The Sixth International Conference on Design Creativity (ICDC2020)
Oulu, Finland, August 26th – 28th 2020
https://doi.org/

Let’s hear children’s voice. An implementation of a design process model to understand children’s views on tangible interaction.

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Abstract: Children provide innovative insights and perspectives when designing and evaluating prospective technologies and interaction methods. However, working with children as design informants requires careful consideration of the methodologies used in different steps of the design process. In this paper, we present our insights on a case-study of a design process with 24 children (9-12-year-olds), aiming for understanding children’s view on new technologies and their perception on tangible interaction. We utilized a lightweight design process model: children first reflected on the use of technologies and participated in an ideation session. Based on the results, researchers built prototypes which were evaluated by the children in the final step of the process. We expect our learnings to help researchers in the field of collaborative design when organizing design activities with children.

Keywords: *children, co-design, design circle, design methodologies, brainstorming, evaluation, tangible interaction.*

1. Introduction

For long, users have been involved in the development of new products and technologies, especially in the Information and Communications Technology (ICT) sector. The seminal work of Druin (Druin et al. 1999, Druin 2002) has demonstrated that already 7 -year olds can be good design partners, as they have adequate skills to express their ideas. Children have different perspective to technology than adults (Guha et al. 2013) so they can provide interesting point of view on technology design. However, most collaborative design methodologies are focused on adults (Vaajakallio et al. 2009), leaving out the challenges of creative collaboration with children. In addition, school dynamics pose an additional layer of complexity for doing collaborative research (Iivari and Kinnula, 2016; Druin et al., 1999). That is why we need lightweight methodologies that require, among other factors, low partner experience, low dimensions of cost and technology, and a process in which the design tasks can be distributed in time among different actors.

In this paper, we present our experiences utilizing a lightweight design process model to structure genuine participation of children when designing new technologies and interactions. In particular, we report a 6-month research case-study in which different actors (children, university students, and university researchers) participated in the ideation, implementation, and evaluation of several prototypes, which utilize different forms of tangible interaction. Tangible user interfaces utilize the materiality of everyday objects in order to interact with the digital world (Shaer and Hornecker, 2010). Hence, applications can be controlled by grasping, touching or manipulating physical objects in the environment. A relatively big proportion of research in Tangible User Interfaces has focused in the benefits of using these interfaces with children (Zaman et al., 2012), but there is no that much research on how kids can contribute to the development of new technologies based on tangible interaction..

Although the concrete goal of the case-study was to understand children's insights on tangible interaction and implementing new application concepts in collaboration with them, in this paper we are not analyzing the novelty, quality, or feasibility of the ideated concepts or interaction methods. In contrast, our focus is on the presentation of the different steps of the design process and in the contribution of the different actors to each step. One particularity of our approach is that we went through a full design cycle in which the actors (children, university students, and university researchers) did not participate together in all the design phases. Children had more prominence in the ideation and evaluation phase, while researchers and university students collaborated to build the prototypes.

With this paper we contribute into the field of Child-Computer Interaction (CCI), by providing our insights on the design process with children. Studies often focus on a single design phase (ideation, implementation, or evaluation). We want to extend this by describing the whole design process and various actors contributing in some of the phases. The focus is still in the ideation and evaluation phases, since these are the phases in which children had a bigger role.

The paper is structured as follows. The next section introduces related research on working with children in technology design. In the third section we present the research design for this study. Then, we outline our empirical findings, discuss the implications of our study and conclude the paper with limitations and future research possibilities.

2. Related Work

The literature presents a vast collection of design process models that include the lifecycle of a product from conceptualization till fabrication (Kumar 2012). In design thinking, process models are basically divided in five major steps: Define, Understanding, Ideate, Prototype and Test (Plattner et al., 2010). In the last years, Danish educational Maker community has adapted those models to education environments by defining a design process model based on six different steps: *Design brief, Field studies, Ideation, Fabrication, Argumentation and Reflection* (Hjort et al, 2016). However, we are not aware of the utilization of this model outside education environments.

Majority of design methodologies are not adapted to challenges presented when co-designing with children. Druin et al. (1999) and his team have been utilizing the Cooperative Inquiry for co-designing with children for more than 20 years. They define a set of techniques that can be used at different stages of the design process. Guha et al. (2013) add new techniques to the Cooperative Inquiry tools such as "*bags of stuff*" and "*Layered elaboration*" that are mainly used in the ideation phase. Hagen et al. (2012) presented a review of co-design methods to include children in the design process.

