those tools could look like, but emphasizing that this was only a first prototype and that we need their perspective as teachers to design the toolkit. Next, we asked the teachers to explore the tools without any explanations from the researchers, as the toolkit would be used in the future by teachers without the support of researchers. Then, we asked the teachers to re-design the toolkit verbally (by speaking out loud their thoughts when exploring the tools) and with hands-on activities. We asked the teachers to use the cards, the inventor diary, and the littleBits to try out activities suggested in the handbook and to build first mock-ups. We formulated for each activity guiding questions to stimulate discussion, for instance: “What kind of information do you need in the handbook?” or “How comprehensible is the inventor diary for the children?” or “How would you use the cards?” We also motivated the teachers to scribble in the printed materials.

Data collection

The co-design workshop was audio-recorded. Two researchers were present. One researcher took notes and pictures, the other one (myself) led the activities. Both researchers also wrote researcher diary notes afterwards reflecting on the insights we had during the workshop.

Data analysis

The audio data from the co-design workshop was partially transcribed. Parts irrelevant to this research, such as informal chats during the workshop or introductions - were summarised. I also included the researcher diary notes in the analysis. The data was analysed using Thematic Analysis (Braun & Clarke, 2006). The six step analysis process was conducted similarly as described in Section 5.1.1, but this time I discussed the themes with a second researcher (who was also present during the workshop) because I was interested in my colleague’s perspective and design insights we drew from the results.

5.3.2 Results

Re-visiting and the teachers’ lack of resources to facilitate technology design activities

The topic of lacking resources was also discussed in the co-design workshop, even when the conversation about possible physical materials to support children with prototyping activities turned from purchasing littleBits towards printing booklets. Petra told us: “We are not allowed to copy pages in colour for all children.” They explained to us that they are only allowed to copy in colour if it is really necessary, because coloured ink is more expensive than black ink. Hence, the teachers were still faced with worries and doubts as to the financial ramifications of the toolkit. However, the teachers’ budget is rather tight, so including electronic components like the littleBits became unrealistic. This quote from Caroline illustrates the teachers’ budget: “We receive 200 euros for each
5.3. Second study: Co-design workshop with teachers

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.\footnote{The original quote in German is: "Wir haben pro Schulhalbjahr 200 Euro zur Verfügung. Aber davon müssen wir das ganze Material kaufen: Bücher, Bastelsachen... Am Ende des Schuljahres ist nichts mehr übrig."}

Online resources as part of the toolkit

Petra and Caroline liked the idea that the children explore the technologies and that the toolkit contains videos. They suggested to provide videos directly in the toolkit without using QR codes (so children do not need a Smartphone with a scanning app to open the videos). Petra explained: \textit{“This means that you need to transfer it (the video) on the computer using an app. Most teachers will back out at this point. And the children do not have a smartphone (in class). At a primary school I do not do this (letting the children use their smartphones).”}\footnote{The original quote in German is: “Da muss man es erst über die App auf den Computer bekommen. Naah, da steigen die meisten (LehrerInnen) schon aus. Und Smartphone haben die Kinder keins (...) in der Volksschule mache ich das nicht.”} Petra emphasized that all parts of the toolkit should be easy to work with and without having any technical knowledge, skills or equipment. If the toolkit contains online resources, they must be easy to use and independent from specific devices. Hence, we asked the teachers how we could provide online tools without being dependent on specific devices like smartphones. Petra suggested: \textit{“Links (...) Or a website you can visit.”} Caroline added: \textit{“Yes indeed! Each class has a computer with access to internet. All children could sit in front of it and what it (the videos) together.”}

When discussing how we could provide the videos (and possible other tools like the inventor diary and the teacher handbook), Petra suggested to create a website with additional, digital resources as part of the toolkit. It has worked very well for her in the past to let the children work independently on a computer in the classroom, as she illustrated with an example. Hence, she concluded that this might work for the toolkit as well when the materials are on a website.

Finding appropriate time-slots for design activities and arranging them with the curriculum

During the co-design workshop, it became apparent that time was not only a constraint for preparing the toolkit activities (as discussed during the interview), 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. \footnote{The original quotes in German are: “Links(...) Oder wenn es da eine Website gibt wo man raufgehen kann.” Caroline:“Ja genau! Es hat eigentlich jede Klasse einen Computer mit Internetzugang. Da können auch alle Kinder davorsitzen und das anschauen.” P: Sie gehen zum Beispiel auch für die Radfahrprüfung auf Radfahrprüfung.at und machen da diese ganzen Tests (...) Wenn man eine Website hat wo diese Videos drauf sind geht das sicher super.”}
Caroline explained: “With all topics (from the curriculum) the time is limited.” Petra disagreed: “Well, it depends, I think it is possible. Especially at primary schools you can arrange this. You need to do it (use the toolkit) when the whole class is present, eight hours straight is difficult. But you can split it (the activities) up.” Teachers might have different time-slots they can use for facilitating technology design workshops with the children and they might need to arrange them within their curriculum. Hence, the toolkit should support this need for flexibility.

Re-usable content for more flexibility and different topics of the curriculum

When discussing whether teachers could share one toolkit with other colleagues, because the schools do not have sufficient technical equipment or the money to buy it, Petra asked for re-usable toolkit content. 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. She explained that they prefer materials they can use several times with the class, because the children become familiar with certain structures and methods. For future use of the toolkit Petra suggested: “Children could solve more societal problems. For instance something related to nature, garbage on the streets (...).” Petra imagined to use the toolkit on a regular basis: “If it (the toolkit) were always available, children could also use it in a free setting when they work on their own. Once a week a couple of children could do something in the field of technology.” Moreover, it would save preparation time for the teachers. Hence, a toolkit should be re-usable for different topics of the curriculum and different subjects.

Power imbalance between teachers and children

Power imbalance is a phenomena which we have already observed during the workshops we conducted during the SPT project with the children (see Chapter 4) and which was reported in related work (see Chapter 2). In the co-design workshop, this topic was brought up by Caroline, when she remembered her experiences from being involved in the SPT workshops: “I like the idea (of giving children the lead in the design process). During the first workshops of the SPT project, I really struggled to refrain from interfering. That is why I sat down in the back of the classroom.” Caroline had to get used to her new ‘role’ as observer and letting the children lead the process, but she welcomed the idea of giving children the freedom to lead the process and exploring different directions. Hence, she was fine with sitting in the back. However, she saw a challenge in supporting those children who need more structures, as her quote illustrates: “I like the idea of not telling...”
5.3. Second study: Co-design workshop with teachers

them (the children) what to do and that they take the lead, but completely unstructured freedom can also be a challenge for creating ideas (...) Children who prefer to be in the background cannot bring in their ideas, you might need structures there.” \(^{15}\) Caroline reflected on this challenge and that, after getting used to remain a passive observer during the workshops in the SPT project, it became a positive experience for her. However, she was concerned about those children who might need a more structured approach to be creative, suggesting to support those children who need additional structures while giving other children more freedom. The importance of balancing structures and freedom is in line with our own experiences from co-design workshops with children \(^{[Makhaeva et al., 2016]}\), and does not necessarily need to be conflicting with the childrens’ role as decision-maker.

The phenomena of power imbalance at schools and that teachers find it hard to adjust to different, more passive roles when teaching, has been discussed in the literature as well. Researchers observed that children, who do not usually have much authority in schools, lack freedom to choose activities or topics \(^{[Iivari & Kinnula, 2016]}\), while their teachers are trying to influence activities \(^{[Barendregt et al., 2016]}\). This might impact the design process and is contrary to the children’s traditional role in PD projects as decision-makers. As argued in Chapter 4, underlying values (like the empowerment of children as decision-makers) are central in PD projects. Hence, when re-designing the toolkit, we should be aware of those existing power imbalances between teachers and children, which might not be resolved with PD approaches which work in a researcher-children setting.

**Embedding the toolkit in a narrative**

When asking the teachers if they could imagine using the toolkit, Caroline and Petra wondered if they could embed the toolkit in a narrative. We brainstormed together about possible narratives, which could be presented as a story written out in the toolkit. While discussing possible narratives, Petra emphasized: “Simple instructions are important. You are stranded here (on an island), you can use this and this (to design something).” \(^{16}\) Hence, a narrative can be a short story in combination with simple tasks for the children to inspire them to start thinking about what kind of new technologies they could invent.

**Summary**

Caroline and Petra confirmed the challenge of limited resources in schools and brought forward three additional challenges of a school context: First, appropriate time-slots for technology design workshops might be different in schools or classes, hence teachers need

\(^{15}\)The original quote in German is: “Ich mag die Idee. In den ersten Stunden wo ich da war ist mir das schwergefallen da nix zu sagen. Deswegen hab ich mich hinten hingesetzt. Ich find den Ansatz gut, dass man ihnen nichts vorgibt und es soll von ihnen kommen. Aber diese komplett unstrukturierte Freiheit (...) ist auch manchmal hinderlich um Ideen zu kreieren. (...) Kinder die sich zurückziehen können ihre Ideen nicht gut einbringen, da ist es wichtig etwas zu strukturieren.”

\(^{16}\)The original quote in German is: “Einfache Angaben. Ihr seid hier gestrandet, das und das habt ihr zur Verfügung.”
5. ToolKit Design Process

to be flexible about when and how long design activities take place. Second, teachers prefer re-usable content they can use more often and third, power imbalances between teachers and children which might impact the empowerment of children as design partners. In the co-design workshop, we set first steps towards generating ideas how to address the first two challenges: A digital toolkit provided to the teachers on a website could support teachers to re-use and print materials whenever needed. Offering guidelines in the toolkit to balance structures and freedom could support teachers to address power imbalances and empower children as decision-makers and designers.

5.4 Second toolkit concept

Based on the results of the co-design workshop, I developed a second toolkit concept.

5.4.1 Moving towards a digital toolkit

To address the need for re-usable and free materials, I transformed the first toolkit concept which consisted of physical, printed booklets and cards into a digital toolkit. I started a website for the toolkit[^17] and moved all parts of the toolkit (cards, videos, teachers booklet and the inventor diary) to this website. Since all participating teachers stated that there is no budget or funding to buy electrical parts or other materials, and those could not be made available in a digital form, I suggested instead in the teacher handbook to collaborate with FabLabs or other places where teachers could get access to electrical parts or machines.

Digital materials have three benefits: First, they are free. Second, they are easy to access and share and third, they are re-usable. Teachers can print the content as often as they need it, and can use it for multiple children and classes they teach. By re-using the toolkit materials, they could save preparation time for future classes. Related to this, digital resources are easier to adapt which can support evolving the toolkit. If the teachers need to add content to the materials, for instance extend the card decks with another topic of the curriculum, they can modify them on the computer.

In terms of scaling and replicating, an online toolkit increases the chances to support the reach of the toolkit beyond the researchers’ contacts and to support teachers not involved in the initial SPT project, and allow multiple uses of the toolkit materials at the same time. For instance, I have later shared the toolkit via social media (Instagram, Twitter). Furthermore, it could allow an online exchange of the teachers’ experiences and peer support in the future, by adding an online forum.

5.4.2 Sharing power in the design process

To address the challenge of power imbalances, the toolkit supports group activities and learning processes steered by the children. The first toolkit prototype already suggested

[^17]: https://spttoolkit.wordpress.com
group activities, but the children needed the teachers to explain to them the technologies based on the cards. The second toolkit prototype contains videos included in the toolkit as part of the website. Hence, children can explore technological concepts by watching videos, avoiding traditional chalk and talk techniques. The design process is framed as an invention project, the children form design teams which invent collaboratively technologies. This does not mean that teachers should completely refrain from structuring activities for children, as Caroline was concerned about, but the toolkit aims to support teachers to balance structures and freedom for children to give them only as much support as necessary to enable them to lead the design process. To assist the teachers in this process, the teacher handbook of the second toolkit prototype was re-written, giving teachers tips to structure the design process if necessary (by suggesting guiding questions they could ask the children, for instance). Ultimately, the teachers decide how they use the toolkit in class and evolve their own practices around the materials.

5.4.3 Giving teachers access to technical resources and skills

As discussed in Chapter 4 and the results from the teacher interview showed (see Section 5.1.2), teachers have limited technical resources and skills. To approach this challenge, we suggested during the co-design workshop to use littleBits in combination with the first toolkit prototype. Petra and Caroline considered littleBits as too expensive and the budget they had to buy technical components was too tight for other alternatives (for instance SAM Blocks or Calliope). This was in line with the results from the teacher interview: A toolkit which needs teachers to buy additional electrical parts would not be able to meet all requirements of the teachers or address the contextual challenges sufficiently. Hence, we suggested in the second toolkit concept to visit a FabLab or similar places where people not trained in technology related fields can get access to technical resources.

5.4.4 Re-designing the toolkit components

Based on the recommendations of the teachers during the co-design workshop, we re-designed the different toolkit components.

Re-designing the teacher handbook

To address the challenge of different curricula and available time-slots for running workshops, the first handbook prototype already offered activities with modular blocks, as the schedule in Figure 5.3 shows. 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. Hence, the teachers can choose if they want to do one module each day/week or several modules one after the other. The results from the co-design workshop indicated that this flexibility is indeed needed by teachers to they can adapt the time-schedule for using the toolkit based on their available time-slots.
5. Toolkit Design Process

Based on the feedback from Caroline about cost of printing colour, we changed the coloured handbook to a black and white version. Instead of colour codes, I used patterns for the modules (see Figure 5.3) and Caroline also sketched a new structure for the schedule which I built upon when re-designing the handbook. A page from the handbook illustrating guidelines for the teachers is shown in Figure 5.4.

To help teachers to support children in design processes who might need more structures, as suggested by Caroline, each module in the teacher handbook contains guiding questions the teachers could ask children. An example of a guiding question is: “Which technologies do you think you could use to build this invention?”

Re-designing the technology cards

During the co-design workshop, the teachers asked for more modular, digital content and only black-and-white cards, since they do not have the budget for colour printing. The technology pictures were changed to icons which show the function of the technologies, since pictures of materials the children are unfamiliar with would be too abstract. Figure 5.6 shows the final prototype of the cards.
5.4. Second toolkit concept

Figure 5.5: First prototype of technology card (pressure sensor) and design trigger card, saying: “Imagine an invention that protects you.” (translated into English for the thesis)

Figure 5.6: Second prototype of technology cards (motion sensor, cable, sound) and design trigger card (protection) saying: Protection: “Imagine an invention that protects you.” (translated into English for the thesis). All cards can be printed black and white and still be usable since they have patterns and symbols.

Re-designing the design trigger cards

The trigger cards evolved during the process similar to the technology cards: Icons were used instead of pictures and black-and-white-patterns added. The shape of the cards was adjusted to visually distinguish them from the technology cards. Figure 5.6 shows the final prototype of the design trigger cards.

Re-designing the fantasy cards

The fantasy cards evolved during the design process similar to the design trigger cards: Icons were used instead of pictures and black-and-white-patterns added. The shape of the cards was adjusted to visually distinguish them from the technology cards. Figure 5.5 shows the initial prototype, Figure 5.6 shows the final prototype of the design trigger cards.
cards. I added cards with sci-fi elements to broaden the topics of the cards, without choosing specific topics from the curriculum (for instance fire-brigade), so the cards remain adaptable to any content the teacher is meant to be teaching the children according to the curriculum.

Re-designing the inventor diary

The diary also evolved during the design process. The initial prototype contained more structured activities and too little blank space which was changed in the final prototype. I also embedded the diary in a narrative (see Appendix C 8.3.6 for the story in the inventor diary) by including a story in the first chapter of the inventor diary. The story is based on the suggestion from Petra (see Section 5.3.2) to let the children imagine that they are stranded on an island and have a toolkit they can use to invent technologies which help them with their life on an island. Like the teacher handbook, the re-designed inventor diary is in black and white to reduce printing costs. Two pages of the inventor diary are shown in Figure 5.7 and Figure 5.8.
Developing technology videos

The videos from the first prototype were existing videos from websites, the children could open by scanning the QR codes from the technology cards. During the co-design workshop, we discussed that it might be too complicated for the teachers to scan QR codes and that primary school children do not use smartphones in the classrooms. Hence, I removed the QR codes and decided to include videos directly on the toolkit website. I also re-designed the videos: Instead of using existing videos, I recorded videos explaining technologies to have a consistent content. All videos have a similar structure: They first show the electrical part and explain what it does, for instance, a pressure sensor, which reacts when putting pressure on it. To show electrical parts and demonstrate how they work, I used littleBits. In the second part of the video, I show how those technologies are used in daily life objects, for instance a distance sensor which is used in cars as parking assistance.

5.5 Third study: Online survey

An online survey was conducted to initially explore how teachers not involved in the design process of the toolkit and teachers not involved in the initial SPT project would react to the second toolkit concept. I explored how the teachers interpreted the second toolkit concept and how they would appropriate the different tools.\textsuperscript{18}

5.5.1 Research approach

Participants

As the online study was an initial evaluation in preparation for the main evaluation presented in Chapter 6, I used an opportunistic sampling method through my social networks and asked teachers who were previously involved in the SPT project to share the invitation with their colleagues. This resulted in five participants, all primary school teachers and two with a specialisation in special needs education. The participating teachers were unfamiliar with the SPT project or our work. I aimed to explore how teachers not involved in the initial project would interpret the toolkit and react to it since the toolkit was co-designed with teachers involved in the SPT project.

Table 5.3 shows an overview of all participants.

\textsuperscript{18} An online-survey is not the ideal way to co-design or test a toolkit, I illustrated my ideas for future research in Chapter 8. The original plan was to conduct a series of co-design workshops with teachers to refine the concept. Unfortunately, I was not allowed to enter schools or have workshops at the University with teachers, due to the COVID-19 restrictions in Austria. Teachers were facing similar challenges, they needed to provide online classes and materials for home-schooling, which resulted in increasing stress and a low response rate for the survey.
5. Toolkit Design Process

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Discussion Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arnold Primary school teacher</td>
<td>Online survey</td>
</tr>
<tr>
<td>Beate Primary school teacher specialised in special needs education</td>
<td>Online survey</td>
</tr>
<tr>
<td>Katherine Primary school teacher specialised in special needs education</td>
<td>Online survey</td>
</tr>
<tr>
<td>Olga Primary school teacher</td>
<td>Online survey</td>
</tr>
<tr>
<td>Rose Primary school teacher</td>
<td>Online survey</td>
</tr>
</tbody>
</table>

Table 5.3: Overview of the participating teachers of the online survey (all names changed), their profession and study setting.

Materials

The online survey was conducting using Limesurvey[^19], including 21 questions (a mix of open and closed questions, key topic was the introduction of all tools and asking teachers how they would use them). The questions are listed in Appendix C[^8.3.6]. The survey was in German. At this point of the design process, the digital files of the second toolkit concept were transferred to a wordpress website[^20] and this link was shared with the participants of the survey. The survey covered six themes:

1. Background questions about the teachers (which school they are teaching, their technical background)
2. How comprehensible the particular components are for children
3. How the teachers would appropriate the particular components
4. What kind of components might be missing or could be added to the toolkit
5. Exploring opportunities for collaborations with technical experts (FabLabs)
6. Closing questions about any additional feedback the teachers might have

[^19]: https://www.limesurvey.org
[^20]: https://spttoolkit.wordpress.com
5.5. Third study: Online survey

Process

The participants received an invitation letter as e-mail (see Appendix C 8.3.6) with a brief project summary and a link to the survey. Before starting the survey, the participants were asked to sign an informed consent form. As part of the online-survey, I introduced the idea of an online toolkit in combination with visits to FabLabs to get access to physical materials (electrical components, machines, technical support).

Data collection and analysis

The data from the online survey was collected in an excel table and analysed based on this excel table with the answers. I compared the answers for the closed question, searching for similarities among answers and contradicting opinions. The open questions were analysed by searching for patterns with open coding. Next, I used the themes generated from the previous collected data and searched for items that would match the previously defined themes. Then, I looked at the previously coded text parts from the open questions and identified new themes based on the codes. As last step I refined the themes and wrote a summary of my findings.

5.5.2 Results

The reactions of the teachers on the toolkit were mixed and there were not many answers given to the open questions. Three teachers stated that they would probably use the toolkit, the other two teachers were unsure if they would use it in the future. Katherine mentioned that she liked the design of the toolkit content. I discuss here the most relevant themes in relation to the design implications for the final toolkit prototype.

Addressing rigid structures of a school context: A modular and adaptable toolkit

The issue of adaptability which was raised in the co-design workshop when discussing the curriculum, was mentioned in the online-survey as well. 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 Arnold illustrates this: “Toolkit topics should be relatable to the school’s curriculum, for instance fire, hydrologic cycle or weather. Show teachers how this relates to their curriculum. In Germany relevant subjects would be ‘Sachunterricht’ (general knowledge) and ‘Werken’ (crafting).”

21 This relates to Petra’s wish for more modularity, so they could re-use materials for different topics. Arnold criticised the decision to offer flexibility in terms of topics - 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

21The original comment in German is: “Bezug zu Lehrplanthemen (z.B. Feuer, Wetter, Kreislauf des Wassers) herstellen (...) Wie bereits geschrieben: Den LehrerInnen den Bezug zu ihren zu behandelnden Unterrichtsthemen aufzeigen. In Deutschland wären das Fächer wie Sachunterricht und Gestaltendes Werken.”
suggested using typical primary school themes the toolkit could build upon or to advise teachers in which subjects they could use the toolkit.

**Addressing the lack of technical equipment: Visiting FabLabs**

Four teachers confirmed our concern that not all schools have access to technological toolkits or materials, they reported that their schools do not have that kind of equipment. To address this challenge, one question in the survey was if the teachers could (and would want to) collaborate with external technical facilities, for instance FabLabs. Four of the five participating teachers were in favour of this idea. Katherine stated that she would be maybe interested, but questioned if they would have sufficient time to visit external facilities and if they could organise a collaboration with them: “*Maybe, if there is time in the lesson plan.*”

### 5.6 Design implications for the final toolkit

Building from the contextual restraints that where discussed during the interview, the co-design workshop and the online-survey, I created a list of design implications (see Table 5.4). For a toolkit to be continued to be used, it must be embedded in the context of practice of the teachers and their constraints (as being part of a school context). In Chapter 6, the list of design implications was re-fined after evaluating the toolkit.

#### 5.6.1 Embedding a toolkit in the schools’ structures and limited resources

The main concern expressed by the teachers in the interview and the co-design workshop was, that a toolkit would not meet their limited resources. The main design implication for the toolkit design process was, thus, that the toolkit is in line with the existing resources in a school context, to ensure future use and sustainability of the toolkit. The majority of the design implications (design implications one to five and nine) are based on this contextual limitation.

Design implications four, six and seven address the rigid school structures. I have previously pointed out that the toolkit’s content should match with the curriculum, or be adaptable so that it can be aligned with it. Furthermore, it should be re-usable. During the co-design workshop, the two participating teachers suggested to develop (at least partly) a digital toolkit, so the materials could be re-used by the teachers. If the content is digital, they could also modify or adapt the materials.

#### 5.6.2 Adding a technical support network to the toolkit

The findings of the interview and the co-design workshop revealed a major challenge for the toolkit in terms of sustainability: Teachers and schools are bound to inherent structures

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22 The original comment in German is: “Vielleicht, wenn dafür im Unterrichtsplan Zeit ist.”
and have very limited resources. In particular: funding, skills, time or (technological) equipment or access to facilities. Similar challenges are reported in the teacher education literature as well (Shah, 2019). This creates a complex problem: If teachers lack the proper equipment to organise technology design workshops with children, offering them a physical toolkit with equipment would be the most logical solution. However, developing a toolkit with physical materials or suggesting alternatives like littleBits requires funding, which schools usually do not have. There are cheaper alternatives for electronic building blocks and DIY communities who could support teachers to build their own materials, however, this requires either technical skills, or time to acquire the necessary skills, but the teachers stated that they have neither the technical skills nor the time to engage themselves with the topic. This complex problem makes it hard to find a ‘one-fits-all’ solution with a physical or digital toolkit.

To address this dilemma, I added a support network (design implication nine) to the toolkit: This could be, for instance, a local support community of technology experts, FabLabs, policy makers or other teachers using the toolkit. FabLabs, for example, offer open workshops and technical support to people who do not have access to the resources required to design technology. Hence, I add a seventh toolkit enabler to the list of enablers included in the toolkit: “Support network (experts & peer support)”. Figure 5.9
5. Toolkit Design Process

shows the final version of enablers in the toolkit.

Figure 5.9: Final version of enablers in toolkit.

The idea of collaborating with stakeholders in PD projects with children has been introduced by Iversen and Dindler (2014) and Bødker et al. (2017) to support the evolution of their project. They conducted collaborative activities among project partners, and shared their findings with politicians, decision-makers and domain experts. I aim to
extend the idea of a support network, including technical experts and people not involved in the PD project (for instance FabLabs or teachers who were not involved in the SPT project).

### 5.6.3 Sustaining practices and experiences of PD projects with a toolkit and infrastructuring

Related work shows that there is no silver bullet when researchers aim to sustain the practices and experiences of PD initiatives in a school context. Building upon the work of Iversen and Dindler (2014) and Bødker et al. (2017), I suggest to create a toolkit as collection of socio-material resources which could support teachers to enable children to design technologies beyond the project’s end. As a conceptual lens I used infrastructuring. As motivated in Chapter 2, I use this term as defined in Science and Technology Studies and used by Karasti et al. (2010) 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.”

With my work, I extended this usage of toolkits by including social materials to address the contextual challenges and restraints of a school context. For instance, a support community or using online platforms or social media to share the toolkit. Figure 5.10 illustrates how a toolkit could be used to share ideas and insights from the initial PD project (in this thesis the SPT project) with the local schools and teachers (but in the same local context with similar characteristics) and how it could invite new communities (in this thesis teachers from schools beyond the local project context) with possible different characteristics. Figure 5.10 is inspired by the work of (Meurer et al., 2018), who visualised the four types of sustainability by Iversen and Dindler.

### 5.7 Final toolkit concept

Based on the design implications, I re-designed the third toolkit concept. During the third design iteration, I focused mainly on the role support networks could play in the toolkit.

#### 5.7.1 New toolkit conceptualisation

In the online survey, I initially tested the idea that teachers collaborate with FabLabs or similar facilities which could support them with equipment and technical skills. Hence, I re-conceptualised the toolkit as collection of social and material tools. Figure 5.11 shows an overview of all social and material tools I created and continue working on for the toolkit. I present now the broader toolkit concept as a mindmap and elaborate the roles a support network could play as part of a social-material toolkit, the third toolkit concept.
5. Toolkit Design Process

5.7.2 Social tools: FabLabs

The situated context of schools and teachers comes with restraints, for instance limited resources, as I pointed out previously. Partly, I could approach this challenge by focusing on digital, low/non-cost materials (i.e. videos). But based on my experiences in the SPT project, the children greatly benefit from experiencing technologies like sensors or outputs, and enjoy seeing their ideas realised in working prototypes. To realistically facilitate design and technology experiences for the children, having a support network of technical experts or other teachers trained in technology design might be helpful (Toolkit enabler 7). Access to FabLabs or other collaborators with design/engineering experts could be one way to approach this. 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.

### 5.7.3 Social tools: Policy-makers

As an alternative way of 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. To address this matter, we introduced the SPT 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), this example shows how a social network could help sustain the impact of a PD project on a political level.

### 5.7.4 Social tools: Online platform and social media

![Image](image_url)

Figure 5.12: Instagram post of teacher reporting about experiences with the toolkit. Instagram post of teacher reporting about experiences with the toolkit.
So far, I discussed possible collaborators and partners in a local context as one approach to build a support network. The third opportunity for social tools relates to the facilitation of a support network beyond the local context: an online platform for peer support and as a source for toolkit materials. I had already decided to make the core part of the toolkit digital (cards, videos, teachers booklet and the inventor diary) available on a website. This website was also shared with the participants of the online survey.

In addition to the toolkit website, I created an Instagram account for the toolkit using the name ‘Erfinderkiste’ (Inventor-box) and posted pictures of the digital tools. The aim of using social media to share the toolkit is to reach teachers not involved in the SPT project and beyond the local, existing network). Social media could also support replication and scaling of PD practices: Teachers on social media, who like the toolkit and use it in class, can share their experiences with the toolkit on their own social media account and ‘advertise’ the toolkit to their colleagues. Figure 5.12 shows a post of a teacher who used the toolkit with her class during the evaluation study (presented in Chapter 6) and shared her experiences afterwards on Instagram. Hence, the toolkit website in combination with the social media account could contribute to an increased reach of the toolkit beyond our contacts and allow multiple uses of the toolkit materials at the same time. Furthermore, it allows an online exchange of the teachers’ experiences and peer support.

5.8 Summary

In this chapter, I have answered the research question “What makes it challenging to have sustainable PD practices and experiences in a school context?”, by exploring contextual challenges and constraints for a toolkit and PD practices in schools. I presented the results of the interview, the co-design workshop and the online survey and discussed how I addressed those challenges with the toolkit. This leads to the third research question I answered in this chapter: What does a toolkit need to contain to support teachers to evolve their own practice around technology and participatory design? By reflecting on the contextual challenges, and the sustainability targets and SPT enablers as presented in Chapter 4, I designed and iterated a toolkit prototype. The findings of the interview, the co-design workshop and the online survey were summarised as design implications for the final toolkit prototype. Finally, I have discussed the challenge of developing a ‘stand-alone’ toolkit in this particular context, and argued for adding a social network to the toolkit. I presented the final toolkit prototype, explored possible roles for a support network and how I facilitated a support network in the final prototype.

CHAPTER 6

Toolkit Evaluation

In the last chapter I reported the toolkit design process and how the toolkit has evolved. This chapter validates the socio-material tools designed for the toolkit and gives first insights into how teachers not involved in the initial SPT project could incorporate them in their own practice. I aim to explore if and how a toolkit could work as an approach to sustain SPT practices and experiences and how teachers not involved in the initial SPT project appropriate the toolkit to embed it into their own practice. This chapter answers the fourth research question: How can teachers not involved in the initial SPT project incorporate the toolkit into their own practice around technology and participatory design?

6.1 Research approach

To explore how teachers would appropriate the toolkit and plan to use it in class, and if it meets the design implications of teachers who were not involved in the initial SPT project, I conducted a two-phase online evaluation study. In the first phase, teachers were asked to plan a teaching unit and three lessons in which they use the toolkit. In the second phase, I conducted focus groups with the teachers to discuss their experiences planning with the toolkit. I also initiated a one-on-one semi-structured interview with

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1 After the final toolkit prototype was built and ready to share with teachers, I was facing severe restrictions related to the COVID-19 pandemic. Initially, I planned to share the toolkit in collaboration with a local stakeholder in Vienna, who organises technology and design workshops for children. I wanted to invite teachers to those workshops and explore opportunities for sharing the toolkit with the local network of the stakeholder. Unfortunately, they had to close for more than a year and a collaboration was no longer possible. Unfortunately, schools also had to close. To still be able to evaluate the toolkit, I conducted an online study with teachers who only needed to plan how to use the toolkit instead of actually using it with their class.

