A Toolkit and Lessons for Designing Smart Things with Children for Outdoor Environments

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Abstract
Smart things are present in children's life, from smart watches to smart toys. Designing smart things with children can help them understand the inner working of smart things and reflect on the usage of technology. This paper stems from action research around smart-thing design with children, conducted across three years, in diverse countries and with different children, and mainly for outdoors' environments. The analysis of data gathered across the research enabled authors of this paper to distil practical guidelines for smart-thing design toolkits for children, which helped children design for a given environment and reflect across design. They might help other researchers organise smart-thing design with children, encompassing different design stages, and make them reflect in design, in relation to the chosen environment.

Keywords
Children, design, smart thing, nature, outdoors, action research

1. Introduction

The role of children in design has been explored extensively in the Child-Computer Interaction and related communities. In the participatory design tradition, researchers or practitioners team up with children so as to support the ideation of novel design solutions and, lately, to reflect while ideating so as to foster critical skills in children's approach to technology. In the making tradition, children are invited to program and prototype solutions, and tinker with different sorts of material, in an informal learning context. In both traditions, children's benefits should be considered in the design process.

However, in order to ensure that children's benefits are considered in the entire design process, from ideation to programming and prototyping, design needs to be framed within an encompassing research approach, which plans for and assesses such benefits. Authors of this manuscript chose to frame design with children with action-research [1]. Specifically, this paper stems from the analysis of an action research experience, longer than three years, with 70 children, 41% females and 59% males, aged 8–16 years old, and across different towns in Italy and Greece, e.g., [3,4,6]. See the table below.

Along years, children were challenged to design smart things, mainly for outdoor-nature parks, e.g., a smart tree which invites park visitors to listen to its story. The SNaP design toolkit was purposefully developed and evolved, so as to support children's gameful design of smart things, according to the chosen environment. Notice that, whereas playful design aims at affording so-called "paidic qualities", characteristic for unstructured play, gameful design aims at embedding "ludic qualities or gamefulness (the experiential qualities characteristic for gameplay)" in design [2].

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Actions were the smart-thing design workshops, in which children used the toolkit for designing and reflecting in design. In other words, in line with the perspective adopted by the workshop but with children as main actors, actions aimed at making children explore the possible usages of technology, reflect on technology and critically develop technology for nature environments.

Data were uniformly gathered and analysed, leading to the reflections which are the focus of this paper. The reflections are shaped as lessons concerning gameful smart-thing design for children, which we hope can spark interest in the community of researchers willing to engage in design of technology-enhanced nature environments.

When	How	Where	Participants
Summer and Autumn 2018	In presence	Athens, Milan, Bolzano	12 (8F, 4M)
Summer 2019	In presence	Bolzano	27 (10F, 17M)
Autumn 2019	In presence	Bolzano	4 (1F, 3M)
Summer 2020	At a distance, in presence	Ioannina, Milan, Bolzano	7 (3F, 4M)
Winter 2020	At a distance	Salerno	20 (7F, 13M)
		Total n. of participant children:	70 (29F, 41M)

2. Design Model

A reference model for structuring the design process in workshops with children is by Smith et al. [7]. This was adapted to the requirements for smart-thing design with children along three years of action research.

Figure 1. The design model

In the resulting model, smart-thing design starts with the exploration of smart things, so as to familiarise children with the design language and what smart things are made of—input devices with certain properties, output devices with other properties, and things of the chosen nature environment, e.g., trees or benches. It steps through the ideation of smart things, when different ideas are brainstormed over, and conceptualisation, when children converge on an idea and play it out. It moves then children into the programming and prototyping of their ideas of smart things for the chosen environment. All stages are intertwined with multiple reflection stimuli, from peers and experts alike. See Figure 1. All stages are made "tangible" and connected by means of the toolkit, explained next.

3. The SNaP Design Toolkit

Generative toolkits are very often used in design processes to facilitate the ideation stage of smart-thing design, whereas programming and prototyping toolkits are employed in the related stages of smart-thing design. These tools can serve as a common "design language" for designers, researchers and users in the design process. Game cards, in particular, have been

