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Purposeful Prototyping with Children to Generate Design Ideas

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Abstract. Prototyping to generate ideas, as part of the design process offers various learning opportunities to sharpen young novice designers' design and making skills. This study situates itself within the landscape of Makerspaces and co-design with children as emerging opportunities of learning and skill building for children. From experiences of co-design with children it is often observed that children engage with outcome and object-focused model making or plain crafting with no intent of iterative prototyping for ideation. This paper describes the case of design prototyping sessions conducted with children aged 8–11 years old as a classroom activity. The sessions were investigated and analysed to reveal enablers and limitations to purposeful prototyping with children. Defining and contextualising the design problem with the children, the variety of prototyping materials for flexible building, interpretation and expression, and mid-prototyping discussions were all found supportive to children's purposeful prototyping.

Keywords: Prototyping · Children · Ideation

1 Introduction

Design processes offer various learning opportunities for young novice designers. Design activities enable children to shape design skills such as thinking in all directions, making productive mistakes, deciding on a direction, sharing ideas, bringing ideas to life and developing empathy [1]. Prototyping activity of building or crafting low-fidelity physical forms for ideation is explored in this study as one such design activity within a design cycle [2].

Prototyping is an integral part of the design process, also in its relevance to hone designers' skills. Prototyping can enable child designers to 'think by making' [3] as they frame and re-frame design problems while making. Designers often inform and develop design ideas through iterative cycles of reflection and action, where prototyping enables ideation in material forms.

The current landscape of the Maker Movement, dedicated to hands-on making and technological innovation [4] has paved the way for exploration of Makerspaces as alternate learning environments. As prototyping activities cater to the development of makers' crafting, making and building skills. Thus, prototyping within primary education

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has the potential to both teach children valuable 21st century skills while also producing innovative ideas [5].

However, novice designers oftentimes lack intentionality during the prototyping process, especially during the early stages of design [6]. From co-design experiences of prototyping activities with children, 7 to 12 years of age, it is often observed that children do not engage in iterative prototyping, nor do they employ divergent/convergent design ideation processes. Rather, they tend to be outcome focused, as they prototype to build a single object rather than develop ideas through prototyping. Children also tend to get lost in abundant material, often picking the most good-looking materials. As a result, time is wasted on irrelevant elements or prototyping does not yield a lot of information to forward the design idea [2]. Children's making capabilities may encourage object-oriented prototypes and ideation rather than those to do with different types of interactions, sounds or organisation of the space. Both the educational yield and innovation outcomes of children's involvement in design would benefit from knowing what supports children in finding and maintaining a focus on ideation during prototyping; for the purpose of this study, we refer to this as purposeful prototyping [2].

In the context of an evidence-based lesson series and accompanying toolkit for co-design with children at primary schools called 'Your Turn' [5], several activities were developed to foster children's understanding of the purpose of prototyping and train their prototyping skills [2, 7]. These activities interrupt the primary design process, leading to the question if the organisation of the prototyping session within a design project itself could also bring about more purposeful prototyping.

2 Research Theme and Methodology

This research sets out to explore what activities, materials and interactions enable or limit purposeful prototyping for ideation amongst children. A real-life design project proposed by the librarians at school was selected for the qualitative exploration of children's prototyping activities. The library at school faced various challenges and needed re-design ideas for the given space. Children participated as designers to generate design ideas by prototyping.

2.1 Session Activities and Materials

In the pilot case study reported here, design prototyping sessions with a group of 20 children aged 8–11 years old and following an International Baccalaureate, Primary Years Programme (IB, PYP), were held as classroom activities. A brief 20-min sensitisation to introduce and define the design challenge was conducted a day prior to the first 45-min design prototyping session with children. A second 45-min prototyping session was held a week later with the same group of children in continuation. Two librarians from the school participated as co-researchers and the class teacher as facilitator. A round of interview post each session, enabled the researcher to gather co-researcher and facilitator experiences and feedback of the sessions.

The following three specific focal points for supporting purposeful prototyping were identified from literature and previous experiences; these were considered during session set-up and analyzed afterwards.

Definition and Situation of Design Problem: A study of intentional prototyping with children for testing and evaluation purposes [2] promotes the formulation of sound goals to enable novice designers and children to focus on the right things while prototyping. Re-design of the library space was explored in its capacity to enable sound goals for children to prototype purposefully. It was selected as a design problem that the children would be familiar with, that would be relevant and motivating for them to engage with, and one with possibilities of multiple directions of exploration and many ideas.