2 A teaching unit encompasses a number of lessons around a central topic (i.e. electricity). It describes for instance the learning aims of the unit, materials needed or topics of the lessons.
6. Toolkit Evaluation

Marie, who used the toolkit in her class, to gather first insights in how children react to the toolkit.

The aims of the evaluation are:

- To explore how teachers would integrate the toolkit in their class
- To compare lesson plans and understand differences and similarities
- To explore if and how teachers were able to appropriate and evolve the resources to make them fit their specific context
- To investigate possible challenges teachers experienced either during the planning or expect to happen during the activities

6.1.1 Participants

Teachers were recruited online, using the social media account set up for the toolkit and sending invitations via e-mail to student teachers in their last year of training. In total ten teachers and three student teachers responded to my invitation. They were informed about the study during a 15 minute zoom talk and could decide afterwards if they wanted to participate in the study. Four teachers declined directly to go further, their main reason for declining was the amount of time their participation would cost them. Three teachers dropped out after receiving the materials for the study. In total six teachers (all names changed), two student teachers and four teachers with at least five years of teaching experience, participated in the evaluation study (see Table 6.1). One teacher (Martha) dropped out after handing in the lesson plans.

6.1.2 Process

The research process covered two phases: In the first phase, to initially explore how teachers could integrate the toolkit in their class, and how they might appropriate the toolkit, teachers and teachers in training were asked to plan three lessons for a teaching unit to use the toolkit materials and organise technology design workshops with their class. The teachers had two weeks to write the plan and sent it back to me, either via e-mail or mail, when they finished. Six teachers handed in the lesson plans.

In the second phase of the study, after the participants handed in their lesson plans, two online focus groups were conducted with them and one one-on-one interview. Four

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3https://www.instagram.com/erfinderkiste.chulen/

4The three student teachers were in their final year with at least half a year of teaching experience and the ten teachers (who completed their training) had at least a year of teaching experience.

5Unfortunately no teachers specialised in teaching neurodivergent children responded to my invitation. I could thus not evaluate if the final toolkit concept meets the needs of neurodivergent children.

6One teacher explained in an e-mail that she had lesser time to spend on the study than expected due to new COVID-19 restrictions, the other two teachers did not give an explanation for dropping out.
6.1. Research approach

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Years of teaching</th>
<th>Discussion Setting</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marie</td>
<td>Primary school</td>
<td>5 years</td>
<td>Interview (I)</td>
</tr>
<tr>
<td>Nora</td>
<td>Primary school</td>
<td>7 years</td>
<td>Focus group 1 (F1)</td>
</tr>
<tr>
<td>Yasmin</td>
<td>Middle school</td>
<td>9 month</td>
<td>Focus group 1 (F1)</td>
</tr>
<tr>
<td>Klara</td>
<td>Primary school</td>
<td>7 years</td>
<td>Focus group 2 (F2)</td>
</tr>
<tr>
<td>Tamara</td>
<td>Middle school</td>
<td>9 month</td>
<td>Focus group 2 (F2)</td>
</tr>
<tr>
<td>Martha</td>
<td>Primary school</td>
<td>10 years</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.1: Overview of the participating teachers of the evaluation study who submitted lesson plans and a teaching unit (all names changed), discussion setting and duration.

teachers participated in the focus groups. The aim of the online focus groups was to explore how the teachers experienced working with the toolkit (at least for planning lessons), where they experienced challenges, and what went well. I also investigated if the toolkit met their needs and wishes, and if there were additional contextual restraints I was not aware of. Marie applied the lesson plans in class, the other participants were not able to use the toolkit or apply anything from the lesson plans in class. Hence, I conducted a semi-structured one-on-one interview with Marie to gather first insights into how children engaged with the toolkit. The interview and the focus groups were based on an interview guide and follow-up questions (see Appendix D 8.3.6).

6.1.3 Materials

The participating teachers were sent materials via mail and e-mail for the study: A digital and printed version of a teaching unit and lesson plan template, a set of littleBits, a consent form and a data protection declaration, and the link to the toolkit.

Lesson plan and teaching unit plan

The form for the lesson plan consisted of four parts (see Appendix D 8.3.6):

- A ‘what if scenario’, containing a background story with information about additional resources the teachers should imagine to have (i.e. access to FabLabs). They were asked to assume for the study that the COVID-19 pandemic is over.
- A couple of questions about themselves, i.e. what their expectations are, what their teaching experience is.
6. Toolkit Evaluation

- A template to plan a teaching unit, i.e. where they were asked to state the topic, materials they need.

- A template for the lesson plan, where they were asked to plan three lessons, including for instance social form and activities. The template is based on a template of the Pädagogische Hochschule in Vienna.

Toolkit

The toolkit was fully available online: [https://spttoolkit.wordpress.com](https://spttoolkit.wordpress.com). It consists of the handbook, the inventor diary, the cards and the videos. In addition to the tools on the website, the teachers received a link to a website where they could locate facilities who support technology design activities in their area.

littleBits

The teachers were sent a set of littleBits to give them an idea what kind of electronic components they could use to facilitate design activities.

Ethics

All participants received a printed and a digital version of a consent form (see Appendix D) they signed, and a digital version of the data protection declaration. During the analysis, their names were made anonymous and all information which could lead to an identification of their identities was removed.

6.1.4 Data Collection

The focus groups and the interview were conducted using zoom. The sessions were recorded and fully transcribed afterwards by me.

6.1.5 Data Analysis

This evaluation explores how teachers appropriate the toolkit in their own context. I aimed to get an in-depth understanding of the teachers’ practices and how they could evolve with the toolkit. The purpose of this evaluation was to inform the toolkit design process and forms the final iteration in this thesis.

To prepare the data for the analysis of the teaching unit and lesson plans, I made a table where I compared the answers from the teachers with each other (see Appendix D). In the table I summarized for instance what kind of materials the teachers planned to use for the lessons and which social forms they planned to choose for the activities. The

8 https://sphero.com/products/littlebits-at-home-learning-starter-kit?_pos=8&_sid=705de502e6_as=r
6.2 Results of the evaluation study

The overall feedback of the teachers was very positive and they reported many interesting suggestions for how they plan to use the toolkit and appropriate it for their own practice. I discuss here their experiences in terms of links to the curriculum, how they used the different tools, modularity of the toolkit, how the teachers re-framed the toolkit, the methodological approaches they plan to use, and how they connect and combine resources.

To give a first impression how the teachers have appropriated the toolkit, Table 6.2 illustrated the different topics they linked the toolkit to as stated in the teaching unit plans and lesson plans.

6.2.1 Choosing a topic for appropriating the toolkit

As the results from the teaching unit and lesson plans as summarised in Table 6.2 show, the focus and topics chosen by the teachers differed among the lesson plans. Marie and Yasmin focused only on teaching technologies and how electricity works and how electronic components can be connected with wires and batteries (a common topic in German and Austrian primary schools). Nora, Klara, Martha, Tamara and Yasmin scheduled at least one hour for idea creation and design activities. As suggested in the toolkit, they planned a couple of hours where the children first learn about technologies and explore the videos and technology cards. Tamara even wrote two plans, each encompassing three lessons. During the first three lessons the children were to learn about sensors and outputs, in the second plan they learned how to use them when designing their own technologies. She chose smart-textiles as a framing and the children would design their own smart-textiles, supported with tools from the toolkit. Klara focused on technologies...
Table 6.2: Overview of topics

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Topic</th>
<th>How appropriated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marie</td>
<td>Electricity</td>
<td>Children learn how electricity works, conducting their own experiments and present the results</td>
</tr>
<tr>
<td>Nora</td>
<td>Electricity &amp; Technologies</td>
<td>Children explore technologies in our daily life, then children design their own technologies</td>
</tr>
<tr>
<td>Yasmin</td>
<td>Cyborg</td>
<td>Children learn in the context of cyborgs about sensors and actuators, then design their own technologies.</td>
</tr>
<tr>
<td>Klara</td>
<td>Technologies in our daily life</td>
<td>Children explore technologies in their daily life, then plan their own technologies</td>
</tr>
<tr>
<td>Tamara</td>
<td>Experimenting with electricity &amp; designing e-textiles</td>
<td>Children first learn how to build electric circuits, then design their own e-textiles</td>
</tr>
<tr>
<td>Martha</td>
<td>Vehicles &amp; TÜV</td>
<td>Children learn about vehicle-related technologies, then design their own vehicles</td>
</tr>
</tbody>
</table>

in the daily lives of children, she wrote in the lesson plan a question the children should be able to answer at the end of the teaching unit: “Technology in our daily lives - where can I discover technical inventions and how do I use them in daily life? What would I like to invent and for what would I use this invention?” (Data source: Teaching unit). Martha chose vehicles as the topic for the teaching unit and would first teach the children about vehicle-related technologies (for instance, a motor) and TÜV criteria, and then the children would design their own vehicles. Yasmin chose cyborgs as framing for the teaching unit and design process, she added in the lesson plan a critical question for the children to discuss when engaging with this topic: “Who, or what, are humans or machines?” (Data source: teaching unit). For the final lesson, she planned a visit to external technology experts. Nora also planned to visit external experts, suggesting an excursion to an open lab. Klara chose the suggested inventor narrative to scaffold the design process.

The findings suggest that the flexibility of the toolkit enabled the teachers to use it for different topics, all related to technology and including design activities. The perspective on technology are stated differently by the teachers: Yasmin chose a critical stand towards technologies by aiming to explore the line between humans and machines, Klara aimed at an open exploration of existing technologies.

9The original statement in German is: “Technik im Alltag - Wo kann ich technische Erfindungen entdecken und wie nutze ich sie im Alltag? Was würde ich selbst gerne erfinden und wozu würde ich die Erfindung nutzen?”

10Short for German: Technischer überwachungsverein (Technical Inspection Association) a company from Germany and Austria that tests, inspects and certifies technical systems.

11The original statement in German is: “Was/wer ist Mensch oder Maschine?”
6.2. Results of the evaluation study

Table 6.3: Overview of topics from the curriculum linked to the toolkit

<table>
<thead>
<tr>
<th>Topic</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>2</td>
</tr>
<tr>
<td>Technologies in daily life of children</td>
<td>2</td>
</tr>
<tr>
<td>Natural phenomena</td>
<td>1</td>
</tr>
<tr>
<td>Sachunterricht (general studies)</td>
<td>1</td>
</tr>
<tr>
<td>Vehicles &amp; TüV</td>
<td>1</td>
</tr>
<tr>
<td>Physics curriculum</td>
<td>1</td>
</tr>
</tbody>
</table>

6.2.2 Finding links to the curriculum

As stated in Chapter 5, schools have rigid structures and teachers are bound to the school’s curricula. Hence, it is important that the toolkit can be linked to topics from the curriculum, otherwise it probably would not be used. The teachers were asked in the teaching unit plan to look for links between the toolkit and their school’s curriculum. During the focus groups and the interview we discussed this further. Table 6.3, which is based on the information stated by the teachers in the teaching unit plans, gives an overview of topics from the schools’ curricula which could be linked to the toolkit by the teachers.

In the teaching unit plans, the teachers were asked to motivate if and how the teaching unit they planned based on the toolkit would be in line with their school’s curriculum. Technology design, an important aspect of the toolkit, is not explicitly part of every schools’ curricula, but all teachers found links to related topics in the schools curricula. Yasmin elaborated in her teaching unit plan: “Technical and textile crafting, exploring -> technical working mechanisms and natural phenomena -> creative problem solving approaches.” [12] (Data source: teaching unit). This illustrates that Yasmin saw a strong link between the topics of the toolkit (exploring technology design processes, for instance) and problem-solving approaches, an important skill which is part of her school’s curriculum.

The teachers discussed in both focus groups that, at primary schools, subjects focus either on creative aspects (for instance art or crafting), or on knowledge generation (for instance ‘Sachunterricht’ [13]). As technology design is a multidisciplinary topic, the teacher chose to focus on one aspect (design or technology), depending on the subject they were teaching. Marie, who teaches ‘Sachunterricht’, suggested collaborating with a crafting teacher who could support her with the design aspects.

The middle school teachers taught the subject ‘Textil und technisches Werken’ which includes both textile and technical crafting. For them, both aspects of the toolkit met

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[12] The original statement in German is: “Technisches und Textiles werken; Erforschung -> Technische Prinzipien Phänomene verstehen; -> kreative Lösungsansätze bzw Lösungswege finden”

6. Toolkit Evaluation

their curriculum, as this quote from Tamara illustrates: “A lot from the toolkit meets the curriculum. In ‘Textil und technischen Werken’ (the subject Tamara is teaching) reflection is an important skill, which is repeatedly part of the toolkit’s activities. For instance, the presentation at the end or inventions, the children think for themselves. What are the technologies, what’s behind them? The toolkit covers everything.” [14] (Data source: F2).

As Table 6.3 and the feedback from the teachers during the interview and focus groups show, the teachers are able to link topics from their schools’ curriculum to the toolkit. This finding suggests that the toolkit could be used by teachers for different topics and covers parts of the curriculum for different schools (primary schools, high schools). To support teachers better with linking the toolkit to topics of their curriculum, Marie and Klara suggested to give concrete examples of activities for each subject (for instance a word map for learning technical terms). Yasmin highlighted that the toolkit could support children to engage in exploring problem-solving approaches.

6.2.3 Activities planned by the teachers using the different tools

The teachers stated in the lesson plans what kind of activities they would plan with the toolkit and which tools they would need for this activity. Table 6.4 shows for what kind of activity the teachers planned to use each tool (Activity) and how many teachers planned to use the tool (Number of teachers).

The handbook was read by all teachers as guidance on how they could use the toolkit, and considered to be helpful to structure the lessons. The lesson plans confirmed this: the teachers first introduce and let the children explore technologies, then they design their own technology and present them at the end. This finding suggests that the handbook supports the teachers to walk children through a design process. Tamara found the guiding questions especially helpful and would use them for multiple activities.

All teachers planned to use the inventor diary and would use it for several different activities. Supporting children with idea generation was the most commonly stated use for the diary, for instance as a place to draw/write down their ideas. Teachers also combined it with the technology cards and used it to match technologies, for instance sensors and actuators. Interestingly, Nora used the inventor diary as a narrative to discuss with the children why teamwork is important and that working in teams increases creativity.

The technology cards were the most planned to use card deck. The teachers extended the opportunities for using the technology cards. For example, two used them as ‘visual reminders’ for technologies or used the video belonging to the card. For the design trigger cards, one teacher suggested to use them to collect previous/existing knowledge about

6.2. Results of the evaluation study

Table 6.4: Overview of tools and how often they are used

<table>
<thead>
<tr>
<th>Tool</th>
<th>Number of teachers who used tool</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handbook</td>
<td>6</td>
<td>Guidance for using the toolkit, using questions to support children in the process (e.g. of idea generation, working mechanisms of sensors/output)</td>
</tr>
<tr>
<td>Inventor diary</td>
<td>6</td>
<td>Explaining children that group work leads to better inventions (compared to working on their own), pasting technology cards into diary, matching technologies, idea generation, brainstorm what to invent, agreeing on one concept within the group, drawing ideas, building prototypes of idea</td>
</tr>
<tr>
<td>Technology cards</td>
<td>5</td>
<td>Learning about technology, visual reminders of technology/videos, idea generation, brainstorm what to invent, finding examples of technology in their daily life</td>
</tr>
<tr>
<td>Theme cards</td>
<td>1</td>
<td>Idea generation, brainstorm what to invent</td>
</tr>
<tr>
<td>Design trigger cards</td>
<td>3</td>
<td>Playing ‘what-if’, idea generation, brainstorm what to invent, collecting previous knowledge</td>
</tr>
<tr>
<td>Videos</td>
<td>4</td>
<td>Exploring opportunities for sensors and outputs, learning about technologies</td>
</tr>
</tbody>
</table>

Four teachers planned to let the children watch the videos, mainly to learn about technologies and to explore how they are used.

The findings suggest that the teachers were able to plan diverse activities with the different tools. The theme cards were used only by one teacher. We discussed this in the focus groups, and a possible reason for that might be that most teachers considered that their pupils were either too old or too young for thought experiments with fantasy/sci-fi elements. Yasmin explained: “Exactly, my children are not open anymore for thought experiments.” [15] (Data source: F1). Another reason for this might be that the cards

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[15] The original quote in German is: “Ja genau, die (Kinder) lassen sich bei mir nicht mehr so schnell auf Phantasiereisen ein.”
were designed based on experiences with neurodivergent children, neurotypical children might prefer different themes.

6.2.4 Improving the tools

The overall feedback on the tools was positive, but the teachers mentioned suggestions for future development multiple times during the interview and the focus groups.

Overall, the teachers could plan their lessons based on the handbook, as this quote from Marie illustrates: “I could make use of everything in the handbook.”\(^{16}\) (Data source: I). In the second focus group, the teachers agreed that they would like to have instructions in the handbook about where they could buy technological resources (for instance electronic components) and how to assemble them, as their schools do not have those resources and the suggested resources in the toolkit; the littleBits were considered too expensive. They would prefer to buy cheaper resources and assemble them with written instructions.

In both focus groups and during the interview, we discussed the complexity of the inventor diary, because all teachers mentioned that they would not be able to use the whole diary. All agreed that the inventor diary consists of modular units they can use when needed, but the would not print the whole diary for the children. Marie and Nora concluded that the storytelling and fantasy aspects probably would not work for their class (first and second grade), because the children might be too young. Klara, on the other hand, thought that their first grades would enjoy them and probably would come up with great ideas.

The teachers valued that the diary offers a structure they can follow, as this quote from Tamara illustrates: “Matching technologies was very exiting (...). The visualisation of an idea was very important and you pick this up several times. The pupils draw something and discuss afterwards with the whole group: What are we going to make out of this? Those are our individual ideas, but what are we going to do as a group with them? This mix.”\(^{17}\) (Data source: F2).

During focus group two and the interview, the teachers explained that it would be better to have a two-sided master copy of the pdf materials as they need to print these several times, such as the cards, and then they only need to cut out and laminate.

For the videos, the teachers of the first focus group suggested to give more examples for how the technologies are used.

Interestingly, the teachers had diverse opinions about which content might be suited for the age of the children, but the findings suggest that the toolkit enabled them to

\(^{16}\) The original quote in German is: “Ich konnte eigentlich alles gebrauchen aus dem Handbuch.”

\(^{17}\) The original quote in German is: “Technologien zusammenlegen war für mich sehr spannend und hat mich gleich geweckt was zu machen. Das visualisieren einer Idee ist ja was voll wichtiges und du greifst das immer wieder auf, dass die Schüler was zeichnen sollen und dann in Kleingruppen sagen: Was machen wir aus dem Ganzen? Das sind zwar unsere einzelnen Ideen, aber was machen wir als Kleingruppe daraus? Dieser Mix.”
make their own choices about what and how to use it. They also had some practical recommendations on how to improve the usability of the toolkit, for instance how to design master copies.

6.2.5 Balancing modularity and structure

The topic of modularity was discussed in both focus groups and the interview and was addressed by the teachers in all cases. As the diverse use of tools already suggests, the teachers considered a flexible use of tools as important. All teachers agreed that the toolkit offers sufficient modularity, as this quote from Yasmin illustrates: “I think that the toolkit is designed in a way that you can pick things, but you also have the option to leave things out. You don not need to stick to the suggestions.”

The first modularity aspect, addressing different age groups, was considered as an important characteristic of the toolkit, like this quote from Nora illustrates: “I liked especially the fact that you did not need to use everything from the toolkit. I could pick something I consider suitable for my little pupils. They are able to fantasise, which technologies can be linked to which topic and how we can proceed based on a first idea and build it. But they cannot build complex things like children at middle school.”

On the other hand, middle school children might be less interested in fantasy and make-believe games, as Yasmin told us: “I believe that you can find something for every age (in the toolkit). I would not use some of the make-believe games because they might be less interested in it.”

The second modularity aspect discussed was the flexibility to appropriate tools of the toolkit and use them for different activities, as the quote from Yasmin illustrates: “I consider the adaptability (of the cards) and that you use the cards flexibly important. It’s important that you are not limited to use them only in certain ways.”

Table 6.6 supports this aspect as it shows that the teachers used the tools, for instance the technology cards, for multiple activities and aims.

The third modularity aspect discussed was the flexibility to use the toolkit within different time constraints. Depending on the subject or setting, the time teachers have to use the tools...
toolkit varies widely. With the second focus group, we discussed this modularity aspect and came to the conclusion, that if you would want to go through a whole design process with the children, teachers would need to have a project week or a similar setting where children can engage intensively over a short period of time with the toolkit. Otherwise, the findings suggest that the toolkit offers sufficient opportunities for ‘short-cuts’, by allowing teachers to only pick certain tools or to fit the design process in six to seven school periods of 45 minutes.

The fourth modularity aspect came out of the lesson plans. Teachers combined the toolkit materials with several topics from the curriculum or other topics related to technology design, for instance designing e-textiles or vehicles. While the toolkit suggests to let the children design technology ‘for the sake of inventing new technology’, without providing a specific setting or type of technology, the findings suggest that teachers were able to specify the design challenge based on a relevant topic of the curriculum (electricity was the most common one). The findings suggest that modularity is a very important characteristic of the toolkit and that it enabled the teachers to mix and match contents of the toolkit and to appropriate them to different age groups, time constraints, curricula or other specific needs of the teachers.

6.2.6 Methodological approaches appropriated by the teachers

The teachers were asked to state in their lesson plans what kind of ‘Sozialform’ they would apply in the lessons. One important aspect of the toolkit was that it supports teachers to set up a design process inspired by PD methodology and approaches, for instance, by suggesting to let children work in design teams, explore technologies collaboratively, negotiate ideas, agree on a concept and collaboratively build technology mock-ups. During the evaluation, I was particularly interested in how (and if) teachers would integrate the suggested methodological approaches in their lesson plans. Table 6.5 (based on the lesson plans) shows an overview of ‘Sozialformen’ and the frequency it was stated in the lesson plans.

The findings suggest that groupwork was indeed picked up and the most prominent Sozialform stated in the lesson plans (25), followed by discussions with the whole class (22). The handbook suggests indeed to alternate groupwork activities and plenum activities, to share results (for instance during presentations) or to discuss new knowledge learned within the groups. Nora described in her lesson plans how she would iterate individual- and groupwork with the “Think-Pair-Share Method”: “Each child thinks of ideas for topics and technology parts (...), then they talk with a teampartner and finally with all four members of the team. Based on all individual ideas they should develop one

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22The German term Sozialform describes the relational structures in class: The interactions between teachers and pupils, and activity (for instance teacher-centred teaching, group work) https://lehrerfortbildung-bw.de/u_mks/sport/gym/bp2004/fb2/03_kriterien/04_meth/01_hand/3_sozial/
Table 6.5: Overview of Sozialformen and frequency used in lesson plans

<table>
<thead>
<tr>
<th>Sozialform</th>
<th>Number occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhibition</td>
<td>1</td>
</tr>
<tr>
<td>Single child working</td>
<td>8</td>
</tr>
<tr>
<td>Excursion</td>
<td>2</td>
</tr>
<tr>
<td>Experiment</td>
<td>1</td>
</tr>
<tr>
<td>Teacher-centred teaching</td>
<td>5</td>
</tr>
<tr>
<td>Groupwork</td>
<td>25</td>
</tr>
<tr>
<td>Cinema chair</td>
<td>4</td>
</tr>
<tr>
<td>Discussion with whole class led by teacher</td>
<td>22</td>
</tr>
<tr>
<td>Teamwork</td>
<td>6</td>
</tr>
<tr>
<td>Presentation</td>
<td>6</td>
</tr>
<tr>
<td>Seat circle</td>
<td>7</td>
</tr>
<tr>
<td>Think-Pair-Share method</td>
<td>1</td>
</tr>
<tr>
<td>Children give a talk</td>
<td>1</td>
</tr>
</tbody>
</table>

1 'Kinositz’ (cinema chair): children think for themselves
2 Children are seated in a circle, the teacher is leading the discussion
3 First one, then two children, then the whole group work together

shared aim. *The inventor teams present their ideas (...).* [Data source: lesson plan]. This elaboration on the method from Nora shows how she imagined that children could collaboratively negotiate ideas, first with a peer, than with the whole team, and finally they present the chosen idea(s) as a team. Tamara was especially enthusiastic about the dynamics supported by group activities, as this quote from her illustrates: “*Matching technologies was very exciting (...). The visualisation of an idea was very important and you pick this up several times. The pupils draw something and discuss afterwards with the whole group: What are we going to make out of this? Those are our individual ideas, but what are we going to do as a group with them?*” [Data source: F2].

Next to the suggested Sozialformen in the handbook, the teachers brought up new Sozialformen in their lesson plans: Klara planned an exhibition for the final lesson, where the children should present their designed inventions to their parents and other children from school. She explicitly stated in the lesson plan that the children are the experts of their inventions: “*Pupils are experts of their inventions. Pupils are available*” [23]

[23] The original statement in German is: “Einzeln überlegt jedes Kind eigene Ideen für Themen, aber auch Technologiebestandteile (...), sprechen dann mit einem Partner aus dem eigenen Team und anschließend mit allen vier Teammitgliedern. Aus allen Einzelideen soll nun ein gemeinsames Ziel werden. Die Forscherteams präsentieren jeweils (...) ihre eigenen Ideen (...)”

[24] The original quote in German is: “Technologien zusammenlegen war für mich sehr spannend und gleich geweckt was zu machen. Das visualisieren einer Idee ist ja was voll wichtiges und du greift das immer wieder auf, dass die Schüler was zeichnen sollen und dann in Kleingruppen sagen: Was machen wir aus dem ganzen? Das sind zwar unsere einzelnen Ideen, aber was machen wir als Kleingruppe daraus? Dieser Mix.”
for answering questions. Visitors walk through the expedition and ask questions and get in touch with the inventors.”

Nora and Yasmin planned an excursion with their class: Nora wanted to go to an open lab and Yasmin wanted to go to a FabLab. During the focus group, Yasmin elaborated on her choice to visit a FabLab: “If there is a teacher standing in front of the children, it is a teacher. But if we visit a place and use machines, children are very proud.”

Yasmin mentioned in her lesson plan, that the children should explore the technologies on their own by watching the videos: “Teachers are prepared to assist the pupils, while the pupils explore (the videos) autonomously.” She frames the lesson in a way that pupils become scientists and embed their invention into a narrative (related to cyborgs). Other teachers used the videos as well as an opportunity for children to explore technologies without a teacher explaining it.

The findings suggest that the role of teacher is a supporting one: The children explore technologies, generate and negotiate their own ideas and discuss either in class or within their design teams. The teacher leads discussions (for instance with guiding questions) in case that the whole class is involved in the discussions. This approach is in line with the PD inspired approach we choose in our project, to enable children to design their own technologies in mixed groups of children while being supported by the researchers.

6.2.7 Connecting and combining existing resources with the toolkit

One aspect of the lesson plan was to explore how teachers would combine the toolkit with existing resources they have previously worked with, or have at their schools. Table 6.6 (based on the lesson plans) gives an overview of the different resources the teachers planned to use in combination with the toolkit.

Marie made her own worksheets based on the technology cards (see Figure 6.1 and Figure 6.2) she used to help the children distinguish between sensors and outputs.

As Table 6.6 shows, the teachers planned to use a diverse range of different resources when working with the toolkit and planned to combine no-tech crafting materials with electronic components. These findings indicate that a digital toolkit can be indeed
### Table 6.6: Overview of resources combined with the toolkit

<table>
<thead>
<tr>
<th>Category</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crafting materials</td>
<td>Buttons, fabrics, felt, glue, needles, paper, pencils, threads</td>
</tr>
<tr>
<td>Digital devices</td>
<td>Laptops, tablets</td>
</tr>
<tr>
<td>Digital materials</td>
<td>Movie showing examples for sensors without explanation, movie showing how to attach a battery to an LED, 'Get to know your Bits’ video</td>
</tr>
<tr>
<td>Electrical components</td>
<td>Alligator clamps, batteries, LEDs, magnets, piezo elements, ventilators, vibration sensors, wires</td>
</tr>
<tr>
<td>Machines</td>
<td>Sewing machine</td>
</tr>
<tr>
<td>Natural materials</td>
<td>Bast, wooden sticks, wood, stones, lemon</td>
</tr>
<tr>
<td>Pictures</td>
<td>of vehicles</td>
</tr>
<tr>
<td>Tools</td>
<td>Saw, screwdriver</td>
</tr>
<tr>
<td>Other toolkits</td>
<td>Technikdetektive, Heißer Draht, littleBits, Electricity-technology toolkit</td>
</tr>
<tr>
<td>Other worksheets</td>
<td>TÜV criteria, sensor-output (see Figure 6.1, littleBits, Schaltkreis mit Servomotor 6.2), electric circuit, circuit with servomotor, functions of littleBits</td>
</tr>
<tr>
<td>Waste</td>
<td>Old boxes, beermats, bottles, crown caps</td>
</tr>
</tbody>
</table>

**Figure 6.1:** First worksheet from Marie, showing sensors output.

**Figure 6.2:** Second worksheet from Marie, showing sensors output.
6. **Toolkit Evaluation**

Table 6.7: Overview of different opportunities for collaborations mentioned by the teachers in the lesson plans, interview and focus groups. If the collaboration is mentioned by the same teacher in the lesson plan/interview/focus group, it counts as “1”.

<table>
<thead>
<tr>
<th>Collaboration</th>
<th>Teachers mention collab.</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>External experts visit schools</td>
<td>2</td>
<td>focus group</td>
</tr>
<tr>
<td>FabLab/Makerspace</td>
<td>3</td>
<td>Lesson plan, interview, focus group</td>
</tr>
<tr>
<td>Hackerspace</td>
<td>1</td>
<td>Lesson plan</td>
</tr>
<tr>
<td>Local tech experts (e.g. electricians)</td>
<td>1</td>
<td>Lesson plan, focus group</td>
</tr>
<tr>
<td>Open lab</td>
<td>1</td>
<td>Lesson plan</td>
</tr>
<tr>
<td>Parents</td>
<td>1</td>
<td>Focus group</td>
</tr>
<tr>
<td>Peer support</td>
<td>1</td>
<td>Focus group</td>
</tr>
<tr>
<td>Academy offering scholarships for outstanding students</td>
<td>1</td>
<td>Lesson plan</td>
</tr>
<tr>
<td>Tech company</td>
<td>1</td>
<td>Lesson plan, focus group</td>
</tr>
<tr>
<td>Tech lab</td>
<td>1</td>
<td>Lesson plan</td>
</tr>
<tr>
<td>Technology/Art museum</td>
<td>3</td>
<td>Lesson plan, interview, focus group</td>
</tr>
<tr>
<td>University</td>
<td>1</td>
<td>Lesson plan, interview</td>
</tr>
</tbody>
</table>

sufficient and might allow the teachers to combine different resources available to them. They also suggest that teachers built upon the idea of combining diverse materials to enable children to engage in design activities and that they were sufficiently informed by the toolkit to choose those materials.