3. Case-study overview.

Our goal was to build collaboratively with children artefacts that could help to understand children's insights on tangible interaction. To that end, we organized a case-study involving a local public elementary school in Finland, with a total of 46 3rd graders (9-10 years old), 8 5th graders(11-12 years old) and two of their teachers. The fifth-grade students were recruited amongst the members of the school student union and volunteered to act as facilitators in some of the activities we organized as part of the case-study. Although all the children participated in the whole process, only 24 of them (20 3rd graders and 4 5th graders) took part in the research. In addition, 3 Master's degree university students in Computer Science participated as design partners for the children in the different phases of the design process, guided by a group of 4 researchers (with background in Human-Computer Interaction).

During the case-study we run three different workshops: The first workshop consisted of two different sessions: one for the 5th graders (WS 1a) who served as facilitators in WS 2 and WS 3, and another for the 3rd graders (WS 1b). The goal of WS 1a and 1b was to make children reflect on technology and interaction. In the second workshop, 3rd graders and university students participated in the ideation process using different brainstorming techniques. 5th graders acted as independent facilitators for the ideation process while researchers were mainly introducing the session, and observing, and helping when needed. The third workshop focused on evaluating some prototypes researchers fabricated based on children's ideas. 5th graders facilitated the evaluation process with an active help from researchers. University researchers and students performed different design tasks before and after each workshop with children.

All activities were part of children’s schoolwork, but all participants were free to end their participation in research at any time.

4. Design process model

For structuring the design process, we used a slightly modified version of the model presented by Hjort et al. (2016), including several iterations in the *ideation* phase and the addition of a *Testing and evaluation* step between the *Argumentation* and the *Reflection* (Figure 1).

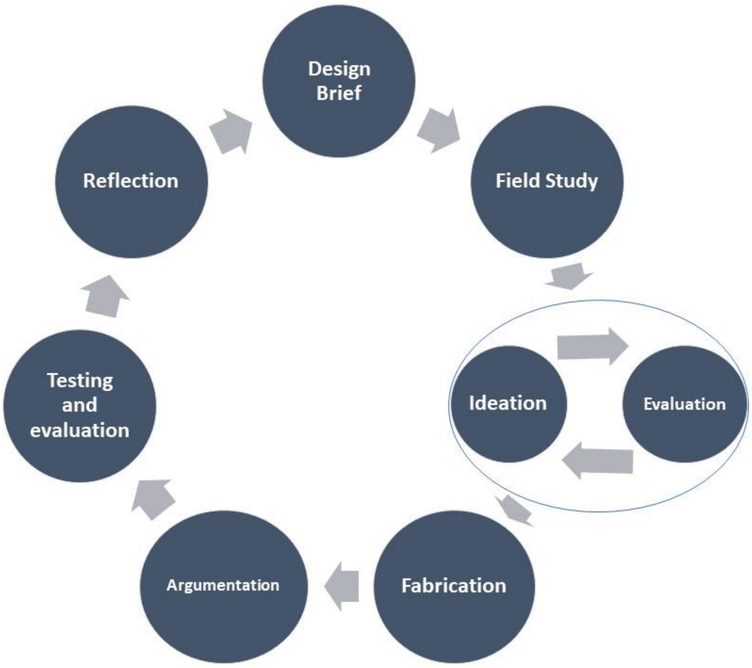

Figure 1. Multi-step design process model we utilized in the case-study

Table 1 describes the different design phases including information on when in the project timeframe they took place and how they were implemented, as well as who were the contributors.

4.1. Design Brief and Field Study

During the project preparatory meetings, researchers sketched the structure of the whole research case-study and defined the design brief: *create some working prototypes of digital applications which use tangible interaction.* We had two separate preparatory workshops with the children: one with the 3rd graders (WS 1a) and one with the 5th graders (WS 1b). The general goal was making children to reflect on present and future technology and interactions. During the first workshop with the 5th graders (WS 1a), we presented tangible interaction concept through practical examples. We brought some real prototypes developed by us (Pyykkönen et al., 2013) and showed them some artefacts such as MaKey MaKey[1] which enable tangible interaction. They also helped us to organize the 2nd workshop (WS 2). During first workshop with third graders (WS 1b), one of our researchers introduced our work. She

[1] MaKey MaKey https://www.youtube.com/watch?v=rfQqh7iCcOU

spent some time with them during their art class, talking about technology and getting their insights on technology and interaction. Finally, children had to draw a picture with the topic "How do I use information technology". They had to explain their drawing in the back side.