The context of the design project was defined with children during the sensitisation by recollecting experiences of use and challenges in the given space, followed by brainstorming initial ideas for re-design. Once established, the design problem was presented on the screen throughout the first prototyping session with children.

Prototyping Materials: Materials were selected to generate quick low-fidelity and flexible prototypes for ideation. The prototyping materials such as basic shapes and small pieces were inspired by Doll's House Make Toolkit to encourage focused applications and scaled models [8] in the given context. Basic and generic materials instead of fancy materials such as glitters or stickers or specific materials such as scaled furniture or puppets were provided for prototyping. These were chosen for their low-level meaning and capacity to build, think and express with. A variety of material and tactile characteristics were provided to offer inspiration for ideation. These ranged from base materials such as paper, cardboard, foam sheets, fabric pieces, shoe boxes to foam pieces of different shapes, plastic cups, odd objects and knick-knacks; material often used for design prototyping. Tinkering material such as needle and thread, beads, buttons and sticks along with crafting material to join, combine, paste or modify prototypes was available for prototyping.

Design Communication: Co-researchers interviewed children during the prototyping activity, 15–20 min after the start of each session. The interviews were intended to engage children in reflective discussions and audio-recorded for documentation. The questions addressed the prototyping activity in terms of what, why and how children were building, development or change in ideas and next steps of prototyping.

Additionally, discussion cones were available for children to raise on their table to call teachers in case of doubts or for any other discussion points. Reflection templates to be filled in by the children, were collected at the end of the first session. The template was prepared to encourage children to reflect in words or drawing, on what materials they picked and why, what they prototyped and their next steps. The second and last session closed with video-recorded presentations of built prototypes by the children.

2.2 Analysis

Qualitative analysis of the data was applied, following the principles of mostly deductive thematic analysis [9]. Session audio recordings were transcribed, visual design output (such as photographs of mid-prototyping activity and of built prototypes) annotated with key statements. The gathered data of 20 children's prototyping activity was organized as 12 prototyping trajectories (Fig. 1 shows an example). The prototyping trajectories were supported by researcher's observation notes and any other filled in reflection templates and 2D sketches and drawings created by the children. Then low-level statements

pertaining to the research theme and sub-themes were formulated, clustered, and relations between clusters formed to map the elements and processes under research. Two main researchers performed a round of mapping, after which results were discussed and refined.

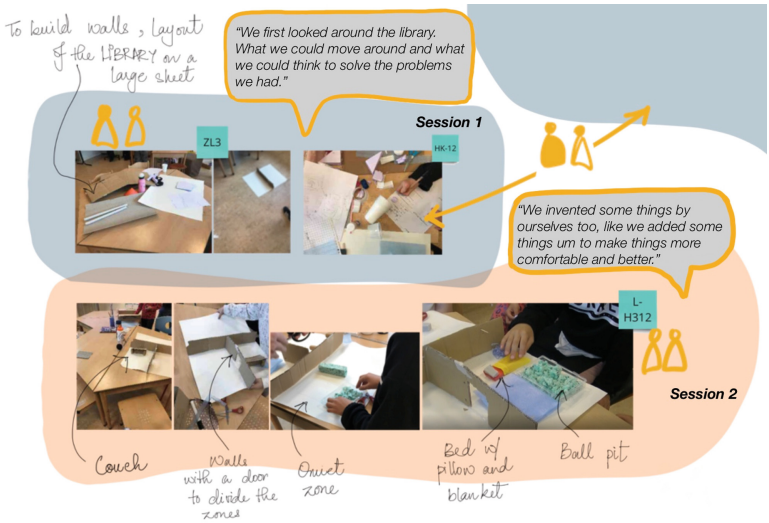

Fig. 1. Participant Z & L, and H & K's prototyping from session one, evolved into H and L's group prototyping during second session, while K joined another group for session 2.

3 Results

Children's prototyping outcomes and experiences are described to reveal enablers/limitations which include the definition and situation of design problem, prototyping material and mid-prototyping discussions.