### 6.3 Opportunities for a support network

As part of the lesson plan the teachers were asked to state opportunities for collaborations when using the toolkit. During the focus groups and the interview we discussed their suggestions for collaborations and were looking for alternative opportunities. As mentioned in Section 6.2.6, two teachers planned an excursion to external experts (an open lab and a FabLab).

Table [6.7](#) shows all suggestions of the teachers from the lesson plans and the focus groups/interview. The majority of the suggested opportunities for collaborations are technology experts who could support teachers with technical knowledge, skills or access to technological resources.

During the interview and both focus groups, the teachers critically discussed the feasibility of the different opportunities for collaborations. Marie and Nora teach at schools in a rural area and could not locate any FabLabs, open labs or museums close to their schools.
Nora told us, that in case that they wanted to do an excursion, they would need parents driving the children to the location. The second challenge of an excursion which was mentioned in the first focus group is the time it requires for the class to travel to the location. They concluded that, usually, an excursion would be too much effort.

In the first focus group, Nora and Yasmin suggested to invite experts to the school, instead of visiting them. Nora told us about a previous programming project at her former school, where a parent from a company and University students visited her school to teach special after school classes. However, this was only possible because of a dedicated parent, a technology company close to the school and a University supporting the project. Yasmin told us of a toolkit called “Blinkenrocket”\(^{28}\), a programmable soldering kit developed for children. The designer of the toolkit can be hired by schools to give soldering and programming workshops, using the rocket toolkit.

Another possibility for collaborations is peer support. In the first focus group, Klara mentioned that they have a 3D printer in school that nobody uses, except for one teacher. She realised that talking to this teacher might be an opportunity for her to learn more about 3D printing and how to use it in class. During the interview, Marie suggested a similar idea: She could collaborate with another teacher from her school on a project where they use the toolkit, for instance someone who teaches crafting. Later, Marie discussed another opportunity for peer-support indirectly: She mentioned that she would like to see more examples for activities showing how to use the toolkit. Marie is designing her own teaching materials and shares them digitally with other teachers, using a teacher community for digital teaching materials\(^{29}\). She also made a worksheet for her class when using the toolkit (see Figure 6.1 and Figure 6.2). Nora and Karla on the other hand were recruited via social media, while they were looking for teaching materials or inspiration for new materials. Hence, teacher communities, either on social media or other platforms, could be promising peer support opportunities to share experiences and materials, or to look for support when planning to use the toolkit.

The findings suggest that teachers are aware of different opportunities for collaborations, but they question the feasibility of an excursion. The teachers who have opportunities for collaborations close to their schools, seem to consider an excursion as a feasible and useful opportunity for children to engage with technology and experts, as two teachers stated in their lesson plans that they plan to do an excursion with their class. For schools in rural areas, inviting experts or dedicated parents to support technology design workshops might be a promising way to look into.

Feasible opportunities for collaborations are peer support, which could happen online by sharing worksheets or plannings, or local peer support, by asking colleagues for support or working together on a project using the toolkit.

\(^{28}\) http://blinkenrocket.de/index.en.html
\(^{29}\) https://eduki.com/de
6. Toolkit Evaluation

6.4 Revisiting design implications

I presented in Table 5.4 the design implications the toolkit is based on. In the interview and the focus groups, I aimed to explore if the toolkit meets the design implications, and if the teachers involved in the evaluation study bring forward new design implications. The results mainly draw from the findings of the interview and the focus groups.

6.4.1 Previous design implications

First, I present the previously defined design implications and reflect upon which design implications were met, and which design implications need adjustment. Then, I present new design implications resulting from the evaluation study. The final list of design implications is shown in Table 6.8.

During the interview and the focus groups, I asked the teachers to describe the effort it took them to prepare the lesson plans and to compare the time they needed with the time they usually need to prepare lesson. For Marie, the effort it took her to prepare the lessons (she actually taught) was similar to the effort it usually takes her to prepare: “It was the usual effort, the same as for every Sachunterricht hour. Two to three hours (...).” [30] (Data source: I). Yara and Nora both enjoyed engaging with the toolkit so they did not keep track of the time. On the one hand, they were worried that other teachers would consider it too much effort to engage with the toolkit, because of its openness. It does not provide rigid structures, the teachers can pick tools they would like to use. This requires time. On the other hand, the toolkit can be used for multiple teaching units or classes. Considering this fact, the effort it takes to prepare the lessons is actually low.

The findings suggest that the toolkit does require some effort to engage with the different tools, and its openness and modularity invites teachers to make choices about which tools they want to use, adapting tools and combining them with existing tools. However, once they have invested this time once, they can re-use the toolkit for multiple teaching units and classes, and may allow them to reduce preparation time for the following lessons.

The teachers who participated in the evaluation study had low to no experiences with technologies. Yasmin and Tamara both studied at an Art University, where they had a couple of classes about technology, and considered themselves to have a little experience with technology-related topics and design. The other teachers had no experience with technology design processes or teaching new technologies in general.

During the interview and the focus groups, I asked the teachers how challenging they experienced the technological content of the toolkit and if they would prefer more, or less technological content. All teachers reported that the technological tools were understandable and they consider them to be understandable for children, as this quote

[30]The original quote in German is: “Das war der ganz normale Arbeitsaufwand wie für jede andere Sachunterricht Stunde. Zwei bis drei Stunden ungefähr, auf jeden Fall in dem Raum, wo ich normalerweise auch arbeite.”
from Marie illustrates: “Well yes, you could definitely understand it and in combination with the handbook for other teachers and me logical and explainable.” [31] (Data source. I).

The lesson plans reflect those findings, as the teachers seemed to feel comfortable about using the technology related tools (cards and videos) for their lesson plans.

When discussing the brief information for teachers in the second focus group, Klara suggested adding optional information for teachers who would like to build their own electronics and where to buy the components. Tamara agreed that, despite her previously mentioned lack of technology skills, she would build her own electronics if the toolkit would contain instructions, as this quote illustrates: “When I have instructions, I am on board!” [32] (Data source: F2).

In the interview, Marie suggested adding more examples of how to use the toolkit in different subjects, for instance, with mindmaps or ‘Dosendiktats’ [33]. Based on those examples, the teachers could evolve their current practices more easily around the toolkit and reduce their preparation time. This suggestion was echoed in the first focus group, where the teachers asked for more examples of how to use the toolkit in different subjects.

The findings suggest that the brief information provided in the toolkit is good as an overview and as mentioned in Section 6.2.4, the teachers felt sufficiently informed to use the toolkit. However, more detailed optional information about certain topics would be helpful for them, for instance instructions on how to build and connect electronic components or detailed examples for specific subjects. Hence, I refine this design implications to: ‘Only brief information for teachers as an overview’ and add a new design implications: ‘Provide additional, detailed information’. As reported in Section 6.2.5, all teachers highlight the importance of modular and short units they can choose from and adapt, to embed them in their curriculum and time schedule. In the second focus group, the teachers discussed that there are also teachers who would probably prefer a more rigid structure, with planning they can follow closely, because they are less interested in the topic and do not want to engage with the toolkit. This could be for instance examples of activities or instructions for how to use the toolkit in different subjects, as discussed in the first focus group.

These findings support the importance of short and modular activity units, but additional, well structured information (for instance examples for activities for different subjects) might be necessary to support teachers who do not want to invest time in picking activities. This leads to a new design implication: ‘Structured examples of activities for different subjects.’

One of the main challenges in the school context was the lack of financial resources. Thus, a free toolkit is an important design implication. This was echoed in the second focus

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31 The original quote in German is: “Ja eigentlich schon, man hat es auf jeden Fall verstanden und mit dem Handbuch für die Lehrer für mich persönlich auch logisch und erklärbar.”
32 The original quote in German is: “Wenn ich eine Anleitung habe, bin ich dabei!”
33 Dictation method: A text is cut into pieces (either on a sentence level or single words) and the children have to puzzle the text back together.
group, Klara explained that the school administration would need to agree to buy the toolkit in case that they would not be free. Theresa stated that she probably would not have bought the toolkit, because it requires effort and time to engage with the tools, adapting them to the specific curriculum, subject and time schedule.

In the second focus group we discussed the opportunities for combining a free toolkit with recommendations for additional tools, or services, to buy. Klara considered the littleBits as too expensive, she would prefer instructions about where to buy simple electronic components she can use to build her own electronics: “Those littleBits are very expensive, but easy in use. The children would not need to screw, but I can imagine that there are cheaper alternatives which might be more complicated to assemble.” [34] (Data source: F2). She stated that it is important that children need a certain number of parts so they are not getting bored when waiting for their turn. The findings suggest that the teachers are happy with a free toolkit and that they are more likely to spend time and effort to use and appropriate tools when it is free.

Marie, Nora and Karla were recruited via social media, while they were looking for teaching materials or inspiration for new materials. An increasing number of teachers share their teaching materials with online teacher communities, as Marie told me. Hence, a toolkit which is digitally available can be shared via those communities, supporting this design implication.

The aspect of matching activities with the curriculum was previously discussed in Section [6.2.2] as the teachers repeatedly mentioned the importance of being able to match toolkit activities with their curriculum and topics. The findings suggest that it is not only important to include activities or tools with exactly match the curriculum, but to provide activities or tools that that can be appropriated by the teachers and used to teach topics of different curricula or subjects. Hence, I refine this design implication to: ‘Activities match curriculum or can be appropriated’.

All teachers agreed that the current examples in the videos or on the cards match children’s lifeworlds sufficiently. In the second focus group Nora and Yasmine discussed how close examples should match children’s lifeworld. Nora: “I want to use the children’s lifeworld as starting point, and the technologies they are familiar with. I do not want to stay there, but moving forward (towards designing new technologies). So I think it’s (the technology examples) appropriate the way it is now.” [35] (Data source: F1).

This quote illustrates that the technology examples should be part of the children’s lifeworld, but not too close, so that they can move beyond the technologies they are familiar with and explore new opportunities for technologies. This relates to Vygotsky’s

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34The original quote in German is: “Diese littleBits sind ja sehr teuer. Natürlich auch praktisch in der Anwendung, dann brauchen die Kinder da nicht lang herumschrauben, aber ich könnte mir vorstellen, dass es auch viel günstigere gibt die aber auch ein bisschen komplizierter zum zusammenbauen sind.”

35The original quote in German was: “Ich möchte die Kinder schon da abholen wo sie sind und was ihrer Lebenswelt, auch die Technik mit einfließen lassen. Aber ich möchte sie ja auch nicht dahin kriegen, dass sie nur weiterhin mit diesen Kinder Sachen umgehen, ich möchte ja auch einen Schritt weiter gehen. Deswegen finde ich das eigentlich ganz angemessen.”
6.5 Summary

Reflecting on the aims I formulated in Chapter 4, where I listed sustainability targets of the SPT project and enablers that could support children in the project and were transferred into toolkit enablers in Chapter 5, my initial findings of the evaluation show first steps towards teachers evolving their practices upon those enablers. Teachers who were not involved in the initial SPT project were able to plan how to integrate the toolkit in their own practice, their lesson plans showed that they would use:

[1978] theory of Zone of Proximal Development (ZPD), which argues that children need experiences within their zones of proximal development and by thus, they are encouraged to build upon existing knowledge and improve it.

As previously presented in Section 6.3, the teachers reacted with mixed feelings on the suggestion to **collaborate with external experts** and the available opportunities for accessing experts differ dependent on the school’s location. However, we explored the opportunity for inviting external people to the schools (instead of visiting them) and Tamara emphasised the motivating effect of external experts on children.

Hence, the design implication is updated to: ‘Local support or suggestions for visiting experts.’

**6.4.2 New design implications**

After re-visiting and updating the previous list of design implications, I add two new design implications to the list which came out of the interview and focus group: Adaptable and flexible tools, and an online forum for peer support.

**Adaptable and flexible tools** As the findings presented in Section 6.2.5 suggest, teachers require tools which are flexible enough to be adapted to the specific needs of their pupils (for instance to address different age groups) or to use the toolkit with different time constraints (for instance during a project week or within a limited number of lessons). This is different to modular units (a collection of units the teachers can choose from based on their available time), as it highlights the flexibility of the unit and tools itself in terms of content, methods or examples for activities suggested. This allows teachers to evolve the tools to embed them in their own practice.

**Online forum for peer support** As the findings presented in Section 6.3 suggest, teachers would like to share examples of what they did with the toolkit and would like to see examples from other teachers using the toolkit. For sharing their teaching materials and looking for new inspiration, they are currently using social media or online platforms for teachers, but an online forum included in the toolkit (as part of the website, for instance) could offer the opportunity to share and find teaching materials related specifically to the toolkit.
<table>
<thead>
<tr>
<th>Design implication</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Little effort for teachers to prepare activities</td>
<td>interview, workshop, survey, interview, focus group</td>
</tr>
<tr>
<td>2. Materials designed for teachers who have no/little experiences with technology</td>
<td>interview, workshop, survey, focus group</td>
</tr>
<tr>
<td>3. Only brief information for teachers</td>
<td>interview, workshop, focus group</td>
</tr>
<tr>
<td>4. Additional, detailed information</td>
<td>interview, focus group</td>
</tr>
<tr>
<td>5. Short and modular activity units</td>
<td>workshop, survey, interview, focus group</td>
</tr>
<tr>
<td>6. Structured examples of activities for different subjects</td>
<td>interview, focus group</td>
</tr>
<tr>
<td>7. Adaptable and flexible tools</td>
<td>focus groups</td>
</tr>
<tr>
<td>8. Free toolkit</td>
<td>interview, workshop, interview, focus group</td>
</tr>
<tr>
<td>9. Toolkit digital available</td>
<td>workshop, interview, focus group</td>
</tr>
<tr>
<td>10. Activities match curriculum or can be appropriated</td>
<td>workshop, interview, focus group</td>
</tr>
<tr>
<td>11. Technology examples match children’s lifeworld</td>
<td>interview, survey, focus group</td>
</tr>
<tr>
<td>12. Local support or suggestions for visiting experts. (i.e. FabLabs, Makerspaces)</td>
<td>survey, interview, focus group</td>
</tr>
<tr>
<td>13. Online forum for peer support</td>
<td>interview</td>
</tr>
</tbody>
</table>

Table 6.8: Overview of final design implications.
6.5. Summary

1. Methodological approaches which reflect PD practices (children lead process, teachers support, children form design teams and are the experts of their projects).

2. Methodological approaches which empower children to organise their own design project, the teacher supports the process but with focus on child-centred teaching, more discussions among children (guided by teachers).

3. Methodological approaches which support diverse roles of technology: starting from the children’s lifeworlds, children design their ‘own’ technology, in totally different areas for technology suggested by the teachers (vehicles, smart textiles...)

4. Diverse local materials in combination with the toolkit, this is for future work: teachers want to have instructions where to buy/how to build electronic components.

Furthermore, the findings indicate that the design implications formulated in Chapter 5 are confirmed by the teachers involved in the evaluation study.

Hence, the initial evaluation suggests that a toolkit is a suitable approach to sustain SPT practices and experiences for teachers and children not involved in the initial project.
In the previous chapter I presented the findings from the evaluation of the toolkit and explored how the teachers incorporated the toolkit into their own practice around technology and participatory design.

In this chapter I discuss implications for future research and opportunities for sustaining practices and experiences of PD projects in a school context. I reflect upon the lessons I learned during the design process of the toolkit and compare the results of the evaluation study with what we initially aimed to sustain within the toolkit. The aim of this chapter is to inform future PD projects in a school context how to support sustainable PD practices and experiences for participating teachers and teachers and children not involved in the initial project.

In the first part of this chapter I reflect upon the results of the evaluation study. I discuss which enablers I transferred from the SPT project (which enabled children in the SPT project to engage in technology design activities) into enablers in the toolkit (which support teachers to enable children to engage in technology design activities) were sustained, and which enablers were challenging to sustain. In the second part of the discussion, I reflect on infrastructuring as conceptual lens when developing a toolkit and aiming for sustained PD practices and experiences and how researchers in the future might benefit from using infrastructuring as lens. In the third and final part of the discussion, I present the six considerations for PD practitioners who aim to sustain practices and experiences of their project.

This chapter answers the main research question:

*How can we increase the likelihood that the positive experiences and practices of PD projects in a school context are sustained for teachers participating in the project and teachers and children not involved in the initial project?*
7. Discussion

7.1 Reflecting on the evaluation - how the toolkit sustained enablers of a PD project

After the SPT project ended, I analysed the positive experiences of the children involved in the SPT project and defined sustainability targets and enablers, experiences and practices we aim to sustain for teachers and children not involved in the initial SPT project. To approach this aim, I developed in collaboration with teachers a toolkit, which could support teachers in the future to facilitate technology design workshops with children. The tools are based on the enablers (SPT practices which enabled children to engage in technology design activities in the SPT project) as defined in Chapter 4 and transferred in Chapter 5 into enablers in the toolkit. Now I reflect upon the results of the evaluation to analyse how teachers applied the enablers. Evaluating long term use of this toolkit lies beyond the scope of this thesis and I cannot claim that the sustainability targets from the SPT project have been sustained yet, or will be sustained in the future. The evaluations gave first insights into how a toolkit might help to sustain experiences and practices of a PD project for audiences not involved in the initial project by illustrating how teachers planned to evolve their practices around the toolkit and the enablers. The results of the evaluation showed that the teachers were able to appropriate the different tools, suggested ideas for facilitating technology design activities based on methods and guidelines in line with a PD approach. Here, I first reflect upon the toolkit approach in general as pathway to increase the likelihood of sustaining practices and experiences of a PD project for teachers involved in the project and similar audiences not involved in the initial project. Second, I discuss the implementation of the enablers in the toolkit and third the challenges I experienced when aiming to transfer enablers from a PD project into enablers in a toolkit for teachers.

7.1.1 Positioning the toolkit approach as pathway to sustain experiences and practices of PD projects

As elaborated in Section 2.2, the topics of sustainability and democratizing technologies have always been a concern in the field of PD. Starting with the empowerment of workers in technology production processes and decision making processes (Bjerknes & Bratteteig, 1995), PD practitioners later aimed to sustain learning outcomes of PD projects to support audiences not involved in the initial PD project (Bjerknes et al., 1987). Clement and van den Besselaar (1993) argued for scaling PD practices within the organizations in which the initial PD project took place so new audiences could learn of the advantages of PD practices and are motivated eventually to apply similar practices in their own department. A toolkit approach connects to those efforts by providing a collection of resources to support audiences not involved in the initial project (and audiences who are not familiar with PD) to evolve their practices around PD practices.

\[\text{1}\] I suggest in Chapter 8 to evaluate the toolkit with teachers and children in schools to be able to determine that a toolkit can be an approach to sustain positive experiences and practices of a PD project.
After starting to explore what kind of educational resources would need to be included in a toolkit to sustain PD practices and experiences in a school context, it became apparent that a ‘stand-alone’ toolkit would not be able to sustain PD practices and experiences in a school context. As argued in Section 5.6, a support network might be necessary to support teachers with facilitating technology design processes with children. A support network could also support democratising technologies in schools which often lack access to new technologies or the funding to buy technologies. The toolkit developed in this research also differs from existing PD toolkits (for instance [Skinner 2020]) or educational resources for PD (for instance [Bjerknes et al. 1987]) in terms of ‘translating’ and adapting PD methods into educational materials which are tangled to the school context and needs of teachers. To ensure that the practices suggested in the toolkit meet the contextual needs and are feasible to implement by teachers, I co-designed the toolkit with teachers and iteratively asked for their feedback on the toolkit parts. Hence, the intended audiences (teachers involved and not involved in the initial project) were actively participating in creating those educational resources. In the next section I further elaborate how the toolkit approach could support sustaining experiences and practices of PD projects and which challenges and drawbacks a toolkit approach holds in a school context.

7.1.2 Reflecting on the toolkit approach as pathway to sustain experiences and practices of the SPT project

This thesis sets out to explore how can we increase the likelihood that the positive experiences and practices of PD projects in a school context are sustained. Especially in PD with children, many of the practices that are established during PD interventions are not carried on after the initial project ends. PD projects with children often take place in schools and practices of teachers are influenced by their respective schools’ and policy-makers’ setting and constraints. Related work (see Chapter 2) showed that PD practices are not always in line with the inherent power imbalances between teachers and children, but that teachers felt inspired by their participation to evolve their practices around PD and technology design activities. In Chapter 5 I uncovered additional challenges and constraints a school context holds for researchers when aiming to sustain their practices and experiences: Teachers have limited resources to facilitate technology design activities (for instance insufficient funding to buy materials or time to learn new skills related to technology design) and the rigid structures of a school context influence their opportunities to evolve their practices (for instance the curriculum their practices need to meet).

To address the contextual challenges and constraints and to increase the likelihood that the positive experiences of the SPT project (the sustainability targets) and SPT practices (the enablers) are sustained, I explored a toolkit approach: I co-designed a toolkit with teachers, based on the enablers of the SPT project (see Chapter 4), which could remain in use by the teachers beyond the project’s end. I motivated my choice for a toolkit approach based on Ledo et al. [2018], who evaluated HCI toolkits and concluded that...
developing toolkits can be a strong approach to empowering new audiences. A toolkit which combines social- material resources could also support replication and scaling of PD practices and experiences and enable participants to maintain and evolve practices by integrating them with/adapting them to their current practices and infrastructures.

To explore if the toolkit I developed in this thesis led to those aims, and if a toolkit approach could be an answer to the main research question of this thesis, I reflect on the results of the evaluation study (see Chapter 6). The findings show that teachers who were not previously engaged in the SPT project or any PD projects, and had no specific skills in teaching technology design processes, were able to evolve their practices around the toolkit. Hence, the toolkit succeeded in empowering new audiences. This argument is further illustrated in Section 7.3.5, when discussing the considerations for future PD practice. The toolkit also aimed for replication and scaling of sustainability targets beyond the project’s end. As previously discussed, I cannot evaluate if the toolkit approach succeeded in replicating and scaling sustainability targets of the SPT project. However, the findings from the design process and the evaluation indicate that a toolkit can support replication and scaling by giving teachers methodological guidelines and structures based on the enablers of the SPT project. To enable replicating and scaling processes, it was crucial for the teachers that the toolkit was flexible and modular to support appropriation of teachers to their particular school’s setting. The results from the evaluation showed that teachers evolved the toolkit and the SPT practices to embed them in their own teaching practices. Hence, a toolkit might be a suitable approach to enable replication, evolving and scaling of PD practices, when being open enough to be used in other settings with different contextual challenges and constraints. As discussed in Chapter 5, I focused during the toolkit design process in particular on supporting integration processes with current teaching practices and infrastructures, to enable teachers to maintain SPT practices. The toolkit supported the integration of PD and technology design processes with the schools’ practices and infrastructures, by combining the teachers’ perspectives and schools’ characteristics with the enablers from the SPT project. The findings from the evaluation indicate that the teachers were able to integrate PD processes in their practices, as for instance the overview of methodological approaches appropriated by teachers (see Section 6.2.6) showed. Based on those results, a toolkit might be also be a suitable approach to enable maintaining PD practices in the schools involved in the initial project.

Hence, a toolkit approach increased the likelihood that the positive experiences and practices of the SPT project are sustained for teachers involved in the project and children and teachers not involved in the initial project. Next, I discuss in detail how the toolkit supported the implementation of the enablers.

7.1.3 Reflecting on the implementation of the enablers by the teachers

In Chapter 5 I presented seven toolkit enablers to sustain the sustainability targets of the SPT project (see Figure 7.1), to support teachers to enable children’s participation in designing technologies:
7.1. Reflecting on the evaluation - how the toolkit sustained enablers of a PD project

Figure 7.1: Transformation of sustainability targets into enablers in the toolkit.

1. Suggestions for methods & approaches based on PD
2. Guidelines for structuring design processes
3. Focus on groupwork and discussions led by children
4. Inventor narrative
7. Discussion

5. ‘What-if’ games

6. Technology samples children can engage with without support from teachers

7. Support network (experts & peer support)

Reflecting on the findings from the evaluation study, I discuss how each toolkit enabler was incorporated by the teachers in their teaching practice.

In summary, all teachers were able to plan technology design activities based on the toolkit. Interestingly, they suggested very diverse approaches, methodologically or related to the topics they combined with the toolkit, for instance.

The first toolkit enabler - suggestions for methods & approaches based on PD, aimed to support teachers to structure design activities and guide children through the process. Technology design activities are not part of the school’s curricula of the teachers involved in this research yet, as stated by all teachers who participated in the studies. Teachers also stated during the first interview, that they lack technical skills and knowledge to be able to support children in developing technical concepts. Hence, this toolkit enabler was a crucial element in the toolkit.

As related work illustrated, PD offers different methods and approaches to support children in design processes and such methods have been frequently used in the past to engage children in design projects (see for instance (Frauenberger, Makhaeva & Spiel 2016; Frauenberger et al. 2020; Wilson et al. 2018; Druin 1999)). Building upon these manifold experiences in involving children in design processes, PD methods and approaches formed the groundwork of the toolkit. The findings of the evaluation show that teachers planned to apply suggestions for PD methods and approaches made for instance in the handbook, as the overview of Sozialformen has shown (see Section 6.5). As is common in PD projects, children lead the design process and work collaboratively in design teams towards a concept. A second example is the use of the technology samples, which were mainly planned to be used as ways to enable children to explore technologies on their own (instead of traditional teacher-centred teaching methods, the teacher explains technologies).

The second toolkit enabler - guidelines for structuring design processes, was partly incorporated in the lessons the teachers planned. Including this enabler in the toolkit was challenging, given the fact that traditional design processes require ideation of concepts (see for instance (Brown 2008; Hevner, March, Park & Ram 2004)). Teachers have limited time and ideating steps in the design process of repeating activities was indeed not explicitly considered by any of the participating teachers. However, teachers planned to conduct more than one design activity and switching between settings (working in design teams or as a whole group, for instance), allowing iterations during the activities and by discussing concepts with the whole class versus within the design teams.

This raises the question of how important the iteration of ideas is for children to be able to design technologies or generate ideas. During the SPT project, we needed several
iterations to refine the prototypes and to discuss how to interpret the children’s ideas as design output. When children are designing their own technologies, without researchers or designers as intermediary persons, fewer iterations might be necessary.

All teachers adhered to the order of activities included in a design process (see for instance [Druin 1999]), starting with technology exploration, leading to idea creation, and eventually prototyping ideas and presenting ideas to the class. This indicates that the design process guidelines supported the teachers to structure the design process similarly to how we structured the design process in the SPT project.

The third toolkit enabler - focus on groupwork and discussions, was received positively by all teachers. The teachers planned activities in different social settings, for instance groupwork with open assignments or discussions with the whole class, led by the teacher. The results from the focus groups showed that the teachers reflected on the focus on groupwork and discussions suggestions in the toolkit and it was pointed out that the children would be encouraged to negotiate concepts and work together on solving problems. Those skills match with the sustainability targets of the SPT project (Children take a leading role in design processes) and enablers from the SPT project (Collaboratively creating concepts and solve problems in design processes).

The importance of collaborative, problem-based learning and student-centered classroom practices, when teaching ICT related topics, has been highlighted by Fu (2013). The author argued for the integration of ICT use (for instance computers) in combination with diverse teaching methods and approaches, as is used in PD projects to engage children actively in technology design activities.

The fourth toolkit enabler - inventor narrative, was meant to give teachers a narrative to embed the design activities. The findings of the evaluation study show that the teachers planned to work with the inventor narrative in different ways: By using selected pages of the inventor diary to structure design activities or as enabler to support children recording their ideas and process, for instance. As inventors, the children could also become the experts of their inventions at the end of the design activities. One teacher explicitly called the children ‘experts’ and planned an exhibition where the children should explain their ‘inventions’ to the public.

These findings indicate that an inventor narrative could support teachers to empower children to take an active role in the design process as ‘inventor’, and being the expert of their own design outcomes. This empowerment aspect in technical subjects is currently lacking in educational programs in European countries [Dindler, Smith & Iversen 2020]. However, Dindler et al. argued that computational empowerment is a fundamental aspect in preparing children for a digital work market, and should thus be part of educational program.

The fifth toolkit enabler - ‘what-if’ games, was received with mixed feelings from the teachers, because the children might be too old for ‘what-if’ games or they do not match with the curriculum (see Section 6.2.3).
Biskjaer et al. (2021) highlight the importance of creativity as a mean to ‘unleash’ the potential of opportunities hidden in the technologies or material, supporting them to express their ideas. They consider creativity as a key learning objective in computing education and argued for putting creativity on the school curriculum.

We had positive experiences with activities that foster creativity and thinking beyond what is yet possible or the materials available. Biskjaer et al. (2021) supported the importance of exploring hidden opportunities, however, the ‘what-if’ games which could be played with the fantasy/sci-fi cards in the toolkit did not enable teachers well to plan activities that support the creative exploration of possibilities for technologies. Exploring why this enabler did not work for the teachers, or how the toolkit could have been designed better, might be an interesting challenge to solve in future work.

The sixth toolkit enabler - technology samples, was integrated by all teachers in their lesson plannings. By planning to show the children technology videos, technology cards or electronic components, teachers planned to let children explore technologies they might be unfamiliar with and explore the opportunities of novel technologies. The teachers felt confident about the level of technical details and were able to interpret what the technologies could do and how they work.

This indicates that the teachers considered technology samples as helpful support to let children explore technologies and that they felt sufficiently skilled to work with the technology samples.

The seventh toolkit enabler - a support network, was discussed with the teachers in terms of facilitation and relevance. I initially considered a support network as opportunity for teachers to gain access to resources and skills they do not (sufficiently) have, for instance technical knowledge, and as pathway to share the toolkit with a wider audience. During the focus groups, a third opportunity was discussed: Teachers have existing relationships with their pupils which might impact the way a teacher can facilitate technology design processes. External experts could take a different role in those processes, for instance as design partner. Yip et al. (2017) identified the different roles adults and children could play during design activities, including for instance design partner, informant, interpreter or observer. They argued that balanced relationships between adults and children are an important aspect in enabling children to take an active part in design processes.