Table 1. Design process model steps and active actors in the case-study

Phase	Definition	Active Actors	Timeframe and place
Design brief	Description of the task. Challenge or problem to work with	Researchers	Before the 1st workshops at school
Field Study	Gaining information and understanding the problem and/or empathizing with the target user group	5th Grade Children	1st workshop at school (WS 1a)
		3rd Grade Children	1st workshop at school (WS 1b)
Ideation & Evaluation	Iterative phase in which big number of ideas are generated, and later assessed. After several cycles one or more ideas are chosen.	1st iteration: Ideation, 3rd Grade Children and University Students	2nd workshop at school (WS 2)
		2nd iteration: Evaluation and Ideation, Researchers and University Students	After the 2nd workshop, at the university
Fabrication	Build or implement a prototype to test the idea.	Researchers and University students	After the 2nd workshop, at the university
Argumentation	Justify in relation to the prototype, including the fabrication decision.	Researchers and University Students	After the 2nd workshop, at the university
Testing and evaluation	Test the prototype. Afterwards, prototypes are evaluated either quantitatively or qualitatively using predefined metrics.	3rd Grade Children 5th Grade Children	3rd workshop at university (WS 3)
Reflection	Reflecting on the whole process, what worked and what did not work. Did the methodology work? Are the results satisfactory?	Researchers University Students 5th Grade Children	After the 3rd workshop, at the university

4.2. Ideation and evaluation

This phase was split into two different iterations. For the first iteration, ideation, we organized the 2nd workshop (WS 2) with the children at the school premises. The second iteration consisted of evaluation of ideas and selection of the most suitable ones to build prototypes. It was done by the researchers at the university premises.

4.2.1. Ideation with children

Ideation Workshop setup. This workshop took place at the school premises. During this workshop, we have special interest in intergenerational collaboration, as it can push boundaries in creativity (Fails 2013). Hence, we had 5th graders as session leaders (facilitators) while 3rd graders, in partnership with university students (adults), acted as informants. A more profound analysis on the motivation and results for this session can be found from our previous research (Kinnula et al., 2017).

The workshop was structured as a general introduction on tangible interaction technologies and two ideation sessions of 25 minutes each with a small break of 10 minutes in-between. At the end, we reserved some time for the children to reflect about the sessions and the ideas. The researchers guided both the introduction and reflection phase and served as support of the session leaders. We decided to explore four different ideation techniques. We formed eight groups of six or seven participants. Each one utilized two different ideation techniques. Before starting the ideation phase, we asked the children to choose among almost 200 different objects that were placed on a desk in the front part of the classroom. Those objects were used later during the different ideation techniques. After choosing their object, the children were reminded that their ideas could be fun, playful or whatever they wanted.

Ideation technique 1. Activity Pad mock-up. For this task, we provided the children with a mock-up of a device (Activity Pad) that had already been developed in our unit (Pyykkönen et al., 2013). Our goal was to obtain new ways of interaction with the device as well as ideas for new applications. We asked the workshop participants to think about the action or actions that might be triggered when the item or items chosen in the previous phase are placed on top of the unit. After that, we asked them to describe other interactions they could come up with.

Ideation technique 2. Build a device of the future. Main technique behind this task is *bags of stuff* (Druin, 1999). In this technique, the bag is filled with art and craft supplies such as yarn, glue, paper, dough, scissors and pencils. Our goal was to get ideas for new interactive artefacts and any services or applications they could provide. We asked the workshop participants to build together a machine or device of the future, that will do something "intelligent" when touched, pressed, moved, heated, or spoken to. We asked them to describe what would it be and how would it work

Ideation technique 3. Funny or useful objects. For this task, the children utilized the objects they have chosen in the previous phase. Our goal was to determine their insight on how everyday life objects can be used to develop new interfaces. We asked the workshop participants to think what kind of interaction with objects could they think of and what kind of services would that interaction trigger. For instance, we asked them to define what would happen when an object is touched, moved, squeezed, thrown or if interacted with other's object.

Ideation technique 4. The drawings. We got the inspiration of this task in the Layered elaboration technique (Fails et al., 2013), where new ideas are added on top of others. For this task, the children got inspiration by the pictures all of them drew during the WS 1a. We present all the pictures, one by one, and asked the children to comment them. Then, we asked what was missing from the picture and what would be nice to have in the future.