Definition and Situation of Design Problem: The introduction of the design problem through a sensitisation activity where children identified the current use and challenges of the space, enabled children to take ownership of the design problem and supported their problem framing while prototyping. As one child reflected on how they, "*thought about all the problems and how to solve them!",* and another child stated, *"I thought about the……different problems we talked about and I thought maybe…we could actually umm do the things, if we add some more things."*

The reflection on challenges in a familiar space, also enabled children to come up with both ego-centric and user-centric ideas. As they claimed how *"some people like loud reading, but others want to read silently",* or why, *"We placed this table here, so teachers can keep their coffee mugs when they are called by some children."* Children also prototyped experiential and detail-oriented ideas based on their needs of the space, such as *"fuzzy and soft couches for a calm, cozy and comfortable space."*

The familiarity with and presence of the context encouraged children to formulate a mental or create a physical 'base'. As one child explained how they started their prototyping, *"We first (looked) around the library. What we could move around and what we could think to solve the problems we had."* Children's 'base' ranged from floor plans sketched and traced with 3D objects to physically stepping in and out of the space to trace the floor plan in 2D and with 3D materials. The prototyping 'base' provided sufficient grounding for further ideation of spatial elements and organisation. 3D prototypes were created with awareness of scale and size, and spatial reasoning. As some children described how, "*In the prototype we only have two, but we're going to use really more. Cause it's going to be big in real life"* or how, *"This moves here, so we have more space there."*

The spatial nature of the design project enabled children to use collections of small objects to represent and quickly change spatial arrangements. Though, the familiarity with the problems and the present restrictions of the space, hampered children from exploring distant concepts for a library, beyond the defined context and challenges.

Prototyping materials: The generic and basic materials with low-level meaning encouraged children to attribute specific meanings to forms of organisation and elements. Materials like cardboard, boxes, sheets of paper, foam pieces, plastic pieces and sticks were all employed in a variety of ways; to develop a scaled physical base, organise spatial layouts and craft furniture pieces including couches, bookshelves, signage, books and more.

Varying textures, forms and material characteristics such as soft fabrics and foam sheets, shapes of stiff foam pieces, hard plastics or cork supported and triggered children's diverse design ideas of space and furniture. While discussing their prototypes one child mentioned picking fabric to represent qualities such as "*soft, fuzzy or comfortable"*, or a *"curved piece of foam to act as a sound reflecting ceiling."*

A child described their initial plan to re-organise the entire library into zones, their prototypes and subsequent ideas were both inspired and limited by the materials in the form of *"11 chairs/couches as various options for seating"*. While the materials limited children's big ideas into those they could make, the restriction inspired children to tackle sub-problems and explore detailed solutions and ideas through prototyping.

In certain instances, materials were explored without explicit relation to the design problem. Craft explorations allowed tinkering with ideas through making. Reflection questions on how they came up with this idea, triggered children to adapt their crafting explorations to design ideas. As one child describe, *"first I was in lunchtime I was playing with some sticky notes and I tried to make a puppet and…I made this, it is a puppet, and I thought it would be nice if we make bookshelves out of these"*. The adaptations of material forms into design solutions thus exhibited a sense of flexibility in ideating as opportunities emerged.

Another child describes during the second session,*"I changed everything, so last week I drew the plan, before I wasn't in partners (in a team), but then today I chose to be in partners…. I'm making these lights over the bookshelves now."* Children also started with low-fidelity, flexible and adaptive pencil lines, placed and assembled pieces to accommodate changing ideas. Though these were replaced with firm lines, stuck pieces and fixed elements of organisation towards the end of the sessions.

Design Communication: The discussion cones to encourage children to initiate discussions, were quickly forgotten as children engaged with building their ideas. Mid-prototyping interview questions of what and why children were prototyping, triggered children to describe their simply built, low-fidelity prototypes with lots of functional details and reasoning supporting their ideas. As one child described a (robot-like) machine they built out of small blocks of foam pieces, when asked what they were making, *"they have chime and they can also make some buttons so the machine can deliver some books and…the machine can also have some sensors and then there's some button that 'to library', so if you press the button to 'library' the machine can take the, the machine can automatically take the book to the library and can give it to the librarian."* A lot of the ideas were not (yet) captured in the prototypes, and only surfaced in mid-prototyping interviews.

Only the question regarding their next steps elicited some speculative responses, when children expressed how their ideas might change or they might add some things or explore more activities and areas within the space. Other reflection questions and the closing presentation, however, triggered static descriptions rather than allow for further speculation.

Very few children filled in their reflection templates. Furthermore, the filled in templates comprised of only sparse details and incomplete descriptions of children's prototyping activities.