A fourth opportunity of support networks became apparent when a participant from the evaluation study shared the toolkit and pictures of using the toolkit with her class on social media (see Figure 6.1 and Figure 6.2). This indicates that a support network can also help sharing the toolkit (and thus, the SPT project enablers) with a broader audience, which might support replicating and scaling PD practices. Iversen and Dindler (2014) discussed as pathway to scale PD practices to increase the visibility and accessibility of PD practices by opening them to a general critique. A support network, on social media or by using different channels (for instance politics), could support similar processes. Hence, building a network of actors sharing the toolkit with their peers can potentially lead to new audiences adopting PD practices.
7.1. Reflecting on the evaluation - how the toolkit sustained enablers of a PD project

7.1.4 Challenges when aiming to transfer enablers from a PD project into enablers in a toolkit for teachers

During the toolkit design process (Chapter 5), I transferred enablers from the SPT project (SPT practices which enabled children in the SPT project to engage in technology design activities) into enablers in the toolkit (which support teachers to enable children to engage in technology design activities). Figure 7.2, a part of Figure 7.1, zooms in on the challenges and constraints of the school context I experienced when aiming to transfer the SPT enablers into the toolkit enablers. Finally, I discuss which SPT enablers might not be fully transferred in a toolkit.

The first challenge relates to the power imbalances between teachers and pupils. In PD processes, balanced power relations between adults and children play a crucial role in empowering children to take an active part in design processes (Yip et al., 2017). As explained in Chapter 4, we approached the challenge of power imbalances between researchers and children by playing two roles: A playpartner of the children who playfully supported their creativity and joined the children in their playtime, and an active observer who structured the design activities, but did not interfere in creative processes or decision-making of the children.

As illustrated in Chapter 5, teachers might find it challenging to refrain from interfering with the design processes and decisions of the children. This phenomena has been discussed in the literature as well (Iivari & Kinnula, 2016). Three problems were described in related work in relation to power imbalances between teachers and children: Teachers were trying to influence activities (Barendregt et al., 2016), the children lacked freedom to choose activities or topics (Iivari & Kinnula, 2016) and children experience activities differently in a school context as they need to “listen to the teachers and the tasks are always aimed at learning and never just fun” (Dreessen & Schepers, 2018).

Power-imbalance were addressed in the toolkit in multiple ways: The teacher handbook suggested children-led activities (for instance groupwork), the inventor diary encouraged children to take a leading role in design processes as inventors, and the support network could offer children access to technical facilities or collaborations with experts. However, balancing power imbalances cannot be fully addressed or resolved with a toolkit, as teachers have existing power relationships with children. During the co-design workshop, Caroline gave us insights in her experiences by being involved in a PD project as ‘observer’, standing back in the classroom instead of taking the lead as teacher. While she appreciated the freedom the
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children had in the design process, it was challenging for her to refrain from taking an active role in the process. Beatrice, who was also present during workshops in the SPT project, had similar difficulties. She was asked frequently by us to refrain from overriding the children’s opinions.

It is not the aim of the toolkit to resolve existing power-imbalances between children and teachers. It can only suggest methods, narratives and possible collaborations to support teachers in taking a more passive role, while still supporting the children in design processes. Based on our experiences in the SPT project and the findings from the design process, a toolkit might be not sufficient to support all teachers with this challenge. As previously discussed in Section 4.4.1, teachers often work in a different setting than researchers: During the SPT project we worked with small groups of children (five children) and at least two researchers were present during each workshop. In a traditional classroom setting in Austria up to 30 children are in one class and often only one teacher is present. This makes it challenging to adopt different roles or children-led practices which might require more support from the teacher or individual guidance.

The second challenge relates to the limited resources and skills teachers have to facilitate technology design activities. As discussed in Chapter 5, teachers lack for instance technical equipment or the money to buy technical components, and only two participating teachers in the evaluation study had technical skills they thought they could use for facilitating technology design activities.

The challenge of limited resources has been discussed in the field of education as well, especially when aiming for child-centred teaching approaches and giving children control over their (learning) process (Shah, 2019). As presented in Section 2.2.6, child-centred teaching approaches are closely related to PD practices, as children are empowered to control their own learning process and get more freedom (compared to teacher-centred approaches) to make their own choices (Cross). Child-centred approaches are criticized in educational literature for being not practical in ‘real classroom settings’ (Shah, 2019) since they require more resources to enable children to take responsibility for their learning outcomes and a low pupil-teacher ratio is needed to meet individual needs of children. Hence, in the current educational system in Austria, it might be challenging for teachers to adopt PD, child-centred practices.

This constraint of limited technical resources and skills was addressed in the toolkit in two ways: Technology videos and cards informed children and teachers about technologies a and show them examples of new technologies in their daily lives, and the handbook suggested opportunities for collaborating with the technical support network. During the focus-groups (see Chapter 6), I discussed the opportunities of a support network, and teachers reacted positively. However, those teachers who lived in rural areas, were concerned about finding technical experts close to their schools. Inviting technical experts to a school could be an option to address this problem, but this might cost money.

Hence, addressing the constraint of limited resources and skills with a support network and technical tools could work for schools which are located in areas with an existing
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infrastructure of technical experts and facilities, other schools might need to explore a
different strategy to get access to technical equipment and skills. The challenge of a high
teacher-pupil ratio and resulting time problems to support each child individually, as we
did in the SPT project, remains unsolved by the toolkit.

The third challenge relates to rigid structures of schools. As illustrated in Chapter 5, teachers are bound to their schools curricula. Hence, teachers asked for a toolkit that supports activities for different timeframes and which could be (re)used in various subjects and for multiple topics from their curricula. During the evaluation (see Chapter 6), their need for modular tools and flexibility has been discussed again. The challenge of rigid structures was addressed in the toolkit with modular units for activities (illustrated in the teacher handbook) and a collection of cards and worksheets in the inventor diary the teachers could choose from. The results from the evaluation showed that teachers considered the overall modularity and flexibility of the toolkit as sufficient for their own practice and were able to plan lessons for different subjects and topics using the toolkit.

The reflections on the challenges and constraints of a school context indicate that a toolkit can partly address challenges of a school context. With modular and flexible content, the toolkit supported the teachers from different schools and with different curricula and subjects sufficiently. The constraint of limited resources and skills could only be partly addressed with the toolkit. Teachers have different skillsets and the majority of teachers is not familiar with running design processes, which has been earlier mentioned as challenge to sustain PD projects by Bødker et al. (2017). Future work will be necessary to explore if a toolkit can give sufficient guidance to teachers to facilitate design processes. Another remaining challenge which could not be addressed with this toolkit is the high teacher-pupil ratio in a classroom setting. Usually one teacher is present and the group of children is a lot bigger compared to the SPT groups of children. This might require an adaptation of PD practices. Future research will also be necessary to explore opportunities for supporting teachers living in rural areas without a technical infrastructure.

While I have focused in Chapter 5 and Chapter 6 mainly on the challenges and constraints of a school context, the skills of teachers, power imbalances and rigid structures might also be beneficial for facilitating design processes with children. In former PD projects, children experienced challenges when being engaged in design processes, as illustrated in Chapter 2. Children experienced for instance, frustrations (McNally et al., 2017), tensions in design teams caused by unwillingness to compromise (e.g. (Van Mechelen et al., 2019)) and children had difficulties with conceptualising ideas and programming (e.g. (Duveskog et al., 2009)). Teachers are pedagogically better trained than researchers and could for instance enable children to deal with the challenges of being part of a design team (e.g. compromising, dealing with frustrations, conceptualising ideas). As illustrated in Chapter 6, the rigid guidelines of their curricula inspired teachers to plan activities with the toolkit in various contexts and for diverse topics. The teachers dealt with the challenge of limited resources by combining materials available at their schools (ranging from technical materials to simple crafting materials).
To conclude, a toolkit might not need to (and certainly cannot) address all contextual challenges and constraints of a school context. However, as argued in Section 7.1.2, a toolkit approach can increase the likelihood of sustaining experiences and practices of PD projects for participating teachers and teachers and children not involved in the initial project when aligned with the contextual challenges and constraints of a school context.

### 7.2 Infrastructuring

In the previous section I reflected on the enablers and how a toolkit approach could support teachers to design technologies with children and by thus, sustaining SPT experiences and practices. Next, I discuss the findings of this work by using infrastructuring as a lens. As discussed in detail in Chapter 2, Neumann and Star introduced in the 90’s the “notion of information infrastructure” (Neumann & Star, 1996). The term describes socio-technical relations, emphasizing the contextual characteristics when creating and using infrastructures. Recent infrastructuring ambitions in PD focus on the creation of dynamic, socio-technical infrastructures, that support long-term use and beyond a project’s end (Björgvinsson et al., 2012).

#### 7.2.1 Infrastructuring as a lens to explore hidden characteristics of a context

Reflecting on my experiences with designing the toolkit, infrastructuring gave me an effective lens to explore the specific context and to pay attention to hidden characteristics and working mechanisms of a school context. As explained in Section 2.4, Simonsen et al. (2020) suggested a conceptual-analytic strategy to uncover existing, hidden socio-technical relations that support working mechanisms of infrastructures, or might cause problems related to contextual effects (Star & Ruhleder, 1996). I applied a conceptual-analytic strategy to analyse existing socio-technical infrastructures of schools as part of the toolkit design process.

I found contextual characteristics on a social level (for instance teacher-child relationships), organisational level (for instance rigid structures, curricula) and on a technical level (for instance lack of physical components or machines to design technologies), and also on a methodological level (for instance enabling children to lead the design process), personal level (for instance teachers are worried to have insufficient technical skills) and resource level (for instance schools lack financial resources to buy materials). In Section 5.1.2, I discussed which technologies the teachers who participated in this research are currently using, how they are embedded in teaching practices and what makes it challenging for teachers to adopt technology-related activities. Hence, applying a conceptual-analytic strategy helped me to discover disruptions and challenges of existing socio-technical relations in a school context, which I used in the toolkit design process as starting point to explore opportunities for improvements and as insights to foresee potential challenges for a socio-material toolkit.
7.2.2 Infrastructuring as a lens to re-conceptualise existing toolkits

Using infrastructuring as a lens also made me re-think the traditional conceptualisation of toolkits. I first applied an empirical-ethnographic strategy (see Section 2.4) to explore how existing toolkits need to evolve to meet the characteristics of a school context and current disruptions of socio-technical relations. The literature review of existing toolkits in Chapter 2 has shown that PD or HCI toolkits for children often are a collection of electrical components, digital infrastructures, physical (no-tech) components, digital components, paper-based materials or workbooks. But in complex contexts like schools, a collection of resources from this list would not meet the requirements of the context (see Chapter 5). It would be for instance too expensive and time-intensive, or the teachers might lack the skills to work with the technical resources of the toolkit. The toolkit needed social infrastructures to support teachers sufficiently in using the toolkit. Hence, I suggest re-thinking the traditional conceptualisation of toolkits, by including a social support network in a toolkit. That could be for instance social infrastructures like a support network of peers or technical experts, or a social media channel I used to share and evaluate the toolkit with a broader audience. Hence, I applied a generative-designerly strategy to generate new infrastructures for the toolkit.

7.2.3 Infrastructure-time as a lens to support sustainable PD practices and experiences

Originally, infrastructuring encompassed the following dimensions: “Embeddedness, transparency, reach or scope, learned as part of membership, links with conventions of practice, embodiment of standards, built on an installed base, becomes visible upon breakdown (Karasti et al. 2010 p.6).” Karasti argued for extending infrastructures with temporal scales: “An infrastructure occurs when the tension between short-term and long-term is resolved. That is, an infrastructure occurs when here-and-now practices are afforded by temporally extended technology that can be used in an everyday, reliable fashion. Infrastructure becomes transparent when it exists as an accessible, ready-to-hand installed base that enables envisioning future usages (Karasti et al. 2010 p.24).”

Infrastructuring takes place in two time time-frames: During project-time (‘here-and-now’) and beyond the project-time (‘infrastructure time’), by supporting future usages of the evolving infrastructure. Supporting future usage can be enabled by anticipating future needs or constraints during project-time. Ehn referred to this as ‘meta-design’ (Ehn 2008), as further illustrated in Chapter 2 designing during project time for design-after-design. Ehn proposes to create environments during project-time, which support continuing design activities beyond the project’s end. Compared to the aim of this thesis, which is to sustain PD practices and experiences which are not related to the initial prototypes or concepts of the initial SPT project, Ehn’s understanding of meta-design relates to the evolution of the initial artefact. In this thesis I aim for an evolution of the initial practices and experiences while the initial artefacts designed in the SPT project are not ‘sustained’ or further being (re)-designed. However, in both cases it is crucial to anticipate the needs or constraints of teachers involved and not involved in the initial project to create
environments which ensure long-term PD practices and experiences. Infrastructuring can be an effective lens when creating those environments. Karasti argued that taking into account especially the dimension of infrastructure time should be a “foundational design consideration.” (Karasti et al, 2010, p.31). Karasti characterises infrastructure time as extended temporal perspective, favoring open-endedness and continuity.

Reflecting on this thesis, the SPT project was concerned with the project-time, the here-and-now practices (technology design workshops at schools) which would end after the project had ended. The toolkit design process was concerned with infrastructure-time, by aiming to extend the impact of the here-and-now practices, creating an accessible toolkit that enabled future usage of the lessons learned from the here-and-now practices (the SPT enablers which were transferred into the toolkit enablers). The toolkit supported open-endedness and continuity by enabling appropriation and re-usage of the tools. Another characteristic of infrastructure time is the range over the past, present and the future: “For the information managers of the research network, ‘infrastructure time’ involves taking account of the past and present in future plans and actions, defining relationships that include update strategies and enable integration not only at the present time but over time (...) This is visible in our case study in the ways information managers, after adoption and initial attempts to implement the standard, consider through contextualization how the new metadata standard could be integrated with their installed base with special attention to keeping data secured and balanced with the demands for coordinating and managing units at the research network level (Karasti et al. 2010, p.26).”

I took into account the past in the toolkit design process, by first exploring the contextual characteristics in which the toolkit would be used (the school context) and the existing challenges and constraints, to enable integration of the toolkit into the existing practices of teachers. Future use was anticipated by evaluating the toolkit with teachers not involved in the SPT project and from different schools to plan how to use the toolkit in their classes. The outcomes of the evaluation uncovered possible obstacles for future use of the toolkit, for instance, teachers who live in rural areas and could not locate technical experts or facilities close to their schools.

Karasti (2010) argued that this long-term perspective of infrastructure-time is required for sustainable collaborative infrastructures, recommending to incorporate the perspective of infrastructure-time as design consideration in projects. I echo the need for considering the long-term perspective of PD practices, especially when aiming for sustaining practices and experiences of the initial PD project and encourage researchers to explore opportunities for creating infrastructures not only during project-time, but also beyond the project’s end.

7.2.4 Scaling infrastructures beyond the project’s local support network

As discussed in detail in Chapter 2, previous infrastructuring efforts in PD projects with children focused on:
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- enabling children to form attachments with local organisations during project-time frames which continue to empower children beyond the project’s end (Schepers et al., 2021).

- utilizing a support network built during project-time and trying to anchor PD practices in the existing network of project partners (Iversen & Dindler, 2014).

Both approaches focused on creating local support networks infrastructures during project-time which would evolve beyond the projects end and continue to support the impact of the PD project. With the toolkit, I aimed to create an evolving support network beyond the local support network of the SPT project. This was approached by building an online peer support network using social media and a website for the toolkit, and by building upon existing co-located infrastructures (for instance Fablabs). During the evaluation (see Chapter 6), the latter revealed new challenges: The local infrastructures in the city where the SPT project took place, Vienna, could support various support networks for teachers. I contacted for instance a FabLab which would support teachers, a science museum which offered to conduct technology design workshops for children and teachers based on the toolkit, and a policy-maker from the city visited our SPT lab. Setting up similar support networks across different cities, or countries, would have been beyond the scope and resources of the SPT project. Hence, to support teachers from different cities in Austria and other (German-speaking) countries, I included instructions in the toolkit to find possible existing support networks close (mainly FabLabs) to the teachers schools. As discussed previously in Section 7.1.4 teachers who live in rural areas were not able to locate any possible collaborators in their areas.

In this thesis I have not explored until which extend political processes are required to support the toolkit and eventually to sustain SPT practices and experiences in a school context. Bødker et al. (2017) argued that sustaining PD initiatives in a school context requires the engagement with political and educational authorities. They referred to activities and processes in which participants create infrastructures, networks and agreements that support sustainability of PD practices using the term knotworking. They facilitated for instance workshops with headmasters, teachers and representatives from municipalities to build a shared vision for municipalities to sustain the initial project’s PD practices. These PD practices were further embedded in the school’s curricula by participating in a public hearing for national stakeholders, pupils and parents. During this hearing, the school could discuss and share their thoughts on new learning skills (for instance design thinking), which are crucial in PD activities. These examples show knotworking with political and educational authorities can support sustaining PD practices and experiences. By accessing (political and/or educational) networks, the reach of PD practices can be increased and embedded in the school’s curricula. This indicates that future work will be necessary to explore if, and how a toolkit approach could support knotworking.

Hence, a toolkit consisting of infrastructures might be a strong approach when remaining to be used in the local context of the PD project, where support networks can be build.
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during project-time, but it might be hard to scale the same approach across co-located places. A digital support network could be a step to increase opportunities for scaling, but access to technical equipment or skills remains challenging to sustain for co-located schools. To approach this challenge, knotworking with political and educational authorities might support sharing PD practices and experiences with similar audiences not previously involved and building new networks might support embedding those practices in a school context.

7.2.5 Infrastructuring as a lens to support sustaining practices and experiences of PD projects for audiences not involved in the initial project

In this section I reflected on the toolkit design process and the evaluation using infrastructuring as a lens. Infrastructuring first informed the exploration of the characteristics of a school context on different levels, aiming to uncover aspects I had not explored earlier during the SPT project, for instance rigid structures or limited resources of teachers. I was mainly interested in characteristics and challenges related to existing socio-technical relations and use of technologies in current teaching practices. To address those characteristics and challenges, the lens of infrastructuring informed the toolkit design process by re-conceptualising existing toolkits and taking into consideration the time-spans of the design process. Finally, the lens of infrastructuring helped me to identify opportunities and challenges when aiming to scale the toolkit approach across co-located schools. To sum up, infrastructuring has been an effective lens to inform the toolkit design process and exploring pathways (and possible challenges) to sustain SPT practices and experiences for teachers not involved in the initial project.

7.3 Considerations for future PD practice

This thesis set out to explore how we could increase the likelihood of sustaining practices and experiences of PD projects in a school context for teachers participating in the project and teachers and children not involved in the initial project. I have applied a toolkit approach, argued for using infrastructuring as a lens to design socio-material tools that meet the constraints and challenges of a school context. In the final part of the discussion, I want to take a step back, reflecting upon the lessons I have learned when preparing for the project’s end and developing resources (the toolkit) as an approach to ensure the likelihood that experiences and practices of the initial PD project are sustained.

The considerations are based on the positive experiences I made when developing the toolkit and the challenges I faced when designing the toolkit. As argued in Section 7.2 the lens of infrastructuring has informed the toolkit design process and the way I approached the challenge of sustaining PD practices and experiences. Hence, the considerations are partly informed by infrastructuring as a lens to approach PD projects when aiming to sustain practices and experiences of their project.
7.3. Considerations for future PD practice

Here, I present six considerations for PD practitioners who aim to increase the likelihood of sustaining practices and experiences of their project:

1. Considering contextual restraints
2. Considering socio-material solutions
3. Considering the project’s core values
4. Considering a pro-active attitude during project-time
5. Considering inviting and designing new audiences
6. Considering scalability

7.3.1 Considering contextual restraints

I have pointed out in Chapter 5 the challenges of a school context, mainly linked to the constraints of teachers and rigid structures—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 in the literature, when researchers aimed to integrate new teaching practices in an educational context [Penuel, 2019; Bødker et al., 2017]. Those challenges are likely not unique about our research context, as pointed out in the literature as well [Taylor et al., 2013; Ledo et al., 2018; Penuel, 2019; Shah, 2019]. It is for instance a known problem, that teachers lack sufficient skills related to design processes and technology to sustain practices and experiences of PD projects, as these topics are not part of their education or training [Bødker et al., 2017; Shah, 2019].

Hence, when setting up PD projects and aiming to create resources that support the sustainability of PD practices and experiences, those resources should be embedded in the context of practice of the people who are going to evolve their practices around those created resources. Therefore the first step of the development process could be to engage in a dialogical process with people who could evolve their practices and by doing this, contribute to sustaining practices of the PD project. A deep understanding of their context is a critical step in the design process.

In the SPT project, we only partly had to face constraints and challenges of a school context. The SPT project was funded well, we had access to technologies, we only worked with small groups of children and had the skills and experience to facilitate technology design processes. But when we aimed to sustain the SPT project’s practices and experiences for teachers and children not involved in the initial project, the challenges and constraints of a school context would have an impact on the teachers who would need to facilitate technology design workshops within their context. During the SPT project, the majority of the teachers contextual constraints and challenges were invisible to us, since we did only partly needed to address them. Hence, as important phase
in the toolkit design process, I iteratively discussed constraints and challenges with the teachers and asked during the co-design workshop if all parts of the toolkit were feasible to use. In the evaluation study with teachers who were not previously involved, I raised the question again, since other schools might have different structures. While the constraints did not differ much, the presented toolkit concepts often raised new challenges or prompted teachers to suggest novel ideas to avoid resource problems. They also gave practical advice, for instance using pattern instead of colour codes for the technology cards categories (see Figure \[5.6\]), or preparing pdfs as master copies. The infrastructures of the schools also differed widely: One school had a workplace with 3D printers, another school collaborated with a technical company, others were located in villages without any collaborations or technical equipment.

Hence, I strongly recommend to carefully explore the contextual restraints and opportunities in which the toolkit will be used, preferably as an iterative process and with multiple different schools. In the SPT project, the majority of communication with the teachers took place ‘off record’, for instance when we picked up the children for the workshop or brought them back to their classroom. I started to explore these contextual restraints and opportunities during those moments. I kept a research diary to capture insights I had during those conversations, which later guided me in the design process to focus on addressing on those contextual constraints and opportunities. In the hindsight, it would have been helpful to create more explicit moments during which I could have reflected together with the teachers on the design process in the SPT project and how they could facilitate similar design activities beyond the project’s end. A different approach would have been to address the contextual restraints and challenges directly, by engaging with educational and political authorities in knotworking activities, as suggested by Bødker et al. (2017).

7.3.2 Considering socio-material solutions

Prior to integrating the toolkit in practice, I explored the context specific requirements and constraints of teachers. I quickly realised that a ‘stand-alone’ toolkit was not sufficient to support teachers adequately in their situated context, due to multiple reasons: Firstly, I was faced with a complex problem: Teachers have limited technical equipment or financial means to buy a physical toolkit (for instance interactive electrical building blocks like littleBits), and have limited knowledge and skills to evolve their practice based on technical equipment and instructions, and the methodological experience to enable children to design their own concepts and technologies. Secondly, teachers are part of the school’s rigid structures and have existing power relationships with their pupils which cannot be addressed with ‘stand-alone’ solutions like electrical building blocks. This problem makes it hard to find a ‘one-fits-all’ solution with a technology-only toolkit.

Using infrastructuring as a lens, as explained in the previous section, I started by emphasising the importance of collecting and aligning socio- and material resources, and then working towards a solution which can meet the contextual restraints and needs on a social level (for instance by building a support network). The findings from the
toolkit design process and evaluation study give first insights about the different angles that are worth exploring when collecting resources, for instance a collaboration with technology experts (i.e. FabLabs), companies, or other teachers for peer support and sharing the toolkit with a broader audience. Infrastructures can thus enable participants to adopt and appropriate socio-material tools beyond the initial design and involve new participants not engaged in the research project.

To support a flexible use as a complex situated context like schools requires, I developed the toolkit which balances modularity and structures. The toolkit is designed to be open for appropriation, while offering sufficient structures that support teachers in fields with which they are unfamiliar (organising technology design activities, for instance). As explained in Chapter 5, this was achieved for instance with carefully chosen methodological guidelines (for instance a flexible workshop structure). On a social level, I supported appropriation by creating an (online) environment on social media for peer exchange and support, inviting toolkit users to their adaptations. The findings of the evaluation study supported the need of modularity and flexibility of the teachers, they expressed for instance the importance of being able to pick and combine different tools.

I thus recommend two things: First, to consider all infrastructures which are necessary to embed solutions in a specific context. Infrastructures can be a social support network of technical experts, like the support network which was part of the toolkit, but could also consist of politicians, decision-makers and domain experts, as suggested by Iversen and Dindler (2014), and Karasti et al. (2014) pointed out that infrastructuring can be an opportunity to reintroduce politics into PD. 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. Hence, I recommend to reflect on existing infrastructures and to explore pathways to create infrastructures, or improve existing infrastructures which support sustaining impact of PD projects.

Second, I recommend to play with modularity to support the evolution of the solutions while incorporating structures and guidelines that support people who are not trained in the field of technology design. The majority of existing toolkits focus on electronical components or digital infrastructures, as discussed in Chapter 2. When we aim to create toolkits for people not trained in technology design (or facilitating technology design activities), structures and guidelines might be necessary to support them in using the physical or digital parts of the toolkit. As pointed out in Section 7.3.1, these guidelines and structures should be embedded in the particular context of use (schools, for instance), and need to be tailored to the constraints of this context. One possibility to support this, is to give modular and flexible guidelines and enabling people in this context to appropriate them for their own needs.

7.3.3 Considering the project’s core values

When developing the content of the toolkit, I not only took into account the expectations and constraints of the teachers, but which underlying enablers of the SPT project
supported children to participate in technology design activities. A central part of PD work in a school context is the empowerment of children through participating in a design process (Kinnula et al., 2017; Dindler et al., 2020; Malinverni et al., 2014; Wilson et al., 2018). PD in particular is not a set of methods which can be adopted and make PD work, it is rooted in values and ethics which shape the way PD practitioners work (Iversen et al., 2010).

A PD lens was a central part of the toolkit, which entails empowerment notions. Hence, I was faced with the challenge of how to ‘pack the spirit of PD in a bag’. The ‘bag’ in the metaphor is in this case a toolkit, which should support teachers to enable children to participate actively in a design process. In the toolkit, I aimed to solve this for instance with the inventor diaries and narrative. They could 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. The findings of the evaluation study has shown that teachers planned to give children the ‘expert’ role and the majority of planned Sozialformen were based on self-driven activities by the children.

In line with Iversen and Dindler (2010), I suggest to engage explicitly with the values the PD project is embedded in and which values enable participants to participate in the processes. After defining those core values that drive the project, it might be interesting to explore ways to sustain them for similar audiences not involved in the initial project. Considering the project’s values contributes to my argument that researchers 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 supported researchers to enable children to participate in technology design activities, and might support teachers to enable children in similar ways. Related work has shown that PD values are not always in line with the values of schools (Iivari & Kinnula, 2016). The empowerment of children for instance could clash with the power imbalances between teachers and pupils, as discussed in Section 7.1.4.

I thus recommend, when setting up PD projects in a school context and defining the project’s core values, to think about the role of the researchers’ values, if certain values are necessary to enable children to participate, and what would happen if audiences not involved in the initial project would facilitate similar activities. Considering the potential tensions between the schools’ values and the researchers/PD values, it might be important to take into account the teachers and schools’ underlying values.

### 7.3.4 Considering a pro-active attitude during project-time

It is not an uncommon phenomena that, in PD, practices are not maintained by the participants after the project ends or that practices are adopted by audiences not involved in the initial project (Given, 2008; Bossen et al., 2010). When setting up the SPT project, we were concerned about how to embed our project’s practices in the school’s context and ensure that the children will benefit from the collaborations. However, what would happen after the SPT 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 SPT 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 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 from the beginning, for instance Fablabs or policy makers, would have helped us at the end to set up a support network for the toolkit. We did not recruit teachers who could support us to develop the toolkit until the end of the project. Doing this at the project’s end brought up challenges: we could not invite prospective collaborators or teachers 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 led to a cancellation of meetings with possible supportive participants. Another challenge was to develop a toolkit with possible physical parts without sufficient funding left to buy materials.

As discussed in Section 7.2, using infrastructure-time as lens could support researchers to anticipate future usages, needs or constraints of the infrastructure beyond the time of the project. For sustainable infrastructuring beyond the project’s end, a pro-active attitude during the project time is crucial.

Reflecting upon this experience, I recommend 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 or build tools at the project’s end for example) and possible stakeholders and participants are identified. In line with this argument, I suggest to have a pro-active attitude when setting up PD projects and 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 at an early stage in the project and during PD activities. Making it part of the project’s agenda and part of the researcher’s routine to explore possibilities for sustaining projects practices and experiences for participants and similar audiences not involved in the initial project might spare time and ensure the building of fundamental structures that need to be in place at the project’s end.

7.3.5 Considering inviting and designing for new audiences

Ledo et al. (2018) previously stated that toolkits have the opportunity to empower new audiences. Drawing upon this, I 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 explained previously. Hence I argue that, knowing the contextual dependencies beyond the PD project at hand, can support the transfer of toolkits or other solutions to a broader context.

\[2\]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
7. Discussion

The PD project and the toolkit development process took place in Vienna and with two different schools. For the evaluation study I recruited teachers from different schools and even different countries (all German speaking since the toolkit content was written in German), using social media. By evaluating the toolkit with teachers from a broader context, I could explore the ability to evolve of the toolkit and if it would work in different schools and with different teachers, teaching to different ages and curricula. 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, not previously involved in PD projects, might have more difficulties to engage with the toolkit when the topic, activities or methods are new to them. The findings of the evaluation study confirmed that teachers from different schools and without PD experience interpreted the toolkit differently. The results revealed new ways of using the toolkit, for instance as part of other topics of the curriculum (e.g. electricity, ADAC\(^3\)) or combining toolkit materials with other materials or toolkits which were available to the teachers (e.g. electricity toolkits, diverse crafting materials).

Hence, I suggest to invite participants not previously involved to different phases of the development process, for two reasons. The first reason is to ensure that the developed solutions are open for audiences not involved in the initial project 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. The second reason is that teachers working in a different context can help exploring new possibilities for future use and possible new opportunities for sustaining PD practices and experiences.

7.3.6 Considering scalability

Most existing technology design toolkits for children are based on physical materials, for instance electronic components, as related work showed (see Chapter 2). 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. However, scalability is an important aspect when aiming to sustain practices of PD projects (Iversen & Dindler, 2014). Iversen and Dindler suggested to recruit external stakeholders, providing an open, accessible prototype for the entire school and inviting the school to give feedback and interact with it. In this thesis, I went further by giving teachers not involved in the initial project and from different schools access to the toolkit prototype using social media and having digital materials as part of the toolkit. As discussed in Section 7.2.4, building a support network beyond the local project context and scaling the existing support network remained a challenge for future work.