4.2.2. Evaluation with researchers

The aim of this iteration was to decide which prototypes would be implemented in the next phase. The process started by analysing the WS 2 data. The university students went through the workshop video and audio recordings. As a result, they listed all the ideas chronologically and labelled by authorship (kid, older kid or university student). Then, the researchers proceeded to code the ideas obtained according to different categories, namely: provided functionality, type of interaction and feasibility. Part of this process was done by creating an affinity wall (Hannington 2012). We first started grouping the ideas according to their provided functionality utilizing post-its. For instance, we labelled the idea "*if you place this thing (figure playing an instrument) to this (Pad), then you would start to hear your favorite music from your stereos*" as "Remote controller". Other example of functionality was "Find an object". After that, researchers proceeded in a similar fashion for grouping the ideas by type of interaction for each of the groups of ideas obtained previously. The previous idea was labelled as "Item recognition". More examples of interaction were "Push Button", "Squeeze" or "Shake". The ideas that got more interaction modes were selected. To take the final decision, researchers evaluated the technical feasibility of the remaining ideas (if it could become a real prototype using mobile devices or other electronics). After the evaluation and selection session we ended up with 3 different ideas for prototypes: a tangible agenda, a lost & found service and a "teddy-mote" control for a video player.

4.3. Implementation / Fabrication and Argumentation

For the implementation of the different prototypes, researchers and students utilized a bunch of mobile phones, a tablet, different sensors, Near Field Communication (NFC) tags, a teddy bear, and some Do It Yourself (DIY) interfaces made up of paper and cardboard.

Prototype 1: Lost & found. The inspiration for this prototype is the child's sentence: "*If you do not find your math's book, you can call it so it will tell you where it is*". To build this prototype we attached a small mobile phone to different objects (such as a glove, and a DVD film). We created some labels out of paper with the picture of the objects and augmented with NFC tags. When an NFC enabled phone touches the label of the object, the phone attached to the corresponding object starts playing a sound that won't stop until the object is found and shaken.

Prototype 2: Tangible calendar. This prototype was inspired by the following claim made by one of the children: "*A calendar that for example, if you place your school bag on it, it tells you which books you need to take that day to the school*". The researchers built an interactive agenda by embedding one Android tablet and two NFC enabled phones in a cardboard resembling a calendar. The tablet provided the schedule for that day. The phones were used as NFC readers: to identify agenda's owner (*id card reader*) and the object placed on the agenda (*object reader*). When the id card and the object were both placed in the agenda the android tablet presented certain remarks related with the required event: for instance, "*this is today's menu*:" appeared if a user puts a Tupperware on top of the agenda.
Prototype 3: Video remote control. The idea behind this prototype came upon the following desire of a kid: "*Use a toy as a remote controller for… video player*". A toy (teddy bear) was equipped with different kind of sensors (gyroscope, accelerometer …). Interacting in different ways with the objects sends a command to a video player in a closer screen.

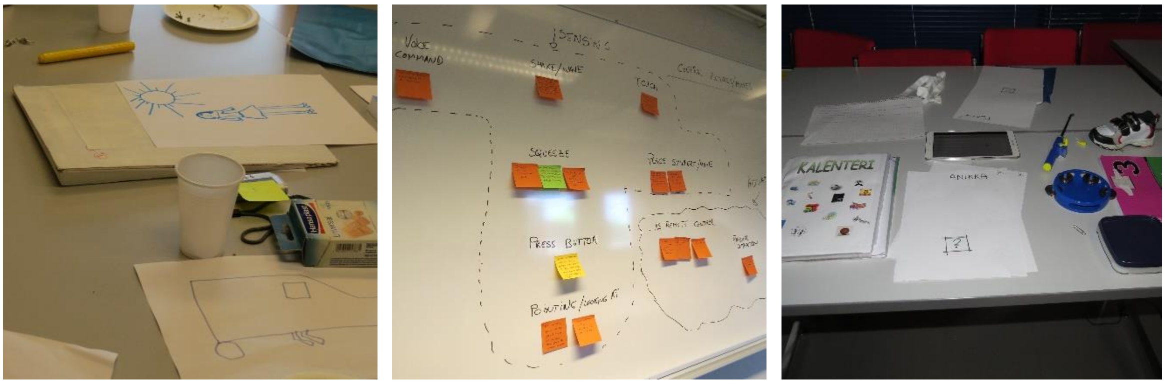

Figure 2. From left to right: Drawings from WS 2, Affinity wall by researchers and Tangible agenda