4 Discussion

Design prototyping sessions with children aged 8–11 years revealed activities, materials and interactions that enabled and limited children to purposefully ideate through prototyping. The identified enablers/limitations include the activities to define and contexualise the design problem, prototyping material provided and design communication.

The activities to define and contextualize the design problem engaged children in experiential reflections, enabling an in-depth exploration of specific problems and emergence of ideas based on personal needs. It can thus be argued that the sensitisation activities enabled children to formulate *sound goals* [2] for creative problem-solving while prototyping. The design problem and familiarity with context enabled children to express user centric and experiential ideas informed by spatial reasoning. The spatial nature of the context encouraged children to develop a mental or physical base for scaled explorations. While relevant anchors to children's problem-oriented explorations, the close-to-home definition and situation of the problem limited children from engaging with divergent thought processes beyond the scope of the identified concrete problems.

The generic quality of materials with low-level meaning encouraged tinkering, iteration, and individual expression to generate specific forms and ideas. The basic materials allowed children to start with low-fidelity prototypes which were flexible and adaptive, assembled or drawn rather than fixed; expressing awareness of the intent of prototyping to accommodate changing and developing ideas. The basic material also enabled children to easily attribute specific meanings and functions to lowly-defined elements (e.g. chairs, light fixtures) within the organisation of their prototyping base. A variety of material properties appeared to support diversity in solutions. In some cases, the prototyping material restricted children's 'grand' ideas into 'buildable' ones and subsequently

steered children towards sub-problem and detailed explorations. The prototyping materials provided in this case study enabled children to ideate purposefully and, in some cases, random tinkering and crafting were adapted to design solutions in response to mid-prototyping reflection questions.

Children's built prototypes were representations of rich details and functional aspects, only communicated during mid-prototyping discussions triggered by co-researchers. Children expressed no interest or motivation in initiating a discussion with co-researchers while prototyping, nor in writing about their activity. Mid-prototyping reflection questions on what and why children were prototyping along with discussion of their next steps and goals stimulated children to describe and reason their prototyping and prototypes in depth. It was observed that the discussions were more descriptive than speculative. The mid-prototyping questions encouraged only some speculative responses and the questions were found lacking with respect to prompting speculation on follow-up steps or ideas. Instances of exchanges with peers triggered new inspiration and iterations, even after they indicated saturation.

Further to the three identified focal points of purposeful prototyping, awareness of session closing in relation to children's ideation, further opportunities of research and limitations of the study are discussed.

Children's flexible and adaptive prototyping trajectories took a turn towards representative 'final' models, and speculative responses turned into descriptive presentations. Both indicate that the awareness of number of sessions and a closing presentation of built prototypes prompted children to converge to their final ideas.

Specific activities to define and contextualize the design project should be further explored in different contexts such as products or services. Choice of prototyping materials and making left up to children, or materials more representational of the design context offer scope of further research on purposeful prototyping with children. Further iteration of in-process reflection prompts, also in the context of collective group discussions should be explored for purposeful prototyping to enable reflection and speculation. Principles for constructive design feedback dialogues amongst young novice designers [10] are proposed as guidelines for future exploration of prototyping dialogues with and amongst children.

The current curriculum of this specific school engages the children in inquiry-based explorations to shape and create their own individual projects, which in many aspects resemble design projects. Having worked on such projects in groups or by themselves before, the children were able to recognise and manage their own group dynamics for purposeful prototyping, given the choice.

5 Conclusions

Based upon this pilot case we propose four pillars for purposeful prototyping. Firstly, the design problem is co-defined in close collaboration with the participating children to foster ownership towards the problem. Prototyping materials that have a large variety of (visual/tactile/material) characteristics and only low-level meaning will allow for flexible interpretation and expression. Informal conversations with reflective and speculative

prompts can actively engage children in ideation while prototyping. Lastly, we propose both, prototyping and ideas are captured as rich stories that transcend the visually apparent characteristics of the prototypes.

Ethical Considerations

The design project was carried out within the primary school's regular design curriculum. Children and parents were informed what research was conducted during the project, after which children were free to opt in (or out and participate in alternative educational activities). A real-life design problem was chosen, and the solutions produced by the participants were communicated to the school team for inclusion in their innovation plans. Children were informed before the start of the project that some, not all, solutions might be implemented. The researchers thank the teachers and children of the participating school class for their contributions.

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