Hence, I echo the suggestion of Iversen and Dindler (2014) to consider scalability of

\(^3\)General German Automobile Association
PD practices, but going one step further by scaling practices to new audiences and new organisations (for instance teachers from different schools not involved in the initial project). This requires to explore different opportunities for scalability, for instance using online platforms (like a website or social media account) which could support scalability beyond the local project context, or knotworking (Bødker et al., 2017), as previously discussed in Section 7.2.

7.4 Summary

In this chapter, I have reflected upon the findings presented in the thesis: how the practices and experiences of the initial PD project could be sustained for audiences involved and not involved in the initial project with the enablers forming the toolkit, how infrastructuring informed the design process of the toolkit and finally which lessons I learned and what I suggest to consider for future PD projects. Sustaining the practices and experiences of PD projects with children might support teachers in the future to enable children to creatively and critically engage with technologies. A toolkit might be a first step towards this aim. The work presented in this thesis has given first insights in exploring a toolkit as an approach to sustain practices and experiences of PD projects to support teachers involved and not involved in the initial project to facilitate technology design activities with children.
Conclusion and future work

After I presented and discussed the findings of this thesis, the final chapter concludes my work. I summarise and position the contributions I made with this thesis and how they relate to the field of PD and HCI. Then, I discuss the overall findings and approach in relation to the quality criteria as described in the methodology chapter. Finally, I discuss the limitations of this thesis and present ideas for future work.

8.1 Conclusion

This thesis aimed to explore how researchers can increase the likelihood that positive experiences and practices of PD projects in a school context are sustained for participants involved and similar audiences not involved in the initial project. To be able to answer this question, I first explored what sustainability means in a PD context and which experiences and which practices should be sustained. Chapter 2 explores how other researchers in the field of PD conceptualise sustainability and which aspects of PD projects they aim to sustain. Chapter 2 ends with an overview of existing toolkits in the field of HCI and PD, giving insights into possible toolkit approaches to sustain project experiences and practices of PD projects. The chosen methodological approaches are presented in Chapter 3 which helped me to address the main question of this thesis: “How can we increase the likelihood that the positive experiences and practices of PD projects in a school context are sustained for teachers participating in the project and teachers and children not involved in the initial project?” I set up the context for this thesis in Chapter 3 by presenting the SPT project which informed and motivated my research as a case study. I presented three cases, where we co-designed social play things by applying a PD approach and involved children actively in the design process.

In Chapter 4 I present the different experiences of the children involved in the SPT project which we aim to sustain, the sustainability targets. I reflect upon the practices which enabled the children to engage in technology design and PD activities and how
we achieved the sustainability targets: the SPT enablers. The defined sustainability targets form the goals for the toolkit, the SPT enablers form the input for the toolkit design process (as further illustrated in Chapter 5), by giving first insights into what might be necessary to sustain similar experiences and practices for children and teachers not involved in the initial SPT project. At the end of Chapter 4, I reflected upon the challenges a school context holds for design activities, for instance teacher-children power relations or rigid structures.

Hence, I explored in Chapter 5 together with teachers what the constraints and characteristics of a school context are. I discussed with teachers if they wanted to evolve their practices around the SPT sustainability targets and enablers and if and how a toolkit approach could be used to address the challenges of a school context. The toolkit aims to support teachers to create processes and activities through which children are enabled to engage in technology design activities supporting creativity, problem solving and critically engagements with existing technologies. I reported the design process of the toolkit and how a toolkit approach could address the specific characteristics of a school context. I present three iterations of the toolkit concepts, illustrating the evolution of the different tools based on an interview, a co-design workshop and an online survey with teachers, and how they might sustain the targets and enablers of the SPT project as summarised in Chapter 4. This chapter ends with an overview of design implications for a toolkit aimed to support teachers to enable children to engage in technology design activities.

I argue that infrastructuring is an effective lens when designing a toolkit for a school context and addressing the challenges of a school context (mainly limited resources and rigid structures). This leads to my first contribution: A socio-material toolkit which supports teachers to engage in technology design activities with children, using methods based on PD practices and a support network. This contribution adds to the existing work on toolkits in HCI and PD by arguing for including a social support network in a toolkit, next to other material tools (digital tools or methodological guidelines, for instance).

In Chapter 6, I evaluated how teachers would plan to use the toolkit in class. The evaluation showed how the teachers were able to evolve their own practices around the toolkit, indicating that a toolkit as approach to sustain positive experiences and practices of PD projects for audiences not involved in the initial project could be used.

In Chapter 7 I reflected upon the findings from the evaluation and what kind of enablers from the SPT project I saw sustained in the findings from the evaluation. I presented infrastructuring as approach to inform the toolkit design process and to enable participating teachers and teachers not involved in the initial project to evolve their practices around the toolkit. Based on these reflections, I make my second contribution: Considerations for future PD practices which can help researchers to enable participants and similar audiences not involved in the initial project to evolve their practices around PD. This contribution adds to the existing work on sustaining practices and experiences of PD projects with children by using infrastructuring as a lens to increase the likelihood that the positive experiences and practices of PD projects are sustained for audiences involved and not involved in the initial project.
This work contributes to the field of PD and HCI, aiming to support researchers when taking preparations for sustaining project experiences and practices. The design guidelines take into account the complexity of project contexts, suggesting a toolkit as approach to create infrastructures which enable participants and similar audiences not involved in the initial project to evolve their practices around them.

### 8.2 Limitations

However, there are also limitations, in terms of: Selection of participants, claims I can make regarding sustainability and the impact of the COVID-19 pandemic on this work.

#### Selection of participants

The majority of children who were included in the SPT project are neurodivergent and this laid the groundwork for the toolkit and shaped my methodological and theoretical understandings as researcher. In early stages of the design process, all involved teachers except for one were specialised in teaching neurodivergent children. Both aspects influenced the design process of the toolkit and might impact the generalisability of my findings. Neurotypical developing children might need different enablers than neurodivergent developing children when being engaged in technology design processes. Teachers specialised in teaching neurodivergent children might have a different set of teaching approaches which might be more, or less, in line with PD methods the toolkit is based upon, making it easier, or more challenging, to evolve their practices around the toolkit. All involved teachers from the evaluation study and the majority of the teachers from the online survey were not specialised in teaching neurodivergent children (since no teachers with this background replied to my invitation and I could not invite teachers who participated in the SPT project since I wanted to evaluate the toolkit with teachers not involved in the initial project). The findings showed so far no difference in needs and wishes between teachers specialised in teaching neurodivergent children and teachers without this background, and all teachers without a background in special education were able to appropriate the toolkit for their own practice.

The toolkit which was developed in this work focused on German speaking teachers and children and all materials were in German. The majority of teachers who participated in the studies (the interview, co-design workshop and evaluation study) work at Austrian schools (Vienna and Upper Austria). For the online survey and the evaluation study I recruited teachers from Germany to explore if their school’s characteristics, needs and wishes were in line with the previous findings. However, the characteristics of schools in other countries might be different from Austrian/German schools. Hence, the findings might not be generalisable for schools in different countries.
8. Conclusion and future work

No sustainability claims possible

PD processes can be messy and unpredictable (Iversen & Dindler, 2014). We can only plan and prepare for sustainability up to a certain extent. Similar to design projects, planning for sustainability should be an iterative process and evolve with the project over the time. Considering the limited time of research projects, I am not able to make any claims regarding whether practices or experiences were actually sustained by teachers. Hence, I could only conclude that a toolkit approach and using infrastructuring as a lens supported teachers to evolve their practices within the time of the research project. Future work must show what the long term results are and if the teachers were able to, and continue to, implement and appropriate the toolkit.

The influence of the COVID-19 on this thesis

As explained in Chapter 1 and Chapter 3, I was facing restrictions caused by the COVID-19 pandemic. The COVID-19 pandemic in Austria led to strict rules and restrictions regarding social contacts in the social and research context: We were for instance not allowed to have face-to-face workshops and external people, such as researchers, were not allowed to enter schools.

This impacted my choice of research methods. I chose my research methods not only based on the most suitable approach which would have helped me the best to answer my research questions, but also by considering the feasibility in line with the current COVID-19 restrictions and resulting challenges. Instead of PD workshops, for instance, I conducted an online-survey, online focus groups, an online interview and written tasks (to write a lesson plan, for instance). As a consequence, I could not offer many hands-on activities and discussions became often abstract and based on ‘what-if’ scenarios.

The pandemic also influenced the selection of participants. Initially, I wanted to evaluate the toolkit with children and asked teachers to evaluate the toolkit with their class. Unfortunately, conducting any workshops in schools with teachers or children became impossible after the schools closed and later during the pandemic. Hence, I used teachers as proxies to evaluate how the toolkit would meet the needs and wishes of children. During the evaluation study, the majority of schools were closed and the children were home-schooled. Hence, only one teacher was able to evaluate the toolkit with her class. Nevertheless, the current toolkit concept lacks the perspective of children. The COVID-19 pandemic also had an impact on the participants’ engagement and recruitment in this research. Teachers were facing an increased workload (caused for instance by home-schooling rules), which had a negative impact on their availability and motivation to participate in this research. Hence, it was challenging to find teachers who wanted to participate, leading for instance to a low response rate of the online survey or drop-outs during the evaluation study.

Lastly, the COVID-19 pandemic impacted the design process of the toolkit. I aimed to build a social support network for teachers as described in Chapter 5, since the toolkit is designed around notions of infrastructuring. To design and evaluate a toolkit like
this, it requires including external collaborators and stakeholders. I contacted multiple stakeholders (for instance a Science lab for children and school classes and a FabLab) who offered to support teachers in using the toolkit. Unfortunately, the stakeholders had to close for a longer period of time than initially expected at the beginning from the pandemic or implemented severe restrictions which made collaborations impossible. As a consequence, I needed to focus on an online support group and social media to share the toolkit and ‘what-if scenarios’ (teachers needed to imagine that they had access to technical resources or FabLabs because they were closed).

To summarise, this thesis was impacted by the COVID-19 pandemic in multiple ways: The choice of research methods, participants and their availability was limited. Hence, I made suggestions for further research after the pandemic in future work 8.3.

8.3 Future work

Since the majority of limitations were caused by the COVID-19 pandemic, I focus here on suggestions for future work without taking into account any restrictions or limitations caused by COVID-19 regulations.

8.3.1 Evaluating the toolkit with teachers and children at schools

Resulting from the restrictions during the pandemic, the toolkit could not be evaluated with children and only one teacher was able to use parts of the toolkit with her class. To evaluate how teachers experience the use of the toolkit and how children interact with it, teachers could be given the toolkit during a second evaluation study to test it with their class. As explained in Chapter 7, an evaluation with teachers who use the toolkit in class is necessary to be able to confirm that the toolkit succeeded in sustaining the positive experiences and practices of the SPT project.

As explained in the Limitations 8.2, only a low number of teachers participated in the design process and in the evaluation of the toolkit. Consequently, I could not cover a broad range of class levels, ages of children they were teaching or different schools (outside Austria, for instance), leading to a lower generalisability of my findings. To inform the design process in terms of insights in diverse schools’ characteristics, a broader range of class levels and ages of children, additional design workshops with teachers and children from different schools (ideally outside Austria) would be important.

8.3.2 Including the perspectives of educational literature and experts

When developing the toolkit, I did not collaborate with experts in the field of educational sciences or evaluated the toolkit with them. Hence, the toolkit lacks educational perspectives. Including those perspectives might increase the likelihood that teachers are able to adopt SPT practices and ensure that the toolkit meets the contextual characteristics of a classroom setting. Hence, I recommend for future work to include literature on teacher
education and the development of classroom resources and to evaluate the toolkit with experts in the field of educational sciences.

### 8.3.3 Exploring long-term use of toolkit

To address the challenge of evaluating long-term use of the toolkit, the toolkit must be shared with a larger number of teachers for a longer period of time. This could be facilitated by for instance increasing the social media presence. This might give insights into how the practice of teachers has changed after using the toolkit and if it is still in use, giving first insights in possible sustainability aspects.

### 8.3.4 Expanding the support network

As explained in the Limitations 8.2 I had limited opportunities to build a support network for teachers who could support the teachers when using the toolkit. I might be interesting to explore more opportunities for support networks, for instance on a local level, to increase the support for teachers and offer teachers a better access to resources (such as machines or technologies). Possible collaborators could be FabLabs (as technical experts and for resources) or museums (such as science or technology museums) who could share the toolkit with a broader range of teachers or new audiences.

As discussed in Section 7.2.4 I have not explored in this thesis which political processes might be required to address contextual challenges and to support the use of the toolkit. Previous work has shown that, to support sustaining PD practices and experiences in a school context, knotworking with political and educational authorities could motivate new audiences to evolve their practices around PD practices and help addressing contextual constraints (for instance by adding topics related to technology design to the curriculum). Hence, actors such as political and educational authorities should be included in the support network.

### 8.3.5 Using approach in a different context

The present work then has so far only been used in a school context and the toolkit approach was developed for the characteristics of this specific context. I argue that there might be more contexts in the field of HCI and PD (for instance FabLabs who engage children in technology design activities) in which a similar approach could support researchers to enable participants and similar audiences not involved in the initial project to sustain similar practices and experiences. Especially in HCI and PD, researchers often engage in situated contexts with multiple stakeholders involved. It might be interesting to apply the considerations for future practices and the toolkit approach in a different context to explore the generalisability of the contributions this thesis makes.

### 8.3.6 Main Takeaways

This thesis makes two main contributions:
8.3. Future work

1. A socio-material toolkit which supports teachers to engage in technology design activities with children, using methods based on PD practices and a support network

2. Considerations for future PD practices which can help researchers to enable participants and similar audiences not involved in the initial project to evolve their practices around PD

I contribute to research and design knowledge on toolkits in HCI and PD by extending the conceptualisation of existing toolkits as: collection of social and material tools. I argue that a socio-material toolkit addresses the contextual constraints and characteristics of schools, in which PD projects with children often take place, better than a stand-alone toolkit. Initial insights from the evaluation indicated that a toolkit approach could increase the likelihood of sustaining positive experiences and practices of PD projects in a school context for audiences involved and not involved in the initial project. This leads to my second contribution: Considerations for future PD practices which can help researchers to enable audiences not involved in the initial PD project to have PD experiences. The considerations draw, like the toolkit approach, on infrastructuring as a lens to analyse, utilise, scale and evolve existing infrastructures as a pathway to increase the likelihood of sustained experiences and practices. I also highlight the importance of analysing underlying values of a project, a driving factor for PD practice, and having a pro-active attitude, which is crucial when infrastructures need to be developed or evolved to support sustaining PD experiences and practices.
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<td>115</td>
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<td>6.2</td>
<td>Overview of topics.</td>
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<td>6.3</td>
<td>Overview of topics from the curriculum linked to the toolkit.</td>
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<td>Overview of tools and how often they are used.</td>
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<td>6.5</td>
<td>Overview of Sozialformen and frequency used in lesson plans</td>
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<td>6.6</td>
<td>Overview of resources combined with the toolkit.</td>
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</table>
6.7 Overview of different opportunities for collaborations mentioned by the teachers in the lesson plans, interview and focus groups. If the collaboration is mentioned by the same teacher in the lesson plan/interview/focus group, it counts as "T".

6.8 Overview of final design implications.
Bibliography


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Appendix A: Initial coding for literature review

Literature review: Sustaining impact in PD projects with Children

The following pages illustrate the results from the initial coding process for the literature analysis in Section 2.3.
<table>
<thead>
<tr>
<th>Article</th>
<th>Sustainability aspects</th>
<th>Project outcomes</th>
<th>Approach used to sustain or measure impact</th>
<th>Collaborations and people involved</th>
<th>Context</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barendregt et al., 2016</td>
<td>Mutual learning</td>
<td>Better learning outcomes for children</td>
<td>Learning through design - formulating learning goals, communicating learning goals and reflecting</td>
<td>children, teachers</td>
<td>schools and after-school facility</td>
<td>Teachers try to influence activities. Teachers are important to create a safe environment for children with special needs, but researchers should explain the mindset to them and get them involved.</td>
</tr>
<tr>
<td>Börjesson et al., 2019</td>
<td>User gains</td>
<td>Improving gains of teachers and children</td>
<td>Classroom participation, PD workshops run by students</td>
<td>children, teachers</td>
<td>school context</td>
<td>Teachers participated with their classes teachers played passive role during design activities</td>
</tr>
<tr>
<td>DerBoven et al., 2015</td>
<td>Values</td>
<td>children's values underlying their design choices (concerning the prevention and reconciliation of Multimodal Analysis, analysing textual and tangible co-design outcomes)</td>
<td>children</td>
<td>two schools</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dreessen &amp; Scheepers, 2018</td>
<td>long-term relationships and long-term participation</td>
<td>sustainable relationships with local actors</td>
<td>backstage activities</td>
<td>Importance of backstage activities with local actors to nurture long-term relationships (youth workers, teachers, FabLab researchers): jam sessions, informal gatherings, phone calls, coffee breaks, Facebook conversations, FabLab infrastructure as context, more “fun” than school context Sustainable relationships with local actors</td>
<td>schools, FabLabs/Maker Culture</td>
<td>Educational context activities related to school fun, not just fun</td>
</tr>
<tr>
<td>Duh &amp; Chen, 2010</td>
<td>Adoption of design outcomes</td>
<td>Game design recommendations</td>
<td>Fantasy Theme Analysis to generate design recommendations, evaluation by game designers to evaluate effectiveness of approach</td>
<td>Collaboration with game designers</td>
<td>Game design</td>
<td></td>
</tr>
<tr>
<td>Duveskog et al., 2009</td>
<td>behavioural changes (i.e. changes in behaviour, lifestyle, stigma, attitude...)</td>
<td>Guide to establish digital projects as alternative to imported technology, better supporting societal changes Technology creation by using PD, students compose stories and reflect how these relate to their own life experiences; interviews with students, multimedia clubs in schools, collaborations with drama group</td>
<td>primary school children, university counseling students, HIC counseling experts, ICT experts</td>
<td>secondary school children,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Franco &amp; Lopes, 2009</td>
<td>Learning outcomes</td>
<td>improved digital literacy of children and educators; being able to build digital content with autonomy in diverse contexts inside and outside school environment. For teachers: experiencing and reflecting how to develop school curriculum</td>
<td>Computer supported collaborative and interdisciplinary learning experiences Educators (ICT facilitator) science fair Workshop at school for teachers</td>
<td>Educators (ICT facilitator)</td>
<td>K-12 education, school environment. Students spreading knowledge about 3D technology during science fair to other individuals. Outcome: change in school's curriculum, ICT teacher has been inspired by science fair and developed on his own technical skills, he now applies at his school and teaches 3D modeling and programming.</td>
<td></td>
</tr>
<tr>
<td>Hansen et al., 2019</td>
<td>Meaningful, long-term motives, sustainable design</td>
<td>motivative teenager to engage in PD activities; namify application Incitements as beverages, fruit and sweets -&gt; no school situation, do something they would never expect in school situation, awarded with cinema tickets and free lunch; tangible tools to inspire participants, motivational cards, tools. To think with, items for identification (t-shirts, key hangers), cooperation in teams, children were encouraged as experts (invited as “experts”), presentations, sharing stories</td>
<td>Litium project, teenagers at schools, two industry partners, pupils 12-14 yo at two public schools, teachers, school administrators</td>
<td>two schools</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Litium project, teenagers at schools, two industry partners, pupils 12-14 yo at two public schools, teachers, school administrators | two schools | |

K-12 education, school environment. Students spreading knowledge about 3D technology during science fair to other individuals. Outcome: change in school's curriculum, ICT teacher has been inspired by science fair and developed on his own technical skills, he now applies at his school and teaches 3D modeling and programming. | |

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K-12 education, school environment. Students spreading knowledge about 3D technology during science fair to other individuals. Outcome: change in school's curriculum, ICT teacher has been inspired by science fair and developed on his own technical skills, he now applies at his school and teaches 3D modeling and programming. | |

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Litium project, teenagers at schools, two industry partners, pupils 12-14 yo at two public schools, teachers, school administrators | two schools | |

K-12 education, school environment. Students spreading knowledge about 3D technology during science fair to other individuals. Outcome: change in school's curriculum, ICT teacher has been inspired by science fair and developed on his own technical skills, he now applies at his school and teaches 3D modeling and programming. | |

Litium project, teenagers at schools, two industry partners, pupils 12-14 yo at two public schools, teachers, school administrators | two schools | |
<table>
<thead>
<tr>
<th>Year</th>
<th>Study</th>
<th>Children's Participation</th>
<th>School Context</th>
<th>Challenges</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>Iivari et al.</td>
<td>Children are able to express their feelings and values of all stakeholders, including children as protagonsits.</td>
<td>School context supports genuine participation.</td>
<td>Teachers in the position of power, which might impact design sessions. Children usually don't act as decision makers. School work and initial concepts often do not support children’s ideas. Children do not usually have much authority. Not much transparency in decision making.</td>
<td>Children realize that they have a choice in design processes. Children are provided with meaningful alternatives to existing design process models, which encourages them to have a voice in designing their own projects. Children are engaged in design processes. Children are provided with meaningful alternatives to existing design process models, which encourages them to have a voice in designing their own projects. Children are engaged in design processes.</td>
</tr>
<tr>
<td>2018</td>
<td>Smith</td>
<td>Children realize that they have a choice in design processes.</td>
<td>School context supports genuine participation.</td>
<td>Teachers in the position of power, which might impact design sessions. Children usually don't act as decision makers. School work and initial concepts often do not support children’s ideas. Children do not usually have much authority. Not much transparency in decision making.</td>
<td>Children realize that they have a choice in design processes. Children are provided with meaningful alternatives to existing design process models, which encourages them to have a voice in designing their own projects. Children are engaged in design processes. Children are provided with meaningful alternatives to existing design process models, which encourages them to have a voice in designing their own projects. Children are engaged in design processes.</td>
</tr>
<tr>
<td>2016</td>
<td>Iivari &amp; Knuula</td>
<td>Children realize that they have a choice in design processes.</td>
<td>School context supports genuine participation.</td>
<td>Teachers in the position of power, which might impact design sessions. Children usually don't act as decision makers. School work and initial concepts often do not support children’s ideas. Children do not usually have much authority. Not much transparency in decision making.</td>
<td>Children realize that they have a choice in design processes. Children are provided with meaningful alternatives to existing design process models, which encourages them to have a voice in designing their own projects. Children are engaged in design processes. Children are provided with meaningful alternatives to existing design process models, which encourages them to have a voice in designing their own projects. Children are engaged in design processes.</td>
</tr>
<tr>
<td>Authors</td>
<td>Year</td>
<td>Learning outcomes</td>
<td>Study</td>
<td>Participants</td>
<td>Research Methods</td>
</tr>
<tr>
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</tr>
<tr>
<td>Iversen and Dindler, 2014</td>
<td>Maintaining, scaling, replicating and evolving PD initiatives beyond individual projects.</td>
<td>PD initiatives. Defined as physical objects, systems, ideas, practices and combinations that can be sustained after a project.</td>
<td>Using well-known PD methods with a focus on methods which support networking, stakeholder engagement etc.</td>
<td>Primary school teachers, members of the school management, IT manager; later contact with politicians, decision-makers and domain experts to communicate findings</td>
<td>Design of educational design for primary school</td>
</tr>
<tr>
<td>McNally et al., 2017</td>
<td>Learning outcomes</td>
<td>Understanding what gains children perceive: collaboration, communication, design process knowledge and confidence. Ultimate outcome: improved PD process and technique, better technologies and enhanced participant-researcher relationship</td>
<td>Co-design skills (creativity, empathy and collaboration) were defined upfront and implemented during the project during co-design workshops. They were assessed with post-interviews and questionnaires.</td>
<td>Primary school teachers, members of the school management, IT manager; later contact with politicians, decision-makers and domain experts to communicate findings</td>
<td>Design of educational design for primary school</td>
</tr>
<tr>
<td>Mechelen et al., 2019</td>
<td>Learning outcomes</td>
<td>Children reported fluctuating skills, but positive trend is visible.</td>
<td>Co-design workshops (storytelling, determining the protagonists' wishes and needs) focusing on exploring problem, ideating solutions and presenting ideas. The data was collected with observation reports, post-interviews and transcripts.</td>
<td>Children</td>
<td>School (close to a hospital)</td>
</tr>
<tr>
<td>Mechelen et al., 2018</td>
<td>Developing empathy</td>
<td>The children's empathy was supported with co-design activities</td>
<td>Co-design workshops (storytelling, determining the protagonists' wishes and needs) focusing on exploring problem, ideating solutions and presenting ideas. The data was collected with observation reports, post-interviews and transcripts.</td>
<td>Children</td>
<td>School</td>
</tr>
<tr>
<td>Mechelen et al., 2014</td>
<td>Meaningful design concepts, values, group dynamics</td>
<td>Balanced co-design dynamics to impoe dialectic process of developing values and ideas in PD</td>
<td>Co-design workshops (storytelling, determining the protagonists' wishes and needs) focusing on exploring problem, ideating solutions and presenting ideas. The data was collected with observation reports, post-interviews and transcripts.</td>
<td>Children</td>
<td>School</td>
</tr>
<tr>
<td>Source</td>
<td>Methodology</td>
<td>Findings</td>
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<td>---------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
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<tr>
<td>Meloni et al., 2020</td>
<td>Empowerment</td>
<td>Design workshop, structured around a design tool (SNaP, card-based game), guiding children in design of smart objects. Data gathered with self-report questionnaires before and after the workshop. Ad hoc questionnaire and moderators semi-structured diaries.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Robinson et al., 2020</td>
<td>Positive and meaningful experiences</td>
<td>Creation of &quot;Not an Any Map&quot;, an interactive physical device, positive outcomes: engaged with technology, increase in agency, overall positive impact on life and the life of the participants family. The participant makes deliberate choices, has personal freedom to access application by himself (independent use of prototype). Application has a positive impact on participant, enables him to progress from a simple toy to a multi-object.</td>
<td></td>
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</tr>
<tr>
<td>Schepers et al., 2018a</td>
<td>User gains</td>
<td>Children developed self-esteem, learning-by-doing skills and broadened their social environment, empowers them. Co-design FabLab workshops with vulnerable children, encouraging children to design their own workshops, evaluative interviews, informal group interviews, semi-structured interviews with youth workers long-term engagement, strong relationships with others.</td>
<td></td>
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</tr>
<tr>
<td>Schepers et al., 2018b</td>
<td>User gains</td>
<td>Fun as user gain, developing self-esteem, being proud of their own skills and persistence and stepping out of their comfort zone fun in: overcoming challenges, working towards finalised object, experimenting, interacting with others. Provide them with intrinsic motivation, keep them engaged, for their own sake not for reward, Observations/senzitizing, participatory mapping, low-tech workshops, evaluations, high-tech workshops, informal brainstorming, observations, semi- and unstructured interviews.</td>
<td></td>
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<tr>
<td>Schepers et al., 2021</td>
<td>Empowerment &amp; Infrastructuring, dynamic relationships formed around issues, long-term realtionship</td>
<td>Children are empowered in infrastructural process, design process accompanied by policy recommendations, matchmaking citizens with local organisations and forming attachments, activities on a social and an interrelational level -&gt; infrastructural approach to empowerment.</td>
<td></td>
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</tr>
<tr>
<td>Smith et al., 2013</td>
<td>sustainable ecologies, appropriation, sustainable use practices</td>
<td>Motivations emerged frm collaborative process, new understandings of the school by exploring physical environment, appropriations of technology and integration with physical environment. Ecological Inquiry resulted in insights created through explorations into social practices, school environment and social ecological inquiry, collaborative explorations inside peoples' own contexts. Scaffolding the emergence of dynamic social practices and meanings; creating environments and ecologies, iterating appropriations, negotiation and collaboration among variously positioned stakeholders.</td>
<td></td>
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</tr>
<tr>
<td>Author(s)</td>
<td>Title</td>
<td>Methods</td>
<td>Participants</td>
<td>Setting</td>
<td></td>
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</tr>
<tr>
<td>Van Rijn &amp; Stappers, 2018</td>
<td>Ownership</td>
<td>Feeling of ownership, parents showed pride through participatory design, context mapping: users are put in the position of expert of their own experiences, encouraging users to express themselves through a workbook with assignments, toolkits for expression, and children receive a toolkit for expression consisting of sensorial materials.</td>
<td>Autistic children, their parents, care professionals</td>
<td>Homes of the participants</td>
<td></td>
</tr>
<tr>
<td>Wakil &amp; Dalsgaard, 2020</td>
<td>Outcomes, defined as creative output</td>
<td>Many existing PD methods rely on abstract components need to be revised to be applied in different domains; same PD methods applied in two different domains resulted in different outcomes in terms of creative output.</td>
<td>Comparing 2 PD projects with similar methods: Future Workshop, Inspiration Card workshop, Mock-up session</td>
<td>School children aged 12-19 in India and Scandinavia, two school classes, an impoverished district in New Delhi and one in Scandinavia</td>
<td>Children in New Delhi had trouble articulating problems and design opportunities, breakdowns, limited creative output and independent proposals (but 3rd workshop game changer) -&gt; different settings require different PD methods, existing PD methods dont yield same outcomes across domains</td>
</tr>
</tbody>
</table>
Existing toolkits literature review