4.4. Testing and evaluation with children

This phase was developed within the WS 3. It was held at the university premises. The aim of this workshop was to let the children test the prototypes and reflect about them and the technology. We designed four different evaluation sessions: three were related to the prototypes and the fourth one was organized as theatre play. The groups for this occasion were the same than in the WS 2.
Evaluation session 1. Finding an Object. First, we explained the children how the *Lost & Found* service worked and let them test the application in pairs: one hid the object and the other one had to find it. After, the group were invited to reflect about the experience: They had to place post-its with their ideas in three different posters named "Good", "Bad" and "Could be better". Finally, they filled a short questionnaire asking questions about their emotions during the activity.
Evaluation session 2. Tangible Calendar. After showing how the Tangible Calendar works we let them test it. After that, we invited them to reflect on how the Tangible Calendar could be improved. For that end, we provided them a mock-up that resembled the Tangible Calendar and asked them to design their own version of a smart calendar that would be useful for school or hobbies.
Evaluation session 3. Toy Remote Control. First, we explained the children how to control a video player manipulating the toy and let them use the control. Then, the children were invited to define their own interactions. Working in pairs one kid manipulated the toy (e.g. shake it) and the other used a real remote control to command the video player.
Evaluation session 4. Preparing a play. We asked two group of children to prepare a small play (max 10 min) using all the material available in the room. They took inspiration for the themes from the pictures in task 4 from the WS2. They finally filled a like-chart feedback form.

4.5. Reflection

All the adults (both researchers and university students) involved in the project wrote a diary just after each workshop held with children, reflecting on what worked and what did not work. Moreover, we also had a final session with all the children, aiming to reflect together about the collaboration along the whole design process. At the end of the project, researchers and university students shared their reflections in a meeting and generated a power point summarizing the results of the case-study.

5. Insights and discussion

The goal of this case-study was to gain new ideas for technology design. In this paper, we have presented a lightweight methodology for organizing the whole cycle of a design process with children in their school environment, trying to disrupt the school routine as little as possible.

When working with schoolchildren, there are certain benefits of combining a research project with school daily routine. For instance, it is possible to have a large group of participants which implies getting a bigger number of ideas. Such is the case of this case-study, as the results were quite good in quantitative terms. More than 300 ideas were generated during the ideation sessions. However, there is a risk the quality of the ideas might vary, compared to intensive working with a small group of children in lab conditions, where it is possible to develop the ideas further in collaboration with researchers (cp. e.g. Cooperative Inquiry method (Druin 1999). We tried to reduce this risk by working with smaller groups formed by a combination of 3rd graders, 5th graders and adults during the ideation phase. Despite the complications that may derive from incorporating one or two school classes into a research project in terms of logistics or even results (e.g. having participants that do not form part of the study itself), there is a democratic aspect that cannot be ignored: researchers working with schools provide a large number of children a possibility to get new understanding on technology and technology design (Iivari and Kinnula 2016).

The methodology presented in this paper does not require any previous experience with design methods or technology use from the participating children. While preparing project, we aimed to do it as lightweight as possible for integration into school dynamics, but at the same time, it should allow the children to experiment, as much as possible, the whole design process. However, children did not have the skills neither the time to build the physical prototypes. In addition, children are not able to analyse the feasibility of different ideas, that is, which ideas can be technologically implemented, and which ones were either too complex or just impossible to build with the existing technology. It is known that children participating in the prototype building would develop their understanding of both the technology (the problem) and the design process (McElroy 2016). Nevertheless, having only researchers and university students in the implementation phases allowed us to keep the timeframe and not overload children during the process. Moreover, this is also very low-cost methodology as it requires very little from technology point of view. This was achieved by assigning the evaluation phase to the researchers. It was decided from the beginning what technologies would be available for prototypes. This information was taken into consideration during the evaluation session when selecting the ideas. While this added constraints to the resulting prototypes, it permitted the fabrication of them in a short time.

The reflection phase is one of the main additions of Hjorth (Hjorth et al.,2016) to the design process model. While there are many design models that ignore the reflection phase, we think it is one of the most important ones. In fact, although in our process model reflection is represented as one phase by the end of a cycle, we have incorporated it along the whole process. Researchers and university students were asked to write down their reflections after each session shared with the children. Moreover, we had two short reflective sessions with the 5th graders after each workshop they participated as facilitators (WS 2 and WS 3). The material generated has helped us understand, both during the process and afterwards when analysing it, what has worked and what has not. However, with the 3rd graders we did not had any reflective session apart from the last one. We will study how to incorporate more reflection with the 3rd graders in our future research.