The following pages illustrate the results from the initial coding process for the literature analysis in Section 2.6.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Toolkit</th>
<th>Use of toolkit</th>
<th>Content Toolkit</th>
<th>Type</th>
<th>Methodological framework</th>
<th>Aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sylla et al., 2012</td>
<td>t-books</td>
<td>storytelling</td>
<td>electronic platform, picture cards</td>
<td>electronical/physical</td>
<td>children engage as story authors, play with language elements, create and share their own stories</td>
<td></td>
</tr>
<tr>
<td>Kazemitabaar, et al., 2017</td>
<td>MakerWear</td>
<td>construction of tech</td>
<td>wearable construction toolkit</td>
<td>wearable, physical/electronical toolkit</td>
<td>Participatory design</td>
<td>empowering children to create personally meaningful computational designs</td>
</tr>
<tr>
<td>Wallbaum et al., 2020</td>
<td>IoT toolkit</td>
<td>learning and design</td>
<td>Distributed wireless modules; visual programming environment</td>
<td>IoT toolkit, physical, electronical, modules; visual programming environment</td>
<td>evaluation</td>
<td>Children understand and are able to interpret embedded computing, learning how to program them</td>
</tr>
<tr>
<td>Arora et al., 2019</td>
<td>DIO Construction Toolkit</td>
<td>Co-making shared constructions</td>
<td>tangible modules with various attachments that allow suspension on the body, supporting input/output functionalities; wireless and can be linked together with AR interface on smartphones</td>
<td>digital-physical construction toolkit</td>
<td>User studies/evaluation</td>
<td>enable constructionist learning for children</td>
</tr>
<tr>
<td>Baek &amp; Lee, 2008</td>
<td>Info Block &amp; Info Tree</td>
<td>building information architecture for children</td>
<td>blocks representing depth of information hierarchy, velcro to attach them; tree consisting of styrofoam trunk, wooden sticks, styrofoam balls of different sizes</td>
<td>physical materials</td>
<td>Participatory design</td>
<td>enable children to build an information architecture in an enjoyable and easy manner, prototypes that fit their needs and abilities</td>
</tr>
<tr>
<td>Barbareschi et al., 2020</td>
<td>TIP-Toy</td>
<td>learning about computational topics, with music for children with different visual abilities</td>
<td>physical blocks, open-source educational coding toolkit</td>
<td>physical/digital/electronical parts</td>
<td>Design consultations with experts and potential users</td>
<td>allowing children with different visual abilities to learn about computational topics through music by combining a series of physical blocks</td>
</tr>
<tr>
<td>Chawla et al., 2013</td>
<td>Dr. Wagon</td>
<td>tangible programming toy</td>
<td>series of programming blocks and a wagon-shaped robot</td>
<td>physical/digital/electronical parts</td>
<td>evaluated at expo, yet to be evaluated with children during user tests</td>
<td>enable children to program. Engaging them to explore introductory programming environments</td>
</tr>
<tr>
<td>Freed et al., 2011</td>
<td>I/O Stickers</td>
<td>handcrafting personalized remote communication interfaces</td>
<td>Adhesive sensors and actuators, wirelessly connected</td>
<td>physical/digital parts</td>
<td>pilot study: workshop with children</td>
<td>empowering children to implement ideas that would otherwise require advanced electronics knowledge; supporting creative learning about communication and making keeping in touch playful and meaningful</td>
</tr>
<tr>
<td>Garzotto &amp; Gonella, 2011</td>
<td>Open-ended tangible environment; RFID tags</td>
<td>Bridging gap between physical and digital worlds with RFID tags, flexible toolkit for disabled children, modifiable to address different needs of children</td>
<td>model based and pattern based web application framework for tangibles, implementing End-User Development paradigm and Meta-design approach</td>
<td>digital; RFID tags</td>
<td>End-User Development paradigm and Meta-design approach; Tangible application model (TAM) framework evolved through interactive activities at schools in real-life educational settings; evaluated with workshop-style sessions with experts</td>
<td>supporting creation and customization of tangible learning experiences for disabled children</td>
</tr>
<tr>
<td>Jacoby &amp; Buechley, 2013</td>
<td>StoryClip</td>
<td>narrative storytelling and interaction design; drawings function as audio recording; and playback interface</td>
<td>silver inKart supplies, hardware-software tool</td>
<td>physical tools; digital tool, crafting materials</td>
<td>workshops with children</td>
<td>motivate technological exploration and multi-level engagement with children</td>
</tr>
<tr>
<td>Study</td>
<td>Toolkits/Kit</td>
<td>Interactions</td>
<td>Components/Features</td>
<td>Findings/Impact</td>
<td></td>
<td></td>
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<tr>
<td>------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
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<td></td>
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</tr>
<tr>
<td>Qi et al., 2015</td>
<td>Chibitronics circuit stickers</td>
<td>crafting with electronics, enabling basic electronic interactions</td>
<td>Modular, flexible circuit components with conductive adhesive pads; LEDs, sensors, pre-programmed function generators and programmable microcontroller, educational support resources (sticker sketchbook with lessons and activities for crafting circuits onto templates)</td>
<td>toolkit released publicly, user activities have been followed through workshops, online communities and media organizations, museums, after-school activities, households and craft studios, formal user studies have yet to be done</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kazemitaar et al., 2016</td>
<td>ReWear</td>
<td>designing e-textiles/wearables</td>
<td>modular plug-and-play construction kit with interactive electronic and computational behaviors for retrofitting existing textiles</td>
<td>exploratory evaluation with children, engaging children in the creative design, play and customization of e-textiles/ wearables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kazemitaar et al., 2015</td>
<td>MakerShoe</td>
<td>designing shoe-based interactive wearables</td>
<td>e-textile platform; single function magnetically attachable electronic modules for circuit creation and design of responsive, interactive behaviors</td>
<td>Participatory design; Cooperative Inquiry, Supporting creation and customization of tangible learning experiences for disabled children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kindborg &amp; Söker, 2007</td>
<td>Magic Words</td>
<td>construction of interactive worlds and games</td>
<td>contextual signs in the form of word pads representing behaviours on graphical characters; drag and drop word pads from gallery onto play area, character words &amp; background words, command words etc</td>
<td>Digital evaluated with children, enable children to create own computer-based toys such as games</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kirlangic et al., 2020</td>
<td>Robo2Box</td>
<td>let children express themselves in an area they lack state-of-the-art knowledge, learning from them what they want for a classroom robot</td>
<td>physical body parts (3D printed legs, arms etc.); Velcro 3D files</td>
<td>user-centric approach, using existing toolkit, toolkit is used before and after storytelling, convey IoT toolkit (codeMe) developed for adults to children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lechelt et al., 2016</td>
<td>ConnectUs</td>
<td>IoT toolkit, learning about IoT concepts and designing their own systems</td>
<td>Interactive sensing cubes (CodeMe toolkit), embedded sensors, displays, Bluetooth physical/digital/electronic building blocks</td>
<td>hands-on user activities with children, engaging children in critical thinking about sensors, sensor data and act of sensing activities for children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lechelt et al., 2020</td>
<td>Magic Cubes</td>
<td>Sensor toolkit, enabling children to explore and visualize sensor data</td>
<td>hand-sized cubes with embedded sensors and numeric or symbolic visualizations physical/digital/electronics cubes</td>
<td>Critical Thinking; open-ended, exploration-based activities for children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liu et al., 2020</td>
<td>ModBot</td>
<td>robotic toolkit, enabling children to learn concepts adn receive construction feedback</td>
<td>electronic, counterweight and shape modules to build underwater robots; software application</td>
<td>user study, workshops with children, expose children to underwater robots, raising awareness; allows children to learn and think in practice, improve abilities of innovation, exploration and independence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mayer et al., 2009</td>
<td>iTheater</td>
<td>storytelling: interactive integrated system for story creation and storytelling</td>
<td>Puppet Interface for controlling virtual characters; set of physical objects as Tangible User Interface Toolkit to perform animation-editing through the objects</td>
<td>user study with mainly adults and one child; allows children to give life to imaginary characters by creating, editing and recording computer animations through movement and tactile manipulation of hand puppets</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
creating interactive objects, computational construction kit
Blend of Scratch and Arduino platforms, based on graphical blocks
digital, free web-based graphical programming interface
based on Learn 2 Teach, Teach 2 Learn (youth empowering program) to enable young people to express themselves using technological tools, not yet tested with children
enabling children to participate in creating tangible user interfaces with access to creative communities associated with Scratch and Arduino projects

creating digital tactile feelings, children can combine sensors to create haptic content
haptic design module based on littleBits
physical/digital/electronical parts, combined with pre-existing technology (littleBits)
usability test with children
allowing children to express their imagination by adding a digital tactile feeling to things, providing experiences of creation

Fun toolkit; evaluating experiences of children
Smileyometer
digital - materials can be printed
Two studies from two different age groups in two different contexts evaluate interactive technology installations with the toolkit
test for user experience with children

Fun toolkit; evaluating experiences of children
Smileyometer, Funometer, Again– Again Table, Fun Shorter; video footage to scrote engagement
digital - materials can be printed
evaluation
collecting information on children’s opinions, attitudes and behaviour directly from the children, include them in decisions about their own environment

learning; make students feel like designers
wooden case, LEDs, conductive glue, modified Arduino, visual programming
digital toolkits, physical/electrical/digital
Design Based Learning approach; literature study and two design case studies; user centered design process
support development of a subset of 21st century skills: creativity, critical thinking, problem solving, collaboration and reflection

construction and animation
actuator, wireless communication device, micro-controller
physical/digital/electronical parts, software
user study with adults
users can easily construct and animate systems using everyday objects

Survey toolkit; Again again used in this paper
digital - printed on paper
comparative study of prototypes, ranging from low fidelity to high fidelity within context of mobile games, user experiences measured with toolkit
measuring user experiences

Survey toolkit
Smileyometer, again-again, fun sorter
digital - printed on paper
comparative analysis of toolkit and the effect of culture on game preference
evaluate user experience and the effect of culture on their game preference

Survey toolkits
came as fun toolkit; This or That: Pairwise comparison scale
digital - materials can be printed
evaluation
evaluating user experience with children

storytelling
box filled with 180 wooden shapes, divided in different categories (i.e. people, nature); children can tell actual stories and future stories
physical materials
pilot study; two co-design sessions
enables children to tell personal stories using various wooden shapes; based on stories, designers engage in conversation about children’s needs and wishes

storytelling
lsl robot, images from books printed on cards
existing technology (robot), printed images
in the wild study, testing toolkit at school
allowing teachers to create, adapt and share interactive learning applications, uptake of technology in class, investigating teachers requirements

Game design
3D environment, drag and drop feature to drop elements in 3D space and create new game level
digital
exploratory study with children who were previously engaged in collaborative inquiry projects
children construct games others would enjoy playing and explore role as developer

storytelling
tangible interface for storytelling; picture cards
paper based tangible interfaces
Cooperative Inquiry, workshops with children
children and teachers can build their own digital enhanced learning activities
<table>
<thead>
<tr>
<th>Study (Year)</th>
<th>Tools/Approach</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tseng et al., 2011</td>
<td>Mechanix tangible design, social learning, interaction design</td>
<td>Interactive display to create, record, view and test systems of tangible machine components, interactive-whiteboard-based system, low-cost materials: acrylic tangible magnetic components, low-cost LED projector, web camera, laptop, wire-mesh, acrylic display; existing technologies (laptop, display, camera, magnetic components); software</td>
</tr>
<tr>
<td>Villanueva et al., 2020</td>
<td>Arbits learning, STEM, electrical circuitry</td>
<td>DIY, AR-compatible electrical circuitry toolkit; digital, vector and CAD files for laser-cutting components; existing components (LEDs, buzzers, motors etc) are combined with cutted parts</td>
</tr>
<tr>
<td>Wolff et al., 2004</td>
<td>Scene-Driver entertainment, re-use of broadcast animation content for new experiences for children</td>
<td>Software toolkit, domino-like game, included set of tiles that depict (i.e. characters from the series) Software (digital)</td>
</tr>
</tbody>
</table>

User studies with children; toolkit is based on learning sciences and interaction design for children; example-based learning, socio-constructivism; documenting tangible design work, facilitating social learning and collaboration, accessible for a broad range of learners.

Yet to be evaluated with children during workshops; hands-on learning tool for electrical circuitry, accessible for children to construct electrical circuits and components; Fablabs should build the toolkit.

Providing engaging experiences for children by re-using broadcast animation content.
Appendix B: SPT project

Informed consent forms
Consent Form
Parents

Name: ______________________________________________

Name of the child: ______________________________________________

We invite you and your child to take part in the research project "Social Play Technologies" and to design new technologies together. We would like to inform you in detail about the project before you agree to take part in this project together with your child:

- Have you read the document detailing information for parents?
- Did you had the chance to ask questions about the project?

The participation in the project is free and voluntarily. You can withdraw your participation at any time and without giving reasons, via email, telephone or verbally.

Your privacy is important to us. During this project audiorecordings and videorecordings, photographs and notes will be taken that document our collaboration for research purposes only. With your participation you explicitly consent to these recordings. All collected data and recordings will be anonymised completely for publications so that they do not contain personal information or hints to identify your child.

For every individual case in which data is published that contains personal information (e.g. pictures for newspapers that show your child), we will ask you for your permission first. You can decide for each case individually.

We highly treasure the wellbeing of your child. Your child should enjoy the collaboration and make positive experiences with technologies. Should you or somebody else in the environment of your child have second thoughts about this, we would like you to ask to contact us immediately so we can react on this.

Date and und signature:

http://socialplay.at
Social play has a key role in the development and the successful inclusion of people with disabilities. Typical characteristics of autism, like difficulties with social behavior and communication as well as repetitive behavior patterns, make social play very challenging for children with an autism spectrum disorder. We aim with this project to find out how technology can support social play between children with and without autism at the age of 6 to 8. During this project we will develop smart play objects that react on social situations in a smart way to improve social play experiences between children with and without autism.

We want to develop technologies that:
- react on social interactions in an intelligent way,
- make collaborative play experiences possible for children with and without autism,
- support social play and,
- are fun to use.

To develop those kind of objects and to integrate them in the play of children, it is important to involve children in an active way in the design phase. The scientific results of this work are the result of the participatory activities that allow mixed groups of children to take part in creative design processes. In each group, 4 to 8 children will invent and research with us. Furthermore, we will develop and realise several smart objects as design cases and evaluate them in a novel way. With our research we are creating new pathways to inclusion by using technologies that are implemented in a play environment.

We would like your child to be part of a group and therefore invite you and the other caretakers of the child to design the technologies of the future. Are you interested? We have answered a few important questions in advance in the attachment. If you have other questions please contact us at any time.

Contact:
Dr. Christopher Frauenberger
Project Leader of Social Play Technologies
Institut für Gestaltungs- und Wirkungsforschung, TU Wien
Argentinierstrasse 8, 1040 Wien
info@socialplay.at
Tel.: 0043 158801 18793

Katta Spiel
katta@igw.tuwien.ac.at
Tel.: +43 660 6409636

Laura Scheepmaker
laura.scheepmaker@tuwien.ac.at
+31 6839 44484

http://www.socialplay.at
Your questions

Who is financing this research project?
The project is funded by the FWF (Förderung der wissenschaftlichen Forschung). The FWF is a central institution in Austria that supports fundamental research and is financed by the Bundesministerium for Science, Research and Economy.

Project number: P 29970-N31
The FWF online: http://www.fwf.ac.at

What does it cost to participate?
The participation in this project is voluntarily and free. All materials are provided by us. All costs that are caused by your participation in this project (like transportation costs etc.) are paid by the project.

Can the participation be withdrawn?
Yes, the participation can be withdrawn at any time without giving a reason.

How does the collaboration work?
When every children and their parents have agreed to collaborate, we first want to get to know another. During meetings with you, the teachers and other important caregivers, we are preparing the basis for a trustful collaboration with your child as early as possible.

During the design phase we have regular group meetings (usually two times a month) during school hours. How much time we have and at which days we meet depends on the needs of the group. We usually work for one hour outside of the children’s regular school periods. We would like to organise 10 to 15 meetings, so we have sufficient time to invent together novel ideas and to realise them.

What happens during a meeting?
We prepare activities for each meeting based on the needs and preferences of each group. We will also provide the materials for the meetings. If necessary, a teacher or other familiar caregiver of the child will be present during the sessions to create a safe environment for the children. Every meeting will be structured and your child will be informed beforehand what we are going to do and how much time the activities will take. Typical activities are drawing, building, tinkering, sketching, talking or exploring technologies. Your child can end the meeting or activity at any time.

Are we recording the meetings?
To document and to be able to analyse our meetings for research purposes we are recording every session on videotape and audio. Photographs are taken of drawings or objects and the researchers are taking notes during the meeting. We will tell every participant beforehand when we start the recordings.

What happens with the recordings?
The privacy of your child and all participants is very important to us. The recordings will be stored on a server of TU Wien and only the three project members have access to the recordings. Parents are allowed to look through the material concerning their child as well and at any time.

Will the recordings be published?
An important part of our research is to publish research results in academic papers or to present them at conferences. We base our work on the recordings that are taken during the group meetings with the children.

Recordings and collected data will be completely anonymised for publications. That means that if we report about the work with your child, we will use fictive names and will refrain from using pictures or videos that would reveal the identity of your child. Any other information that could reveal his or her identity will be removed as well.

In case that specific information of your child should be published, for example a picture of your child in a newspaper, we will always contact you in advance and ask for your permission. You can decide for each individual case or withdraw your agreement completely.

http://socialplay.at
What is the role of the parents and the teachers?
We would like to work closely together with you to guarantee that your child will make positive experiences during this project. That means that we will keep you updated and inform you on a regular basis about the process so that you have the final say in decisions and are not obliged to anything.

Moreover, we believe that you are an important expert in the life of your child. Therefore, we think that the collaboration with you is very important, in addition to the experience of the teachers and other caregivers. We will keep in touch with you to ask for your opinions and ideas.

Will my child be able to do... better?
This project has no therapeutic goal. We have an holistic view on the child and do not focus on the disability or disorder. That means that we cannot and do not want to promise therapeutical progress. What we want to achieve is to give your child positive experiences with the design of technology and that the project results in something fun that supports social play between children with and without autism.
Who we are

Dr. Christopher Frauenberger

Christopher founded the Social Play Technologies project and leads it for the Institute for Design and Assessment of Technology at TU Wien. He is responsible for the process and planning, but also works with the children. He has long-term experience with autism and technology and is specialised in developing methods and tools that allow autistic children to take part in the design process of technologies.

Email: christopher.frauenberger@tuwien.ac.at
Telefon: 01 58801 18793

Laura Scheepmaker

Laura Scheepmaker is a PhD student and project assistant. She has studied Creative Technology (BSc) and Industrial Design Engineering (MSc) at the University of Twente (Netherlands). She has joined the Social Play Technologies project in 2017 in which smart objects are co-designed with autistic children.

Laura’s research interests are design research, research through design, participatory design with children with disabilities and designing smart products. Laura has worked as a teacher and social worker in Germany prior to her academic education.

Email: laura.scheepmaker@tuwien.ac.at

Katta Spiel

Katta has a background in Cultural Studies and Computer Science from Bauhaus-Universität Weimar. Before joining Social Play Technologies, Katta was also part of the successful OutsideTheBox project in which the research team co-designed technologies with individual autistic children. Katta’s PhD centers around experiences of autistic children with technologies and including their first-hand perspectives. Other research interests include Games and Play, Critical Computer Science, Gender Studies and Philosophy of Science. Katta plays Roller Derby and can be found knitting in most meetings.

Email: katta@igw.tuwien.ac.at

Address: Institut für Gestaltungs- und Wirkungsforschung, TU Wien, Argentinierstrasse 8, 2 Stock, 1040 Wien

http://www.socialplay.at
Consent Form
Parents

Name: ____________________________________________

Name of the child: ____________________________________________

We invite you and your child to take part in the research project “Social Play Technologies” and to design new technologies together. We would like to inform you in detail about the project before you agree to take part in this project together with your child:

• Have you read the document detailing information for parents?
• Did you have the chance to ask questions about the project?

The participation in the project is free and voluntarily. You can withdraw your participation at any time and without giving reasons, via email, telephone or verbally.

Your privacy is important to us. During this project audiorecordings and videorecordings, photographs and notes will be taken that document our collaboration for research purposes only. With your participation you explicitly consent to these recordings. All collected data and recordings will be anonymised completely for publications so that they do not contain personal information or hints to identify your child.

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We highly treasure the wellbeing of your child. Your child should enjoy the collaboration and make positive experiences with technologies. Should you or somebody else in the environment of your child have second thoughts about this, we would like you to ask to contact us immediately so we can react on this.

Date and signature:

http://socialplay.at
Was ist Ihnen wichtig?

Die Arbeit mit Ihrem Kind macht uns sehr viel Spass und wir fühlen uns von den vielen kreativen Ideen, die während unserer Treffen entstehen, inspiriert. Wir denken aber auch immer wieder darüber nach, wie sehr unsere eigenen Vorstellungen und Werte die Zusammenarbeit prägen. Wir wollen daher herausfinden in wie weit sich unsere Vorstellungen und Werte mit dem decken, was Ihnen wichtig ist - für Ihr Kind und seine Entwicklung und für Sie selbst. Wir bitten Sie daher, uns ein paar Fragen zu diesem Thema zu beantworten.


Vielen Dank!

Beantworten Sie bitte folgenden Fragen entweder in kurzen Sätzen oder mit Schlagwörtern, die Ihnen spontan einfallen. Zögern Sie auch nicht, Anmerkungen zum Projekt zu machen die nicht zu einer der Fragen passen.

Was ist Ihnen besonders wichtig wenn Ihr Kind an aussertourlichen Aktivitäten wie diesem Projekt teilnimmt?

Welche Erwartungen haben Sie für Ihr Kind an die Teilnahme an unserem Projekt?
Welche Erwartungen haben Sie selbst?

Warum haben Sie sich dazu entschlossen, an unserem Projekt teilzunehmen?

Was bedeutet für Sie Inklusion und wie sehen Sie Ihr Kind als Teil der Gesellschaft?
Research ethics SPT project
Research Ethics

Introduction
Social Play Technologies for autistic children (SPT) aims to invite autistic and allistic children to co-design ubiquitous computing artefacts to scaffold social play activities in mixed (autistic and non-autistic) and physically co-located groups.

Workplan
The work is organised in two, identical cycles, each spanning one year of design and evaluation, interrupted by summer holidays. Within each year, we will co-design with two groups consisting of four to eight autistic and allistic children. Recruitment of participants and contextual research will commence at the start of the school year in September with design work starting when appropriate relationships have been fostered.

For contextual research we arrange meetings with teachers and the children for informal interviews and conduct observations in schools and use alternative methods such as probes and diaries to augment the data we collect. If possible, we include parents at this stage as well.

We aim to meet children in intervals of two weeks for design work over a period of five months (depending on holidays, roughly 10 - 20 sessions). Each session will take place in the school, in a separate room or the classroom. Next to the children there will always be at least two researchers present and, if possible, a teacher known to the children. Sessions will last between up to one hour depending on the routine and attention spans of children. We will prepare appropriate materials and activities for each session which interpret a chosen participatory design approaches. Since we develop these activities as part of this research, it is impossible to provide details at this point in time. However, we will implement a rolling ethics monitoring mechanism (see below) that ensures that each planned activity is considered from an ethics perspective and is compatible with the overall research ethics we outline in this document and poses no risks to the participants.

In some cases, we will try to arrange excursions with children, for example to visit a FabLab or the University. All excursions will be planned carefully in accordance with the children and the parents and at least one professional carer or one parent will accompany the group at all times.

In the evaluation phase, the interval of meetings will be increased to every two to four weeks. At these meetings we will conduct observational studies and interviews, and collect data from the artefacts. We will also record video data during observed interactions. In between we will ask parents, carers, teachers and children to keep diaries or make notes of observations. We aim to minimise the work load by supporting each group with appropriate tools to collect such data.

Participants
Our target group are autistic and allistic children between six to eight years of age (i.e., primary school entry level). Two considerations have led to this decision:

1. All children should be able to participate in the likely workshop activities and thus have basic skills such as drawing, constructing with building blocks, imaginative play etc., depending on the PD approach.

2. All children should be as young as possible to be minimally primed by the existing technology landscape.

Autism is incredibly diverse and often additional disabilities or behavioural problems are present. The decision to involve an autistic child in the project will be made on a case by case basis, carefully judging whether the child would be able to meaningfully participate in the planned activities. A decision will be made in collaboration with the parents, teachers and mentors who know the child well.

Recruitment
Participants are recruited through previously established connections with individual schools and mentors of the Stadtshulrat Wien.

Consent
Informed consent to take part is central to the ethical procedure we implement in the project and we will ask all participants, including children, parents, teachers and others, to formally agree to being involved. This will mostly happen in written form, but can if needed also be done orally. Sample consent forms are available in the appendix, but they share the following qualities:

- Forms are written in accessible, age-appropriate language and provide unambiguous ways for participants to agree or disagree with aspects of their involvement.
- Participants are fully informed about the purpose and the goals of the project as well as their intended role in it.
- The forms provide information about what participants can expect from taking part, both in terms of likely activities, required investment of time as well as potential outcomes and ownerships.
- Participants are free to terminate their involvement at any time and without providing any reason. In situations where the feedback towards activities is ambiguous, we will carefully determine whether it is in the interest of the child to continue the process.
- Participants are encouraged to ask any questions as they arise.
- Specific attention is paid to the legal implications of collecting data from the work such as personal information, pictures or video. Participants can choose between different levels of anonymity in the publication of their data (see below).

Collaboration will only commence if all participants have provided consent.

Risks and benefits to stakeholders
Children
The physical, psychological and emotional wellbeing and safety of the children involved is centrally important to us. If any of the researchers or participants observes any signs of the work having negative impacts on the children, or any other involved stakeholders the collaboration will be immediately paused and only continued once all participants have agreed that it is safe to do so (see conflict resolution below).

We are aware of the following potential risks to the children and will act to minimise the risk of their occurrence (potential counter strategies in parenthesis).

- Anxiety and stress during workshop sessions (flexibly adapting tasks during the workshop, taking breaks, aborting the session, seeking the help of professional carers).
- Behaviour meltdowns including actions intended to cause physical harm or self-harm (being vigilant for early signs and immediately seeking the help of the professional care team)
- Injuries during workshop activities (materials for activities have to be chosen to minimise the risk of any injury, the use of materials will be discussed with teachers and mentors considering each particular child. e.g., regarding DIY materials like glue, scissors etc., activities must be designed to ensure physical safety)

There are also various potential benefits to participants that the project aims to realise:

- Enjoyable and novel activities for children during the design process.
- Empowerment of children and other stakeholders by demonstrating how they can take charge of the design of technology they interact with in their lives.
- Scaffolding a novel interaction channel between the child and her social peers that potentially leads to positive behaviour change.

Teachers

Teachers play a key role in the collaboration we aim to establish. Potential risks to them include:

- Additional time effort (the project team seeks to minimise disruptions in schools and is sensitive to the work load of teachers and mentors)
- Mismatch between activities in the project and the curriculum in class (the team tries to design activities considering the current curriculum and thereby work in accordance to educational goals)

The work has the following potential benefits for teachers and mentors:

- Novel activities to engage the child and supporting teachers in their daily work.

Researchers

The project recognises the roles of researchers involved as stakeholders in the work and is committed to provide an equally safe and enjoyable working process for them. Below, we have identified potential risks and possible counter-strategies:

- Emotional and psychological stress. Working with children with disabilities can be strenuous and may effect researchers on an emotional and psychological level. (researchers are encouraged to seek advice from the academic peer group at the institute, particular from Prof Geraldine Fitzpatrick who acts as a mentor and advisor for the project. Psychological support structures are also in place at TU Wien which the researchers can contact).
- Pressures related to academic work (as with potential emotional stress related to working with children with disabilities we encourage team members to make use of...
psychological support if needed. Additionally, we aim to find an external mentor for each team member who can advice regarding academic work, e.g., secondary PhD supervisor, career coach)

- Injuries during workshop activities (as for children, we aim to design activities with health and safety for all participants in mind)

It is the hope that researchers also benefit from their involvement on different levels, ranging from conducting enjoyable workshop activities to the academic achievements and rewards.

**Data Collection & Protection**

During the work we will collect data in the form of personal information, photos, videos, drawings, artefacts and/or log data. For example, we will describe habits, video tape workshops, photograph artefacts built during the workshops, audio record interviews, keep research diaries detailing our experiences or collect drawings made by children (or other stakeholders). Most raw data will be digitised and stored electronically on the project server. Access to the raw data is restricted to the members of the project and appropriate measures are taken to protect the data on the server and the backup (encryption, access control).

We will ask participants as part of seeking their consent whether they are comfortable with us collecting data in this form and under which circumstances they would prefer us to not collect any data. We will also stress that participants can always ask for us to stop recording or delete any previous recording without providing any reason.

In the project, the raw data will be analysed and processed as part of our research. We will provide participants with a range of options regarding the potential use of this processed data. The levels of use are:

1. Data can be used in scientific publications if fully anonymised (all personal data removed)
2. Video and pictures can be used in scientific publications if faces and other significant personal features are distorted.
3. Video and pictures can be used in scientific publications unaltered if no other personal information is provided.
4. Data can be used in clear and for any kind of publication (e.g., webpage, newspapers) after seeking consent from the parents for each individual case.

The use of data that allows the identification of children is strictly an exception and will generally be minimised, even when consent has been given. Unintentional consequences like stigmatisation in peer groups can never be fully avoided and parents might not always be aware of such implications. The project team has a general responsibility to make judgements in the best interest of the child.

**Rolling Ethics Monitoring**

The nature of our work requires us to remain open for change and flexible with regards of developing our methods. Consequently, the way we interact with participants and involve
them in our research might change. We therefore need a mechanism to continuously assess our research ethics. To this end, we introduce the following rolling ethics monitoring into our research process:

1. Before each coherent series of workshops with participants, the project team will hold a designated meeting to assess the ethical implications of the specific activities that are planned. The assessment will be guided by a check list developed from this document and the recommendations of the ESRC Research Ethics Framework1.

2. After each cycle, there will be an annual, comprehensive research ethics review on the basis of the experiences made in the work. The project team will adapt its ethics procedures accordingly and will document any change in subsequent version of this document. If any substantial changes are planned, the project team will call on a panel of experts within the Institute to collect feedback.

Conflict Resolution
In case of any conflicts arising during the work, we have two mechanism to resolve them:

1. If any conflicts involve the work with children, we will pause the collaboration immediately and call a meeting with all participants around this child (parents, teachers, mentors, carers) or the group of children. If no resolution can be found that is supported by all, the collaboration will be ended. Naturally, the parents of the children always have the last word in determining the kind of collaboration they want them and their child to be involved in.

2. If conflicts arise within the research team, we seek the advice from our academic peer group at the institute, particularly from Prof. Geraldine Fitzpatrick who has agreed to act as an advisor and mentor for the project and its members. Any member of the team is encourage to contact her directly if they do not want to voice the issue within the group or if the issue is confidential.

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1 http://www.esrc.ac.uk/images/framework-for-research-ethics-09-12_tcm8-4586.pdf
Figure 1: Excerpt of initial theme generation process.

Coding examples

Researcher diary entry of a SPT workshop

Figure 2: Excerpt of theme generation process.