6. Conclusion

In this paper we present a lightweight and flexible design process model that goes from conceptualization to testing and reflection and that can be utilized when co-designing with children, especially when incorporating research projects into school daily routine. We have effectively implemented it in a case-study in which a group of children of different ages, university students and researchers have collaborated to design, implement and evaluate different prototypes which use tangible interaction. We have shown how flexibility, for instance having different actors participating in different stages, permits to organize co-design activities without interrupting the school dynamics, but complementing them. We hope this research will inspire researchers and practitioners to organize co-design activities with children including a full design cycle, and not just one of its phases.

References

Alborzi, H., Druin, A., Montemayor, J., Sherman, L., Taxn, G., Best, J., ... & Sumida, L. (2000). *Designing StoryRooms: interactive storytelling spaces for children*.

Druin, A. (1999). Cooperative Inquiry: Developing New Technologies for Children with Children. In: *CHI '99. Proceedings of the SIGCHI conference on Human Factors in Computing Systems. Pittsburgh, Pennsylvania, USA, 15-20 May 1999*. ACM, pp. 592–599.

Druin, A. (2002). The role of children in the design of new technology. *Behaviour and information Technology*, vol. 21, no. 1, 2002, pp. 1–25.

Guha, M. L., Druin, A., & Fails, J. A. (2013). Cooperative Inquiry revisited: Reflections of the past and guidelines for the future of intergenerational co-design. *International Journal of Child-Computer Interaction*, *1*(1), 14-23.

Fails, J. A., Guha, M. L., & Druin, A. (2013). Methods and techniques for involving children in the design of new technology for children. *Foundations and Trends® in Human–Computer Interaction*, 6(2), 85-166.

Hagen, E. S., Røsvik, S. M., Høiseth, M. and Boks C. (2012). Co-Designing with children: Collecting and structuring methods. In DS 71: *Proceedings of NordDesign 2012, the 9th NordDesign conference*, Aarlborg University, Denmark. 22-24.08. 2012.

Hanington, B., & Martin, B. (2012). *Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions*. Rockport Publishers.

Hjorth, M., Smith, R. C., Loi, D., Iversen, O. S., & Christensen, K. S. (2016, October). Educating the reflective educator: Design processes and digital fabrication for the classroom. In *Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education* (pp. 26-33). ACM.

Iivari, N.; and M. Kinnula (2016). Inclusive or Inflexible - a Critical Analysis of the School Context in Supporting Children's Genuine Participation. *In: NordiCHI '16. Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, Gothenburg, Sweden, 23-27 October 2016. ACM, pp. 1–10.

Kumar, V. (2012). *101 design methods: A structured approach for driving innovation in your organization*. John Wiley & Sons.

Kinnula, M., Molin-Juustila, T., Sanchez Milara, I., Cortes, M., Riekki, J. (2017) What if It Switched on the Sun? Exploring creativity in a brainstorming session with children through a Vygotskyan perspective. *Journal of Computer Supported Cooperative Work* (CSCW), 26(4), 423-452.

Knudtzon, K, Druin, A., Kaplan, N.,Summers,K. Chisik, Y., Kulkarni, R., Moulthrop, S. Weeks H., Bederson, B. (2003) Starting on Intergenerational Technological design team. *In Proceedings of the 2003 Conference on Interaction Design and Children*, pp. 51-58

McElroy, K. (2016). *Prototyping for designers: Developing the best digital and physical products*. " O'Reilly Media, Inc.".

Plattner, H., Meinel, C., & Leifer, L. (Eds.). (2010). *Design thinking: understand–improve–apply*. Springer Science & Business Media.

Pyykkönen, M., Riekki, J., Jurmu, M., & Sanchéz Milara, I. (2013). Activity pad: Teaching tool combining tangible interaction and affordance of paper. In *Proceedings of the 2013 ACM international conference on Interactive tabletops and surfaces* (pp. 135-144).

Shaer, O., & Hornecker, E. (2010). Tangible user interfaces: past, present, and future directions. *Foundations and Trends® in Human–Computer Interaction*, *3*(1–2), 4-137.

Vaajakallio, K., Lee, J. J., & Mattelmäki, T. (2009, June). It has to be a group work!: co-design with children. In *Proceedings of the 8th international conference on interaction design and children* (pp. 246-249). ACM.

Zaman, B., Vanden Abeele, V., Markopoulos, P., & Marshall, P. (2012). The evolving field of tangible interaction for children: the challenge of empirical validation. *Personal and Ubiquitous Computing*, *16*(4), 367-378.