I. kritzelt dafür wild übers Papier, was S. merkt und sehr verwundert. S. wird in dieser Einheit vor allem an seinen eigenen Dingen zeichnen, aber immer wieder auch kurz zu den anderen schauen, und zur Action am Spielfeld. Erzeichnet nach dem Ubahnsystem einen Charakter, der eine Vier darstellt, und einen anderen, ein X, und möchte diese gerne ausschneiden, um sie dann mit nach Hause zu nehmen. Inzwischen hat sich I. auf den Boden gesetzt, auf einen runden Fleck, den C. gerade malt. Vor ihr entsteht ein Gesicht. Plötzlich hat I. die Idee, dass sie gerne die Zeiger einer Uhr sein möchte, und sie legt sich auf den Boden und bittet C., eine Uhr zu zeichnen. Synchron dreht sich I. mit dem Gezeichneten mit. Dann spielen wir G. Spiel. Sie hat Felder eingezeichnet, und Spielregeln angedeutet (was passiert bei welcher Würfelzahl etc.), fragt aber nicht nach Würfeln. Sie improvisiert mit den Anweisungen, und am Schluss gewinnt I., die als Erste in die Mitte auf den Schatz springt. Ein weiteres Spiel ist Tempelhüpfen, das wir letztes Mal auch schon gespielt haben. (Anm.: wessen Idee war das, und wer hat’s gezeichnet,

Beob.:

1. Das Licht, das nur einen rel. kleinen Bereich ausleuchtet, schafft die Notwendigkeit von räumlicher Nähe, somit gibt es automatisch das Gefühl von Gruppe und Gemeinsamkeit.

2. Welche Formen des Mitspielen sind für S. möglich? Ohne MediatorIn kaum möglich (aber es ist sowieso angedacht, dass einE LehrerIn anwesend ist) welche Tags braucht es? invertieren, Raster, Richtungswechseltag

3. Die Anwesenheit von C. tut der Gruppendynamik sehr gut. - sie ist interessiert, alles auszuprobieren, und versteht meist auch, „was wir von ihnen wollen“, und ist außerdem ein gutes Bindeglied zu Gabi

4. I. ist sehr kreativ und bringt viele eigene Ideen ein

Pictures taken during workshops
Figure 3: Wooden tokens, representing technologies.
Figure 4: The individualised sensor pads, an early prototype of the MusicPads.
Appendix C: Toolkit design process

Initial themes from teacher interview
Themen erstes Treffen Lehrer:innen Koffer

Was haben die beiden Gruppen gemeinsam:

- Kinder müssen Regeln verhandeln, gemeinsames Spiel verhandeln

Montessori Ausbildung von B. als Inspiration:

- In Freiarbeit mit Material arbeiten, gemeinsam planen, danach selber Material suchen. Pool von unterschiedlichen Materialien, zB Bee-Bot, Blue Board...

Relevanz von Koffer für Schulen:

- Schule von Bianca hat als Thema neue Technologien, wird immer wichtiger und Teil des Curriculums.

Erfahrungen von Bianca mit Designprozessen:

- Kinder sollen etwas bauen, und dann zB abmessen. Kepler Steine und Lego integriert ins Spiel mit Bee-Bot. Gemischt mit Holz, Lego, Bee-Bot... was die Kinder kennen. Unterschiedliche Materialien mischen und verbinden.
- Selbstkontrolle wichtig, Lehrer ist Begleiter,

Erfahrungen von Susi mit Designprozessen:


Was haben Lehrer:innen jetzt für Koffer:

- Spektra (Chemie), aber ohne Beschreibung
- Faustus (?) Koffer, nie verwendet (enthält Bildern von Gesichtern, Kinder lernen Gefühle), Rollenspiele -> sehr gefragt in der Schule, alles Material in einem Koffer mit Beschreibung
- Wenig Koffer für Sonderschulen

A4- Seite Regel um mit den zeitlich begrenzten Resourcen umzugehen:

- Kurz Informationen (A4!) wie was funktioniert und was es ist -> im Internet zu viele Informationen, selbst erarbeiten schwierig.
- Prozess bei dem Lehrer zusammen Wissen erarbeiten -> okay, aber Grundwissen erforderlich falls Fragen der Schüler kommen (zB was ist Strom)
- A4 Seite auch für Kinder!
- Schwierig Lehrer zu gewinnen die es bis jetzt ablehnen, Lehrer keine Zeit andere Lehrer zu unterrichten, Interesse muss von Schülern ausgehen
Bestehende Infrastrukturen in Schulen:

- Keine Zeit für lange Projekte -> eher in Richtung Projektwoche, oder in mehreren kurzen Einheiten

Erwartungen der Lehrer:innen an den Koffer:

- Übersicht, was das Kind lernt wenn es mit dem Koffer arbeitet -> Kompetenzen VS spielerische Auseinandersetzung, Problemlösung, Materialien geben Lösung nicht vor
- A4 Seiten mit Informationen, 1x für Kinder, 1x für Lehrer
- Miteinander arbeiten/lernen wichtig, nicht Ergebnis
- A4 Beschreibungen über Material (für Kinder und Lehrer)
- Material muss im Koffer komplett vorhanden sein (wenig Ressourcen von der Schule/Eltern)

Was nicht im Koffer sein soll:

- Erster Gedanke, wenn Schulen Technologien brauchen, Tablets -> aber kein “spanendes” Produkt, nicht sozial. man kann viel vielfältiger denken -> wir wollen nicht mit Bildschirmen arbeiten

Zu wenig finanzielle Resourcen um Koffer kaufen zu können:

- Geld für Bücher und Bastelmaterial, häufig nicht viel übrig für Bastelsachen
- Von Eltern anfordern, aber alle Lehrer müssen überzeugt sein, via Elternverein, aber problematisch (für Eltern, zu teuer)

Erwartete Probleme mit Koffer:

- Kein Interesse an Prozess -> Ergebnis wichtig
- Wenig Zusammenarbeit zwischen Lehrern, unterschiedliche Interessen
- Technik fremdes Fachgebiet -> Wissen notwendig
- Kinder finden vergleichen wichtig.

Fertige Aktivitäten:

- Viele Arbeitspläne nicht zufriedenstellend. Heft mit Platz für Fotos, Kinder berichten selber was sie gemacht haben -> besser
- Nicht als Buch für mehrere Lehrer zum austauschen -> Lehrer arbeiten alle unterschiedlich (mit den Robotern arbeiten zB nur 2 Lehrer)
- Bianca hat sich selber Bee-Bot Aktivitäten erarbeitet. Kreative Kinder (G und E) haben geholfen und Ideen geliefert.
- Susi: Sprache wichtig, Wörter über den Bereich kennen und Strukturen kennen.
Informed consent forms
Informationen zur Teilnahme am LehrerInnen Workshop

In den letzten 2,5 Jahren haben wir zusammen mit drei Gruppen von Kindern Technologien entwickelt, die sie in ihrem Spiel unterstützen. In diesem Jahr möchten wir unser Wissen weitergeben und wachsen lassen, und neben wissenschaftlichen Publikationen auch eine "Werkzeugkiste" für LehrerInnen entwickeln.


Um die Werkzeugkiste besser auf die Bedürfnisse von LehrerInnen und Kindern abzustimmen, brauchen wir die Expertise von Pädagogen und, wie auch bei den vorherigen Workshops, Kinder als Experten. Um das Material vorbereiten zu können, würden wir gerne einen LehrerInnen Workshop veranstalten, um unser Konzept zu besprechen und anzupassen. Danach ist ein weiterer Workshop zusammen mit den Kindern geplant, um die Werkzeugkiste zu testen.


Wir würden uns sehr über Ihre Teilnahme freuen!

Kontakt:
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Projektleiter
Laura Scheepmaker
laura.scheepmaker@tuwien.ac.at
Tel.: +43 681 10586237

Institut für Visual Computing und Human-Centered Technology, TU Wien
Argentinierstrasse 8, 1040 Wien
info@socialplay.at
http://www.socialplay.at
Tel.: 0043 158801 18793
Plan for PD workshop with teachers
Workshop Planung

Ablauf:
Mich vorstellen, was ich für das Projekt mache
Workshop Planung, Formulare

1. Konzept Toolkit erklären:
   - Warum Toolkit?
   - Was soll im Toolkit sein
   - Material vorstellen
   - Ablauf Workshop besprechen

2. Feedback Toolkit
   - Wir gehen Handbuch durch
   - Pro Block Feedback/Verbesserungsideen besprechen

3. Re-Design
   - Was ist noch nicht verständlich für Kinder?
   - Was kann man mit dem Material (Karten, Logbuch) machen?
   - Welche Infos brauchen LehrerInnen im Logbuch?
   - Fotos drucken?
   - Bauen strukturieren?
   - Welche Informationen bräuchtest du um solche Workshops machen zu können?
   - Was sollte im Handbuch stehen?
Survey questions
Technologie Toolkit Umfrage

Umfraugeantwort 1

Antwort ID
1

Datum Abgeschickt

Letzte Seite
5

Start-Sprache
de

Zufallsgeneratorstartwert
168361788

Allgemeine Fragen

Bevor Sie spezifische Fragen über das Toolkit beantworten, möchte ich etwas mehr über Sie wissen. Welche Schulform unterrichten Sie?

Haben Sie technisches Interesse?

Karten

Mit den Technologie Karten lernen Kinder den spielerisch, wie Technologien funktionieren und wie man sie kombinieren kann zu eigenen Erfindungen. Die Thema Karten inspirieren Kinder, sich Technologien auszudenken, die über bekannte Geräte und Technik hinausgehen. Mit den Impulskarten erhalten sie Anregungen, was ihre Technologien alles können und wofür man ihre Erfindungen einsetzen könnte. Bevor Sie die folgenden Fragen beantworten, schauen Sie sich bitte die Karten an, die auf der Toolkit Seite sind: Karten Wie viele Technologien sollen pro Kategorie (Sensoren/Ausgaben/Technik/Impuls/Thema) zur Auswahl stehen? [Sonstiges]

Wie verständlich sind die Karten für Schüler*innen? Würden die Kinder verstehen, was auf den Karten erklärt ist und was sie mit den Karten machen können?

Wie könnten die Karten noch verständlicher gestaltet werden?

Wünschen Sie sich noch andere Karten oder fallen Ihnen Karten ein, die hilfreich sein könnten?

Handbuch

Fällt Ihnen noch etwas ein, was im Handbuch stehen sollte? Welche Informationen brauchen Sie noch, um den Unterricht vorbereiten zu können?

In welcher Form soll das Handbuch sein? [Sonstiges]

### Logbuch

Das Logbuch leitet die Schüler*Innen mit Aufgaben durch die Unterrichtseinheiten. Schritt für Schritt durchlaufen sie so einen „Design Prozess“ und erfinden ihre eigenen Technologien. Mit dem Logbuch führen die Kinder ihr eigenes „Erfinder Tagebuch“ und lernen gleichzeitig, Fortschritte über ihre Arbeit zu notieren. Bevor Sie die folgenden Fragen beantworten, schauen Sie sich bitte das Logbuch an: Logbuch Wie verständlich sind die Aufgaben im Logbuch für Schüler*Innen?

<table>
<thead>
<tr>
<th>Wie könnten die Aufgaben noch besser/einfacher formuliert werden?</th>
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<tbody>
<tr>
<td>Nein</td>
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</table>

<table>
<thead>
<tr>
<th>Welche Inhalte sollen im Logbuch sein? Mehrere Antworten sind möglich. [Lösungsvorschläge für Logbuch Aufgaben]</th>
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</thead>
<tbody>
<tr>
<td>Nein</td>
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<table>
<thead>
<tr>
<th>Welche Inhalte sollen im Logbuch sein? Mehrere Antworten sind möglich. [Einführungsgrüße (die erklärt, warum sie etwas erfinden sollen)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nein</td>
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</table>

<table>
<thead>
<tr>
<th>Welche Inhalte sollen im Logbuch sein? Mehrere Antworten sind möglich. [Aufgaben]</th>
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<tbody>
<tr>
<td>Nein</td>
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</table>

<table>
<thead>
<tr>
<th>Welche Inhalte sollen im Logbuch sein? Mehrere Antworten sind möglich. [Platz für Notizen]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nein</td>
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</tbody>
</table>

Fällt Ihnen sonst noch etwas ein, was im Logbuch stehen sollte?

### Internetseite

In den Videos werden die Technologien erklärt und gezeigt, die auch auf den Technologie Karten stehen. Bitte schauen Sie sich 1-2 Videos an: Videos Wie verständlich sind die Videos für Schüler*Innen?

<table>
<thead>
<tr>
<th>Wie könnten die Videos noch besser/einfacher verständlich sein?</th>
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<tbody>
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</table>

<table>
<thead>
<tr>
<th>Wie lang sollen die Videos sein? [Sonstiges]</th>
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<tr>
<td></td>
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</table>

Was für zusätzliche Inhalte wünschen Sie sich noch auf der Internetseite?
## Abschluss

<table>
<thead>
<tr>
<th>Frage</th>
<th>Antwort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Was fehlt oder sollte anders sein an dem Toolkit, dass Sie sich vorstellen könnten, es im Unterricht einzusetzen?</td>
<td></td>
</tr>
<tr>
<td>Haben Sie noch Kritik oder Feedback?</td>
<td></td>
</tr>
</tbody>
</table>
Information for teachers about survey
Einladung zur Technologie Toolkit Umfrage

Liebe Lehrer*Innen,

Im Rahmen eines Forschungsprojekts an der TU Wien, in dem wir interaktive Technologien für soziales Spiel zusammen mit Volksschulkindern gebaut haben (http://socialplay.at/de), habe ich ein Technologie Toolkit entwickelt.


Das Toolkit ist digital und kostenlos beziehbar: https://sptoolkit.wordpress.com. Es besteht aus vier Teilen:

- **Technologiekarten**, mit denen Schüler*Innen mehr über Technologien lernen
- **Handbuch** für Lehrkräfte, in denen Aufgaben und Beispiele für Unterrichtseinheiten beschrieben sind
- **Erfinderlogbuch** für Kinder mit Aufgaben und Platz für Notizen
- **Videos**, die Technologien und Maschinen zeigen und erklären

Ich würde mich sehr über Ihre Hilfe freuen! Gerne können Sie das Toolkit und diese Umfrage mit Kolleg*innen teilen. Wenn Sie noch Fragen haben, können Sie mir jederzeit eine E-Mail schicken: laura.scheepmaker@tuwien.ac.at.

Herzliche Grüße,
Laura Scheepmaker

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Argentinierstrasse 8, 1040 Wien

http://www.socialplay.at
PDFs included in Inventor diary
Erfinder Logbuch

Namen der Erfinder und Erfinderinnen

______________________________  ____________________________  ____________________________

______________________________  ____________________________  ____________________________

Malt ein Bild vom Erfinderteam:

Zum Glück habt ihr eine Kiste mitgenommen, in der es viele technische Bauteile gibt. Aber wie baut man sich seine eigenen Technologien? Dafür habt ihr dieses Logbuch, das euch hilft, die Technologien kennen zu lernen und Ideen zu bekommen, was man mit ihnen bauen könnte.

In der Kiste indet ihr Karten, die euch dabei helfen Technologien zu erfinden. Mit den technischen Bauteilen könnt ihr eure Erfindungen zum Schluss
Erfinder arbeiten nicht alleine, ihr braucht ein Team. Denn zusammen kommt man auf die besten Ideen. Erfinder arbeiten nicht alleine, ihr braucht ein Team. Denn zusammen kommt man auf die besten Ideen.

Beim Erfinden müssst ihr kreativ werden, denn es ist ganz schön kompliziert, zum Beispiel einen Computer selber zu basteln. Ihr braucht Bastelmaterial und viel Fantasie, und nicht immer lässt sich alles bauen. Wenn ihr eine Idee für eine Erfindung habt, malt sie erstmal auf.
Das können die Technologien:
Diese Technologien passen zusammen:
Legt Technologiekarten, die zusammen passen, auf die Vorlagen.
Diese Technologien passen zusammen:
Diese Technologien passen zusammen:
Technologie Spiel

Male die Technologien die eure Gruppe gezogen hat:
Diese Technologien passen zusammen:

Technologie

Technologie

Technologie

Technologie
Diese Technologien passen zusammen:
Diese Technologien passen zusammen:
Diese Technologien passen **nicht** zusammen:
Diese Technologien passen nicht zusammen:
Das könnte man mit den Technologien erfinden:
Malt die Themenkarten die ihr habt:
Malt, wie ihr spielt:
Technologie und Thema

Diese Karten passen zueinander:
Platz für Notizen der Erfinder und Erfinderrinnen
Das könnte man mit den Technologien erfinden:
Diese Technologien haben wir ausgesucht:
Für diese Themenkarte(n) erfinden wir etwas:
Das sind unsere Ideen:
Das ist unsere beste Idee:

Weil...

__________________________

__________________________

__________________________
Diese Materialien brauchen wir für die Erfindung:
Diese Technologien brauchen wir:
Technologie
So soll die Erfindung aussehen:
So funktioniert die Erfindung:

So sieht die Erfindung aus:
PDFs included in Teacher handbook
Erfinderkiste
Handbuch
<table>
<thead>
<tr>
<th>Einheit</th>
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<tr>
<td>Einleitung</td>
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<td>Einführung</td>
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<tr>
<td>1. Einheit</td>
<td>12</td>
</tr>
<tr>
<td>2. Einheit</td>
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<tr>
<td>3. Einheit</td>
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<tr>
<td>4. Einheit</td>
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<td>6. Einheit</td>
<td>22</td>
</tr>
<tr>
<td>7. Einheit</td>
<td>24</td>
</tr>
</tbody>
</table>
Einleitung


Die Erfinderkiste ist auf partizipativen Design Methoden* basiert. Teamarbeit ist wichtig, dazu gehört auch die Zusammarbeit zwischen Lehrkräften und Kindern als Design Partner.

Das Material aus der Erfinderkiste bietet Vorschläge für Unterrichtseinheiten, die offen sind für Anpassungen und auf die Klasse oder aktuelle Themen abgestimmt werden können.

Die Erfinderkiste besteht aus:
- einem Handbuch für Lehrkräfte
- Logbüchern zum Ausdrucken für die Schüler*innen
- Videos, die Technik erklären
- Kartensets zum Thema Technik und Inspirationskarten
- wir empfehlen elektronische Bausteine zu nutzen: beispielsweise LittleBits, Arduino oder Calliope.

* Einen Auszug aus unseren Publikationen: https://socialplay.at/en/publications
<table>
<thead>
<tr>
<th>Aktivität</th>
<th>Material</th>
<th>Vorbereitung</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Einführung</strong></td>
<td>Vorgeschichte und Erklärung Logbuch.</td>
<td>Kontext der Vorgeschichte auf gewähltes Thema abstimmen.</td>
</tr>
<tr>
<td><strong>Technologische Möglichkeiten</strong></td>
<td>Technologie Workshop, hier lernen Kinder Technologien kennen.</td>
<td>Karten um andere Technologien erweitern.</td>
</tr>
<tr>
<td><strong>Technologien kombinieren</strong></td>
<td>Kinder entdecken Möglichkeiten Technologien zu kombinieren.</td>
<td>Techkarten in Batches stecken und Aufgabenkarten aussuchen.</td>
</tr>
<tr>
<td><strong>Themen Rollenspiel</strong></td>
<td>Rollenspiel zu dem gewählten Thema und Kinder entdecken neue Möglichkeiten für Technologien.</td>
<td>Angelehnt an die Fantasiekarten, die im Standard Set enthalten sind, Karten für das gewünschte Thema erstellen.</td>
</tr>
<tr>
<td><strong>Tech und Thema</strong></td>
<td>Kombination aus Technologie und Thema.</td>
<td>Impulskarten ergänzen für spezielle Themen.</td>
</tr>
<tr>
<td><strong>Ideen</strong></td>
<td>Gruppen denken sich Ideen aus, wie/wo man Technologien verwenden könnte.</td>
<td>Fragen zum speziellen Thema gestalten.</td>
</tr>
<tr>
<td><strong>Bauen</strong></td>
<td>Gruppen schreiben/zeichnen Ideen in Logbuch und überlegen sich, wie ihre Idee/Erfindung aussehen könnte.</td>
<td>Themenspezifische Placeholder/Objekte.</td>
</tr>
<tr>
<td><strong>Präsentieren</strong></td>
<td>Gruppen präsentieren Idee/Erfindung.</td>
<td>Fragekarten ergänzen.</td>
</tr>
</tbody>
</table>
In diesem Handbuch stehen Vorschläge für Unterrichtsstunden und Aktivitäten, zusammengefasst in der Tabelle. Dieses Handbuch dient nur als Beispiel, wie man mit dem Material arbeiten könnte. Es ist auch möglich, Ideen zu einem bestimmten Thema zu entwickeln, was gerade in anderen Fächern besprochen wird. Beispielsweise Strom, aber auch Themen, die auf den ersten Blick nichts mit Technik zu tun haben. Was könnte man zum Beispiel erfinden, damit wir im Alltag weniger Müll produzieren? Oder was könnte man aus Müll noch basteln?

Ein Technologie Design Prozess besteht aus mehreren Schritten. Mit der Erfinderkiste konzentrieren wir uns auf die folgenden 4 Phasen:

Zunächst lernen und entdecken die Kinder, was für Technologien es gibt und was man mit ihnen machen könnte. Die verschiedenen Karten helfen ihnen dabei, etwas über Technologien zu lernen und sollen sie inspirieren, neue Dinge mit ihnen zu finden. Danach können sie konkrete erste Ideen für eigene Erfindungen sammeln und „Prototypen“ bauen. Die Kinder arbeiten in Kleingruppen (Erfinder Teams). Das kann für gewisse Spannungen sorgen, denn sie sollten sich auf eine Idee (ihre Erfindung)


Planung

- Einführung
- Technologische Möglichkeiten
- Ideen
- Bauen
- Präsentieren

Technologien kombinieren

Themen Rollenspiel

Technologien und Thema

Ablauf Beispiel:
- Erklärung Logbuch und Geschichte auf der ersten Seite lesen
- Gruppen bilden (4-5 Schüler*innen pro Gruppe)
- Schüler*Innen füllen erste Seite aus
- Es wird besprochen, zu welchem Thema sie in den nächsten Stunden etwas erfinden sollen.

Legende für das Handbuch:
- Kleingruppen
- Klassenaktivität
Materialübersicht
Technologiekarten:

Sensorenkarten: Diese Karte muss immer als erste gelegt werden. Sensoren nehmen Veränderungen in der Umgebung wahr und lösen dadurch eine Reaktion (Ausgabe) aus.

Ausgaben kommen als letzte Karte. Sie geben die gelesenen Daten, die sie von den Sensoren erhalten haben, aus.

Diese Karten erklären wichtige Technologien, die man braucht, um Prototypen zu bauen. 3D Drucker und Laserschneider kann man in Fablabs (offene Werkstätten) ausprobieren, viele bieten Führungen für Schüler*innen an.
Themenkarten sollen die Schüler*innen dazu inspirieren, sich neue Anwendungsmöglichkeiten für Technologien auszudenken. Es gibt Karten zu den Themen Magie und Science-Fiction. Es ist auch möglich, selber Karten zu anderen Themen zu erstellen, die gerade im Unterricht diskutiert werden.
LittleBits:
LittleBits sind Technologie Bausteine, die durch eingebaute Magnete einfach verbunden werden können. Ähnlich wie bei den Technologiekarten gibt es Sensoren (pink) und Ausgaben (grün). Zu jeder Technologiekarte (Sensoren/ Ausgaben) gibt es einen LittleBit.

Internetseite:
Auf der [Internetseite](https://www.fablab.de) der Erfinderkiste finden die Schüler*innen erklärende Videos zu den Technologien.

Möglichkeiten zur Kollaboration:
Viele sogenannte Fablabs oder Makerspaces laden Schulklassen in ihre Werkstätten ein, wo Kinder neue Technologien ausprobieren und experimentieren können. Vielleicht ist auch ein Fablab in eurer Nähe: [https://maker-faire.de/makerspaces/](https://maker-faire.de/makerspaces/)
In dieser Einheit lernen die Schüler*innen, welche unterschiedlichen Arten von Technologien es gibt und können erste Erfahrungen mit dem Einsatz von Technologien sammeln.

Material: Technologiekarten, ggf LittleBits

Ablauf Beispiel:
Mit den Technologiekarten finden Schüler*innen und Lehrer*innen alle wichtigen Informationen über die Funktionsweise der Technologien. Auf der Internetseite werden die einzelnen Technologien mit einem Video erklärt.
Mit den LittleBits können die Schüler*innen selber Technologien ausprobieren und kombinieren.

Ein Kind aus jeder Gruppe zieht eine Technologiekarte und liest sie vor/ beschreibt, was auf der Karte zu sehen ist. Dann sucht es ein passendes technologisches Beispiel dazu. Kann es kein Beispiel finden, schaut sich die Klasse ein Video an, welches verlinkt ist. Findet es jetzt das Beispiel? Was könnte man mit so einer Technologie machen?
Die Schüler*innen kombinieren ihre Karten. Wie könnten sie zusammen passen?
Logische Kombinationen sind Eingang - Ausgang, wie beispielsweise Bewegungssensor - Motor.

Vorbereitung:
- Technologiekarten ausdrucken und zusammen kleben, ggf laminieren.

Fragen, die die Schüler*innen inspirieren oder ihnen weiterhelfen:

- Wo hast du so eine Technologie schonmal gesehen?
- Wofür könnte die Technologie gut sein?/ Was könnte man damit bauen?
- Welche LittBits passen zusammen?
- Was ändert sich, wenn sie verbunden sind?
- Welche LittBits passen nicht zusammen?
In dieser Einheit lernen die Schüler*Innen, welche Technologien kombiniert werden könnten. Die Struktur ist immer die selbe: Inputkarten passen zu Ausgabenkarten. Im Logbuch können die Kinder ihre Technologiekarten ablegen und sortieren.

Material: Technologiekarten

Ablauf Beispiel:

Schüler*innen ziehen neue Technologiekarten. Danach setzen sich die Gruppen zusammen und überlegt, welche Karten zusammenpassen. Vielleicht haben sie schon erste Ideen, was man mit den kombinierten Technologien erfinden könnte.

Jeweils 2 Gruppen tun sich zusammen. Die Technologien werden wieder neu gemischt und auf die Gruppen verteilt. Die Aktivität wird wiederholt.

Vorbereitung:
- Einführungskapitel im Handbuch lesen, dort steht beschrieben, wie Technologien
Fragen, die die Schüler*innen inspirieren oder ihnen weiterhelfen:

• Wofür könnte die Technologie gut sein?/ Was könnte man damit bauen?
• Welche Sensoren passen zu welchen Ausgaben?
• Gibt es auch Sensoren, die zu anderen Sensoren passen?
• Gibt es Ausgaben die zusammen passen?
• Welche Technologien passen nicht zusammen? Warum?
• Was könnte man mit diesen Sensoren/Ausgaben machen?

Material: Themenkarten, ggf. Stecknadeln oder Faden

Ablauf Beispiel:

Jedes Kind zieht eine Themenkarten. Sie lesen sich die Karten gegenseitig vor/klären das Bild und überlegen sich, was die Karte bedeuten könnte und was sie damit machen würden. Die Karten werden in Badges gesteckt.

Die Kinder spielen die Funktion ihrer Karte, indem sie sich überlegen wie sie mit ihrem Körper und Gegenständen im Raum die Funktion anderen Kindern erklären könnten.
Das Rollenspiel kann mit den Impulskarten strukturiert werden, indem die Lehrkraft nacheinander eine Impulskarte zieht und vorliest.

Vorbereitung:
- Themenkarten drucken und ggf. laminieren.
- Themenkarten können mit Stecknadeln, wenn vorhanden, auf die Kleidung der Kinder gespickt werden oder mit einem Faden um den Hals getragen werden.
- Falls gewünscht, können auch Karten zu anderen Themen erstellt werden, die gerade im Unterricht diskutiert werden.

Fragen, die die Schüler*innen inspirieren oder ihnen weiterhelfen:

- Was für Probleme könnte man mit dieser Technologie lösen?
- Welche Technologie passt zu dem Thema?
- Wem könnte diese Technologie helfen?
- Was fällt dir noch zu diesem Thema ein?
In dieser Einheit lernen die Schüler*innen, Technologien mit bestimmten Themen zu verbinden und erste Ideen zu entwickeln, was für Technologie sie erfinden könnten und wofür.

Material: Themenkarten, Technologiekarten

Ablauf Beispiel:

Themen- und Technologiekarten werden gemischt und jedes Kind sucht sich zwei Karten aus jeweils einer Kategorie aus/ Kinder bekommen Karten von der letzten Stunde. Danach bekommen die Schüler*innen die Aufgabe, die Karten zu kombinieren. Danach erzählen sie innerhalb der Gruppe, was ihre Idee ist. Als nächstes können sich die Schüler*innen überlegen, ob sie sich etwas ausdenken können mit allen oder so viele Karten wie möglich die sie innerhalb der Gruppe haben.

Jede Gruppe präsentiert ihre Idee.
Vorbereitung:
- Falls gewünscht, neue Themenkarten zu anderen Themen erstellen, sonst die Karten der letzten Einheit wiederbenutzen.

Fragen, die die Schüler*innen inspirieren oder ihnen weiterhelfen:

• Welche Probleme könnte man mit dieser Technologie lösen?
• Welche Technologie passt zu dem Thema?
• Wem könnte diese Technologie helfen?
• Was fällt dir noch zu diesem Thema ein?
In dieser Einheit lernen die Schüler*innen sich eigene Technologien auszudenken.

Material: Technologiekarten, Zeichenmaterial.

Ablauf Beispiel:

Jede Gruppe bekommt ein Kartenset mit Technologiekarten und Zeichenmaterial. Im Logbuch stehen Aufgaben, die ihnen dabei helfen eine gemeinsame Idee zu entwickeln. Zunächst sollen sich die Kinder einen Anzahl (zB 5) Technologien aussuchen, die in ihrer Erfindung sein sollen. Dazu können sie sich Themenkarten aussuchen, zu denen sie etwas erfinden wollen.

Jede Gruppe präsentiert ihre Idee.
Vorbereitung:
- Zeichen- und Bastelmaterial besorgen, gerne auch Material mit dem die Kinder normalerweise nicht arbeiten. Material kann auch recycelt werden, zB Klopapierrollen, Kartons...

Fragen, die die Schüler*innen inspirieren oder ihnen weiterhelfen:
- Mit welchen Technologien wollt ihr etwas erfinden?
- Welche Ideen hattet ihr schon? Welche gefällt euch am besten?
- Für wen wollt ihr etwas erfinden?
- Was soll die Erfindung können?
- Welche Technologien braucht man, um die Erfindung zu bauen?
In dieser Einheit lernen die Schüler*innen ihre Ideen zu realisieren.

Material: Karten, Bastelmaterial, ggf. LitteBits

Ablauf Beispiel:


Vorbereitung:
- Bastelmaterial besorgen, gerne auch Material mit dem die Kinder normalerweise nicht arbeiten. Material kann auch recycelt werden, zB Klopapierrollen, Kartons...
Tipp! Es gibt in vielen Städten offene Werkstätten, sogenannte „FabLabs“ oder „Makerspaces“, die Schulklassen besuchen können. Dort können sie sich Maschinen und Technologien in Aktion anschauen, löten lernen und vielleicht hat dort ein Experte Zeit, die Kinder beim bauen zu unterstützen. Vielleicht gibt es ein FabLab in eurer Nähe: https://maker-faire.de/makerspaces/

Fragen, die die Schüler*innen inspirieren oder ihnen weiterhelfen:

- Welche Idee wollt ihr bauen und warum?
- Welche Technologien braucht man, um die Erfindung zu bauen?
- Was für Material braucht ihr um die Erfindung zu bauen?
- Was könnt ihr anderen Kindern über die Erfindung erzählen?
- Gibt es etwas, was ihr nicht basteln konntet? Malen ist auch okay.
In dieser Einheit lernen die Schüler*innen ihre Erfindung anderen Kindern zu erklären.

Mit dem Logbuch Eintrag können sie die Erfindung präsentieren. Sie können auch selber ein Poster gestalten.

Ablauf Beispiel:

Die Gruppen überlegen sich Fragen, die sie den anderen Gruppen stellen könnten. Sie üben ihre Präsentation.

Jede Gruppe präsentiert ihre Erfindung. Dazu lesen oder zeigen sie den Logbucheintrag und was sie gebastelt haben. Die anderen Schüler*innen dürfen Fragen stellen.
Vorbereitung:
- Eventuell zusätzliches Lernmaterial zum Thema Präsentationen besprechen mit den Schüler*innen.

Fragen, die die Schüler*innen inspirieren oder ihnen weiterhelfen:
- Was könnt ihr anderen Kindern über die Erfindung erzählen?
- Was gefällt euch an eurer Erfindung?
- Habt ihr die Erfindung schon getestet?
- Welche Fragen habt ihr an die anderen Gruppen?
Technology cards, Design trigger cards, Fantasy cards
Bewegungssensor gehen an, wenn sich jemand bewegt.
Wenn es wärmer oder kälter wird, geht der Temperatursensor an.
Kabel verbinden Sensoren mit Ausgaben, in dem sie Strom weiterleiten.
Geräusche oder Musik kommen zum Beispiel aus Lautsprechern.

Wenn es wärmer oder kälter wird, geht der Temperatursensor an.
Sensoren bemerken Veränderungen in ihrer Umgebung, zum Beispiel Bewegungen.
Ein Ventilator dreht sich und kühlt so die Luft ab.

Bei Geräuschen geht der Geräuschsensor an.
Ausgaben lesen Sensoren und wandeln Informationen um in Bewegung, Geräusche usw.
Temperatur verändert sich, es wird wärmer oder kälter wie zum Beispiel eine Herdplatte.
Drucksensoren sind wie ein Knopf: sie gehen an, wenn man sie drückt.

Wenn Licht auf einen Lichtsensor fällt, dann geht er an.

Eine Batterie liefert Energie, wenn man die beiden Enden verbindet.

Kleine Lampen, die Licht geben, werden auch LED genannt.

Ein Abstandsensor misst den Abstand zwischen zwei Dingen.

Laserschneider schneiden platte Flächen, zum Beispiel Holz, mit einem Laser.

Ein Servomotor ist ein elektrischer Antrieb, der sich vor- und zurück dreht.

Ein 3D Drucker kann Objekte drucken, in dem er Schicht für Schicht ein Material schmilzt.

Laserschneider schneiden platte Flächen, zum Beispiel Holz, mit einem Laser.

Vibrationselemente vibrieren, wie zum Beispiel Smartphones.
Zaubertrank
Magische Kerze
Feenflügel
Glaskugel
Zauberstab
Roboter
Cyborg
Teleport
Ufo
Raumschiff
Schutz
Denke dir eine Erfindung aus, die dich schützt. Gegen was? Wie?

Kritik
Suche dir einen Gegenstand im Raum aus. Stört dich etwas daran? Würdest du ihn ändern?

Magie
Suche dir einen Gegenstand im Raum aus. Was für magische Kräfte hat er?

Technik
Suche etwas im Raum, was technisch ist. Hast du eine Idee, wie es funktioniert?

Anzeige
Suche dir einen Gegenstand. Stelle dir vor, er könnte etwas messen. Zum Beispiel Geschwindigkeit oder Temperatur. Wo wäre die Anzeige?

Tragbare Technologie
Was für tragbare Technik kennst du? Suche dir einen kleinen Gegenstand, was für Technik kannst du damit bauen, die man tragen kann?
Appendix D: Toolkit evaluation study

Informed consent forms
Einverständniserklärung zur Studienteilnahme

Das Forschungsprojekt "Social Play Technologies", in dessen Rahmen die Entwicklung der Erfinderkiste stattgefunden hat, wurde unter der Leitung von Prof. Christopher Frauenberger an der Technischen Universität Wien (TU Wien) durchgeführt.

Ein paar Informationen zur Teilnahme:

- Ihre Teilnahme ist freiwillig und es entstehen keine Kosten für Sie.
- Sie können jederzeit und ohne Angaben von Gründen Ihre Teilnahme beenden.
- Ihren Daten wird eine Teilnehmer Identifikationsnummer zugeteilt, damit ich die Daten besser analysieren kann.

Bitte bestätigen Sie Ihre Teilnahme, indem sie Zutreffendes ankreuzen:

| Ich bestätige, dass ich an der Studie in Form einer Unterrichtsplanung und einer Fokusgruppe teilnehmen möchte und dass meine Teilnahme auf freiwilliger Basis erfolgt. |
| Ich bestätige, dass ich eine schriftliche Erläuterung des Forschungsprojekts sowie die Datenschutzerklärung erhalten habe und die Möglichkeit hatte, Rücksprache bei Nachfragen und Unklarheiten zu halten. |

Name des Teilnehmers:

Unterschrift:

Datum:

Wir bedanken uns herzlich für Ihre Teilnahme!
Laura Scheepmaker, MSc. (Projektmitarbeit)
Prof. Christopher Frauenberger (Projektleitung)
Prof. Geraldine Fitzpatrick (Supervision)
Datenschutzerklärung

Der Datenschutz und dessen Sicherstellung sind wichtige Anliegen der TU Wien. Die Verarbeitung personenbezogener Daten erfolgt unter strikter Wahrung der Grundsätze und Anforderungen, die in der DSGVO¹ und dem österreichischen DSG² festgelegt sind. Die TU Wien verarbeitet ausschließlich jene Daten, die für die Erreichung der angestrebten Zwecke erforderlich sind, und ist stets bestrebt, die Sicherheit und Richtigkeit der Daten zur gewährleisten.

1. Projektübersicht

Im Rahmen des “Social Play Technologies” Forschungsprojektes an der Technischen Universität Wien haben wir eine Werkzeugkiste für Kinder entwickelt, mit denen sie in die Erfinderrolle schlüpfen und eigene Technologien entwickeln können.

Die Erfinderkiste besteht aus einer Reihe von digitalen Unterrichtsmaterialien, die Ihnen dabei helfen soll eine Unterrichtsarbeit zum Thema Technologie Gestaltung vorzubereiten und durchzuführen. Dabei können die Kinder verschiedene Phasen eines kreativen Gestaltungsprozesses durchlaufen, beginnend mit der Ideensammlung bis hin zur Umsetzung und Präsentation ihrer Erfindungen als gebastelte “Prototypen”. Dabei können sie spielerisch technische Zusammenhänge lernen und über die Rollen von Technologien in ihrem eigenen Leben nachdenken.

Jetzt wollen wir erforschen, wie LehrerInnen unser Unterrichtsmaterial einsetzen würden und laden Sie herzlich dazu ein mitzuwählen.

2. Datenerhebung

Im Rahmen des Projekts wenden wir verschiedene qualitative Forschungsmethoden an, um entsprechende aussagekräftige Daten zu sammeln. Konkret sind folgende Methoden geplant:

- Vorstellung des Projekts und Kennenlerngespräch mit LehrerInnen
- Evaluationsstudie der Erfinderkiste mittels Unterrichtsplanung mit LehrerInnen
- Fokusgruppen oder Einzelinterviews mit LehrerInnen

2.1. Welche Daten werden in der Studie gesammelt?

Das Kennenlerngespräch, die Interviews und Fokusgruppen werden mit Ton- und Videoaufzeichnungen dokumentiert. Die TeilnehmerInnen werden informiert, wenn die Forscherinnen mit den Aufnahmen beginnen.


Für die Unterrichtspläne werden Vorlagen und Anregungen vorbereitet, die die TeilnehmerInnen entweder handschriftlich ausfüllen oder mittels selbst gewählten digitalen Mitteln (als digitale Textdatei oder

¹ Datenschutz-Grundverordnung  
² Datenschutzgesetz

2.2. Wie werden die Daten verwendet?

Alle schriftlichen Aufzeichnungen und Aufnahmen, die im Rahmen des Projekts gesammelt werden, werden in erster Linie für das Forschungsprojekt verwendet. Zudem behalten wir uns vor, die anonymisierten Daten für weitere Forschungszwecke zu nutzen.


Folgende Datenkategorien werden bei der Datenverarbeitung verarbeitet:
- Kontaktdaten (Name, E-Mail-Adresse)
- Soziodemografische Informationen über TeilnehmerInnen (Unterrichtende Schulform, Arbeitserfahrung, Fächer, Technische Kenntnisse und Interesse)
- Tonaufzeichnungen der Fokusgruppen
- Tonaufzeichnungen der Einzelinterviews
- Handschriftliche Notizen der Forscherin
- Von den TeilnehmerInnen erstelltes und ausgefülltes Textmaterial (Unterrichtsplanung)

3. Datenverarbeitung

3.1. Zweck der Datenverarbeitung

Die Verarbeitung der Daten erfolgt zum Zweck der wissenschaftlichen Forschung mit dem Ziel, Einsatzmöglichkeiten unserer entwickelten Forschungsergebnisse (die Erfinderkiste) im Schulkontext zu explorieren.
Im Detail bedeutet dies, dass wir die Daten zur wissenschaftlichen Auswertung und Analyse nutzen und die Ergebnisse für die Erstellung von wissenschaftlichen Publikationen und weitere Forschungszwecke im Rahmen einer Doktorarbeit einbeziehen werden.

3.2. Weitergabe der Daten
Alle Auswertungen und Darstellungen von Ergebnissen, die veröffentlicht oder an Dritte weitergegeben werden, erfolgen in anonymisierter und aggregierter (zusammengefasster) Form. Sie erlauben daher keine Rückschlüsse auf Ihre Person.

3.3. Rechtsgrundlage für die Datenverarbeitung
Die Verarbeitung und Verwendung Ihrer personenbezogenen Daten erfolgt auf der Grundlage des Art 6 Abs 1 e) DSGVO und Art 89 DSGVO iVm §3 UG und beschränkt sich auf die oben genannten Zwecke. Die Verarbeitung personenbezogener Daten basiert auf den Grundsätzen und Anforderungen, die in der Datenschutz-Grundverordnung (DSGVO), dem österreichischen Datenschutzgesetz (DSG) und dem Forschungsorganisationsgesetz FOG festgelegt sind.

3.4. Speicherdauer/Löschungsfrist
Ihre Daten werden solange gespeichert, wie es die gesetzlichen Aufbewahrungsfristen vorschreiben bzw. wie es der Zweck erfordert.

3.5. Rechtsbehelfsbelehrung
Im Zusammenhang mit der Verarbeitung Ihrer personenbezogenen Daten stehen Ihnen die Rechte auf Auskunft, Berichtigung, Löschung, Einschränkung der Verarbeitung und Widerspruch zu, sofern durch die Ausübung dieser Rechte die Erreichung des Forschungszwecks voraussichtlich nicht unmöglich gemacht oder ernsthaft beeinträchtigt wird (§2d Abs. 6 FOG).

Wenden Sie sich dazu bitte an: geraldine.fitzpatrick@tuwien.ac.at

Wenn Sie glauben, dass die Verarbeitung Ihrer Daten gegen das Datenschutzrecht verstößt oder Ihre datenschutzrechtlichen Ansprüche sonst auf eine Weise verletzt worden sind, können Sie sich bei der zuständigen Aufsichtsbehörde beschweren: Österreichische Datenschutzbehörde (DSB), Barichgasse 40- 42, 1030 Wien.

4. Kontakt
Sollten Sie weitere Fragen oder Anliegen zur Verarbeitung Ihrer Daten haben, wenden Sie sich bitte an:

Fachliche Ansprechperson an der TU Wien:
Prof. Geraldine Fitzpatrick
TU Wien, Forschungsbereich Human Computer Interaction
Argentinierstrasse 8, 2. Stock E193/5, 1040 Wien
Tel: +43-1-58801-187-35, Mail: geraldine.fitzpatrick@tuwien.ac.at

Verantwortlicher:
Rektorat der Technischen Universität Wien, Karlsplatz 13, 1040 Wien

Datenschutzbeauftragte:
Mag. Christina Thirsfeld
Technische Universität Wien, Karlsplatz 13/018, 1040 Wien datenschutz@tuwien.ac.at
Forms for planning the teaching unit and lesson plans
Einführung


Stellen Sie sich vor, dass Sie den Link *zu der digitalen “Erfinderkiste” von einer/-m Kolleg*in bekommen haben, und Sie möchten die Erfinderkiste gerne mit Ihrer Klasse ausprobieren. Um die Kinder dabei zu unterstützen, Ihre Erfindungen zu bauen, hat Ihre Schule zwei LittleBits Sets zur Verfügung gestellt. Wenn Sie andere Materialien nutzen oder kennen, können Sie diese natürlich auch verwenden.

Teil der Erfinderkiste ist ein Hilfsnetzwerk von Technologie Experten, die Ihnen bei technischen Details helfen können. Sie können beispielsweise mit einem FabLab **kollaborieren, eine offene Werkstätte für Menschen die Technik und Maschinen nutzen wollen, aber selber wenig oder keine Erfahrung damit haben. Kinder sind auch willkommen und können dort 3D Drucker oder Laserschneidemaschinen ausprobieren. Unterstützt werden sie dabei von technischen Experten.


Wenn Sie noch offene Fragen bezüglich der Studie haben, schreiben Sie mir bitte:
laura.scheepmaker@tuwien.ac.at

* https://spttoolkit.wordpress.com
** https://www.offene-werkstaetten.org/seite/offene-werkstaetten
Fragebogen

Damit ich die Daten besser analysieren kann, würde ich mich freuen, wenn Sie mir ein paar Informationen über Ihre Unterrichtserfahrung geben würden.

- Wie lange unterrichten Sie schon?

- Welche Schulform unterrichten Sie?

- Welche Fächer unterrichten Sie?

- Was ist Ihre Erfahrung mit Technik (Unterricht), bzw gestalterischen Fächern?

- Was ist Ihre Erfahrung mit FabLabs oder ähnlichen offenen Werkstätten?

- Was sind Ihre Erwartungen von der Erfinderkiste?
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<thead>
<tr>
<th>Thema/Themen der Unterrichtseinheit:</th>
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<tr>
<td>Ziel der Unterrichtseinheit:</td>
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<td>Bezüge zum Lernplan/Möglichkeiten zur fächerübergreifenden Arbeit:</td>
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<td>Möglichkeiten für Zusammenarbeit mit externen Fachleuten für diese Unterrichtseinheit: (Sie können auch lokale Institutionen vorschlagen, mit denen Sie kollaborieren würden)</td>
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<tr>
<td>Anzahl der Unterrichtsstunden:</td>
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<td>Lernziele der Kinder:</td>
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<td>Mögliche Lernergebnisse für Sie:</td>
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Benötigtes Arbeitsmaterial und Lernmittel:
(beispielsweise Bastelmaterial, digitales Material aus der Erfinderkiste, technische Hilfsmittel...)
### Unterrichtsablauf

Bitte planen Sie 3 Unterrichtsstunden als Beispiele, in denen Sie Material aus der Erfinderkiste mit Ihrer Klasse benutzen. Wenn Sie zusätzliches Material oder Lernmittel benötigen, oder Material verändern möchten, können Sie dieses gerne notieren. Es reicht eine kurze Beschreibung was sie ändern oder ergänzen würden.

Wenn die Vorlage zu sehr von Ihrer gewohnten Vorlage abweicht, können Sie gerne Inhalte ergänzen oder ändern.

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<th>Phase/Zeit</th>
<th>Inhalte</th>
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<th>Sozialform/Methodik</th>
<th>Arbeitsmaterial</th>
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## Unterrichtsablauf

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</table>
Excel sheet with a summary of the teaching units
| Lehrkraft | Thema UE | Ziel UE | Bezug zum Lernplan/Sicherheitsauf | Möglichkeiten für Zusammenarbeit | Anzahl Unterrichtsstunden | Lernziele Kinder | Mögliche Lernteste für Sie | Arbeitsmaterial |
|----------|----------|---------|---------------------------------|---------------------------------|--------------------------|----------------|----------------------|----------------|----------------|
| **Ziel UE** | **Die schüler Bezüge zum Mögliche** | **-7** | **Martha** | **Klara** | **Nora** | **Yasmin** | **Tamara** | **Nora** | **Klara** | **Martha** |
| **Ziel UE** | **Cyberborg „Was/wer Ist Mensch oder Maschine?“** | **Technisches und Textiles werken: Erforschung - Technische Prinzipien & Phänomene verstehen; > kreative Lösungsansätze bzw Lösungswge finden** | **Fahrzeuge, TÜV Kriterien, bauen** | **Verzweigungen (zaubereinmaleins); Zitronenbatterie (sicher, Experiment; Experimentierkoffer „Technikdetektive“ + passendes AB, Werkzeugpackungen „HeiHer Draht“ (Winkler Schultedid))** | **-** | **-** | **-** | **-** | **-** | **-** |
| **Ziel UE** | **Experimentieren mit elektronischen Bauteilen (Hier Anhavl von LittleBits)** | **Lernendenplanungs (Infantechnik Physikunterricht)** | **3 Doppeleinheit (= 6 Einheiten) (hier sind 3 Doppeleinheit (= 6 Einheiten) geplant)** | **Technologien selbständig entdecken, Technologien zum eigenen Vorteile nutzen** | **18** | **Die sitzer nehmen Strom in ihrem Alltag wahr und erkennen Technologien. Sie nutzen diese für ihre eigenen Projekte.** | **technisches Wissen erweitern** | **Karten Erfinderkiste, Logbuch, Videos, Kabel/Leds/Schalter/Sensoren, Bastelmaterial, LittleBits/Strom-Technikleisten der Schule** | **-** | **-** |
| **Ziel UE** | **Strom & Technologien** | **Kern curriculum Sachunterricht Niedersachsen, Bereich Technik/Perspektivrhein (Perspektive Technik der GGSU)** | **18** | **Die sitzer nehmen Strom in ihrem Alltag wahr und erkennen Technologien. Sie nutzen diese für ihre eigenen Projekte.** | **-** | **-** | **-** | **-** | **-** | **-** |
| **Ziel UE** | **Technik im Alltag - Wo kann ich technische Erfindungen entdecken und wie nutze ich sie im Alltag? Was würde ich selbst gerne erfinden und wozu würde ich die Erfindung nutzen?** | **Technik im Alltag - Wo kann ich technische Erfindungen entdecken und wie nutze ich sie im Alltag? Was würde ich selbst gerne erfinden und wozu würde ich die Erfindung nutzen?** | **6 Erfahrungen im eigenen Alltag und Umfeld entdecken und verstehen. Selbst erfinden (realistisch oder Phantasielokal); Skizzen/Modelle eigener Erfindungen anfertigen und präsentieren.** | **6 Erfahrungen im eigenen Alltag und Umfeld entdecken und verstehen. Selbst erfinden (realistisch oder Phantasielokal); Skizzen/Modelle eigener Erfindungen anfertigen und präsentieren.** | **-** | **-** | **-** | **-** | **-** | **-** |
| **Ziel UE** | **Wir bauen Fahrzeuge** | **Schüler erkennen Funktionen von Autozeiten, Funktionone, TÜV Kriterien, bauen eigenes Fahrzeug anhand TÜV Kriterien** | **TÜV Fahrzeuge** | **7** | **Schüler erkennen Funktionen von Autozeiten, Funktionone, TÜV Kriterien, bauen eigenes Fahrzeug anhand TÜV Kriterien** | **-** | **-** | **-** | **-** | **-** | **-** |
Example of one teaching unit and lesson plan filled out by Marie
**Unterrichtseinheit**

<table>
<thead>
<tr>
<th>Thema/Themen der Unterrichtseinheit:</th>
<th>Experimente zum Überthema &quot;Strom&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ziel der Unterrichtseinheit:</td>
<td>Kinder für den Bereich &quot;Technik&quot; zu begleiten</td>
</tr>
<tr>
<td>Bezüge zum Lernplan/Möglichkeiten zur fächerübergreifenden Arbeit:</td>
<td>Kenntnisse über technische Gegenstände in der unmittelbaren Umgebung der Kinder erwerben. Umgang mit Objekten und spezifische Arbeitsweisen kennenlernen</td>
</tr>
</tbody>
</table>
| Möglichkeiten für Zusammenarbeit mit externen Fachleuten für diese Unterrichtseinheit: (Sie können auch lokale Institutionen vorschlagen, mit denen Sie kollaborieren würden) | Fit Wels  
ABS Electronica Linz |
| Anzahl der Unterrichtsstunden: | 6 Unterrichtseinheiten |
| Lernziele der Kinder: | Die Kinder sollen die Funktionen der Tischleuchte erfassen.  
Die Kinder sollen technische Begriffe verwenden können. |
| Mögliche Lernergebnisse für Sie: | Fachliche Sicherheit im Bereich "Technik" |

Benötigtes Arbeitsmaterial und Lernmittel:  
(beispielsweise Bastelmaterial, digitales Material aus der Erfinderkiste, technische Hilfsmittel...)

- Bild - Not - Karten + dazu passendes Arbeitsblatt  
- Technologiekarten + Videos  
- Karte: "Wir experimentieren" (zauber einmaleins)  
- Zitronenbatterie - Experiment  
- Experimentierkoffer "Technik Detektive" + passende AB  
- Werkpackungen "Heißer Draht" (Winkler Schulbedarf)

*Die Kinder sollen eigene Experimente durchführen, dokumentieren und präsentieren können.*
# Unterrichtsablauf

Bitte planen Sie 3 Unterrichtsstunden als Beispiele, in denen Sie Material aus der Erfinderkiste mit Ihrer Klasse benutzen. Wenn Sie zusätzliches Material oder Lernmittel benötigen, oder Material verändern möchten, können Sie dieses gerne notieren. Es reicht eine kurze Beschreibung, was Sie ändern oder ergänzen würden.

Wenn die Vorlage zu sehr von Ihrer gewohnten Vorlage abweicht, können Sie gerne Inhalte ergänzen oder ändern.

<table>
<thead>
<tr>
<th>Phase / Zeit</th>
<th>Inhalte</th>
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<th>Sozialform / Methodik</th>
<th>Arbeitsmaterial</th>
<th>Notizen</th>
</tr>
</thead>
</table>
| 1. Stunde    | Übersicht verscharfen | - Was geschah in den nächsten Stunden?  
- Wann haben sie uns? | Kinder auf Platz  
Freitalt | Visualisierung  
ein Werden als  
Karten oder  
an der Tafel | Einführungsstunde |
| Sammeln zum Begriff Technik  
> Weiterführung  
> Was da ist  
> Braucht Strom? | Gruppenarbeit  
Windmap erstellen | großes Blatt,  
Stifte  
Leuchtstift |
| Informationen  
Köhler | Hinführung Strom  
> Was ist das?  
> Wann passiert? | Begriffe festigen  
auflauf einer  
Tischlampe, Elektronen, Stromkreise, Sensor, Ausgabe  
Spiel: Ist’s missing | Bild / Wort =  
Karten 
Karteilisten |
| Organisation  
+ min | Unterscheidung Sensor / Ausgabe  
> Ausführen | Geleitete Gespräche  
Sitzkreis | verschiedene  
Bilder,  
Technologiekarten  
zur Hilfe  
eine Videos dazu aussehen |
<table>
<thead>
<tr>
<th>Phase/Zeit</th>
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</tr>
</thead>
<tbody>
<tr>
<td>5min</td>
<td>Lückenkei ausfüllen</td>
<td>gemeinsam wird der Lückenkete ausgefüllt + AB ins Heft eingelegt</td>
<td>Frontal</td>
<td>Arbeitsblatt</td>
<td>AB : Was ist Strom²</td>
</tr>
<tr>
<td>Phase/Zeit</td>
<td>Inhalte</td>
<td>Schülerinnen - LehrerInnen Aktivität</td>
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<tr>
<td>3. UE</td>
<td>Werkstück vorstellen „Heißer Dacht“</td>
<td>Frontal</td>
<td></td>
<td>Gummi Werkstück</td>
<td>nach 1-2 Etappen experimentieren im Werkunterricht</td>
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<td></td>
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<td>Zu sichern, was man damit macht</td>
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<tr>
<td></td>
<td>Overblicke Verschaüler</td>
<td>Werkzeug nach Anleitung; Teile kontrollieren; Arbeitsvorschriften besprechen</td>
<td>Frontal/gespräch</td>
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<tr>
<td></td>
<td>Werkstück erstellen</td>
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<td>Werkzeugen in Klasse verteilen; vom Winkler plus Pest + Anleitungen</td>
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<tr>
<td></td>
<td>Selbstständige Aktivität 90 min</td>
<td>Schülerinnen erstellen das Spiel „Heißer Dacht“ Lehrperson hilft bei Umbauschritten</td>
<td>Einzelarbeit</td>
<td>diverse Werkzeuge, die zur Erstellung benötigt werden (Säge, Schrauben stöcker, Leim, ...)</td>
<td></td>
</tr>
</tbody>
</table>
Script for focus groups
<table>
<thead>
<tr>
<th>Zeit</th>
<th>Themen</th>
<th>Fragen</th>
</tr>
</thead>
<tbody>
<tr>
<td>00-01</td>
<td>Begrüßung</td>
<td>Aufnehmen! Danke schön, Erklärung was wir machen, Jeder kurz vorstellen (Name, Schulform, woher)</td>
</tr>
</tbody>
</table>
| 2-10 | 1. Frage: Erwartungen erfüllt (follow-up) | • Was waren eure Erwartungen von der Erfinderkiste?  
• Hat die Erfinderkiste eure Erwartungen erfüllt?  
• Welche Erwartungen wurden nicht erfüllt bzw hätten besser erfüllt werden können?  
• Habt ihr etwas unerwartetes von der Erfinderkiste gelernt? |
| 21-30 | 3. Frage: Spezifische Fragen zu Inhalten | • Was waren die Inhalte, die euch angesprochen haben bzw mit denen ihr etwas anfangen konntet?  
• Mit was nichts?  
• Passen die Inhalte zu den Kindern bzw deren Alltag? |
| 31-40 | 4. Frage: Spezifische Fragen zur Nutzbarkeit | • Was sagt ihr zum Zeitaufwand den es kostet alles vorzubereiten? (zu viel/wenig Text zB)  
• wie verständlich waren die technischen Inhalte für euch? |
| 41-55 | 5. Frage: Was soll anders? | • Wie würdet ihr das Toolkit in der Zukunft nutzen?  
• Was für zusätzliche Inhalte würdet ihr euch wünschen?  
• Die Erfinderkiste ist jetzt nur digital und dadurch kostenlos. Wieviel würdet ihr (also die Schule) zahlen, wenn man auch Material wie zB die Littlebits dazu bekommen könnte? |
| 56:1 | Abschluss | Dankeschön, noch anderes Feedback? Offizieller Teil zu Ende |
Example of notes taking to identify possible themes and relevant codes
- Handbuch:

  allgemein: viel Text, wenig Bilder

Ideen für neue Inhalte:

- Bilder (Erinnerungsbilder) von Technologien, um im Klassenraum aufzuhängen -> Themenwände an der Klassenraumwand, damit Kinder das präsent im Blickfeld haben.

- Beispiele für Einsatzbereiche von Erfinderkiste: Zum Beispiel integrierbar mit Thema Strom, aber wo könnte man sie nochmal auftauchen lassen? Werken zum Beispiel? Anknüpfungspunkte

- Übersichtsposter, Kinder können einordnen wo sie sich befinden (wo sind zB Bewegungsmelder drin)

Beispiele:

- mehr Beispiele

- Visuelle Hilfen für Kinder

- Visuelle “reminders”, Bildkarten von Videos

- Einsatzmöglichkeiten im Unterricht

- Können Material einsetzen ohne sich vorher selber viele Gedanken zu machen

- Im Bereich werken: Vorschläge für verschiedene Werkstücke

- Inspirationsmaterial für Verwendung (Bilder, Blog, Handbuch)

Modularität:


“also ich finde sie war so aufgebaut, dass man Sachen nehmen konnte, aber auch weglassen konnte. Man war jetzt nicht gebunden an den vorschlägen.”

- für jedes Alter etwas dabei, Gedankenspiele und fantasieren zb eher für jüngere Kinder, komplexe Dinge bauen erst ab Mittelstufe.

Kollaborationen:

Herausforderungen: Weiter Weg von Schule zu Kollaborationspartner, große Klassen, einmaliges Projekt -> zu großer Aufwand
Je nach Lage der Schule wenig Angebote für Kollaborationen (Makerspaces als Beispiel)

Kosten/Nutzen Abwägung: Makerspaces bedeuten ggf Fahrtweg für 2 Stunden unterricht

Argumente für Kollaborationen:

Gibt es bereits Kollaborationen, motiviert es andere Lehrkräfte das Thema auch zu bearbeiten.

Bestehende Beispiele für Kollaboration:

- Zum Thema programmieren: Mutter die bei technischem Unternehmen arbeitet wollte tech Bildung bei Mädchen fördern, hat eine Technik AG für Mädchen angeboten (programmieren), ABER das war in einer Großstadt.

Zusammenarbeit auch mit Uni, Technik Studenten haben Seminar für einen tag an der Schule gegeben.

- Gemeinden und Musikschulen, für gemeinsames Musik machen
- Betriebe, für Berufsorientierung (mehrere Tage schnuppern)
- Gesundheitsamt besucht Schulen zur Kontrolle
- Landfrauenbund kommt zum kochen mit den Kindern für gesunde Ernährung

Möglichkeiten für Kollaborationen im Rahmen der Erfinderkiste:


- Zusammenarbeit mit lokalen Betrieben (möglich im Rahmen der Berufsorientierung), zB Elektriker
- Firmen geben Reststücke oder Abfall an Schulen

Technik anknüpfen an Lebenswelt der Kinder:

- Kinder da abholen wo sie sind, aber auch einen Schritt weiter gehen (nicht nur Beispiele zeigen die sie auch selber nutzen)
- Anfangen mit Grundlevel (plus und minus, Batterie mit LED verbinden schon schwierig)