used to engage non-experts in a wide range of design processes, acting as sources of inspiration and a tangible, play design material, e.g., [3,4].
Game cards can be used to motivate participants towards the design goal and help them understand its context. Examples are scenario and mission cards of Tiles [5]. Although not necessarily in the form of game cards, motivation material is frequently used in workshops with children, e.g., the work by Smith et al., e.g., they used briefing statements to start immersing children in a scenario [7]. SNaP also employed similar briefing statements for immersing children in a context, as well as motivation cards in the form of *mission* cards for giving the design goals; by playing these cards, each player chooses her or his own mission for the smart things under design. Cards for smart things also tend to have so-called *technology* decks for input (e.g., buttons) and output devices (e.g., LED matrix), which are related to physical devices. Cards need also to represent the *things* to be made smart, and thus they are highly context dependent. In the work reported in this paper, they were related to park elements, such as benches or trees. Examples of such decks of cards are in Figure 2, left side.
Cards are part of a board game, physical or digital, which guides children (1) to explore cards and hence components of smart things, (2) to brainstorm and ideate with cards, (3) and finally to conceptualise ideas of smart things. The game board embeds different reflection lenses that children explore while designing, e.g., "does your idea make sense for the mission of making people interact with nature elements?". See Figure 2 for the first level of the board game, for exploring thing cards and technology cards and for starting the ideation of smart things.

Figure 2: Examples of cards (left), and the first level of the ideation tool of SNaP, which contextualises this design stage in a nature environment familiar to participating children (right)

Besides tools for ideating, the SNaP toolkit also supports the transition of ideas into interactive prototypes of smart things. In the research reported in this paper, the digital version of SNaP enables children to automatically generate a basic program to start from in the block-based Makecode programming environment (available at makecode.microbit.org/). See Figure 3. The program is generated from the input and output cards which are part of children's conceptualisation of a smart thing. Then children can continue exploring how to make their ideas evolve through programming and prototyping, besides reflecting in such stages, as well, on the technology under design.

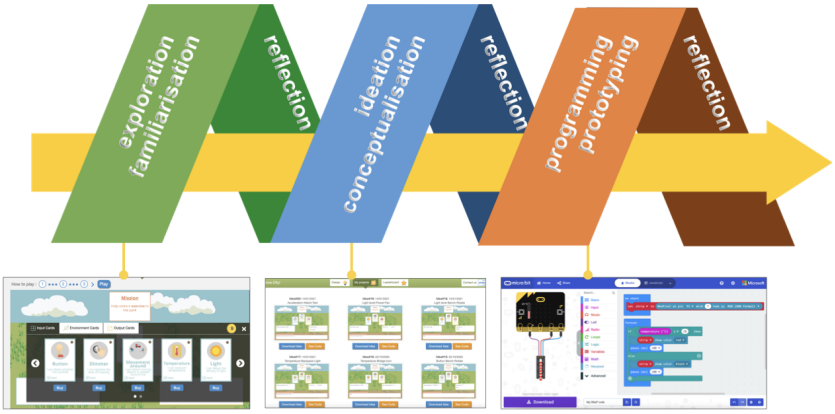

Figure 3: The latest version of the SNaP toolkit, digital, which automatically generates programs for children's ideas in the Makecode block-based programming environment: see snap.inf.unibz.it/play.php

4. Lessons and Conclusions

Along three years of research, children used the SNaP toolkit. Across all years, data were uniformly gathered and classified, e.g., in relation to children's usages of SNaP. Data were lately processed with a content analysis and reflected over so as to extract guidelines for smart-thing toolkits for children. The main lessons are extracted and elaborated in the remaining part of this paper.

4.1. Gameful Design

Games or game elements help motivate and guide children in the design of their smart things. In the research reported in this paper, design was made gameful with the SNaP toolkit, offering children a fun and not-intimidating way to explore the design process. Children, being in general familiar with playing board games, easily grasped how to use SNaP's boards and its mechanics, and they were motivated to try to reach the winning condition even in cases of no former experience, e.g., to make the town park more attractive for their peers.

The design process should be structured as a game or with game elements so as to motivate and guide children in design.

4.2. Story-line

In games, story-lines or narratives, when present, help motivate players towards the game goal, and immerse them into the game. In the same vein, briefings were used in design with children to communicate the design goal, e.g., [7]. In SNaP–framed design, the design goal was shared via the story-line of SNaP, whereas mission cards of SNaP turned the goal into objectives for smart things. For instance, in Summer 2019, the story-line started as follows: "we need to help the Mayor of our town to design a new nature park with smart things for your peers" [4]. A mission card for a smart thing by a child was thus "make people interact in the park".

The story-line or narrative should motivate children and make the design goal tangible (e.g., through missions for players to accomplish).

4.3. Mechanics and Aesthetics

In SNaP-framed design, the mechanics and aesthetics of the toolkit helped children navigate through the design process and contextualise design in the chosen environment, e.g., the Talvera park of Bolzano represented in Figure 2, right side. The closed rule-bound nature of games stimulates an awareness of structure and function, and it can transform spontaneous decisions into more formal understanding. Children, when playing for the second time with SNaP, were in fact able to remember the game rules and levels which helped them proceed with design with no help from adults, indicating their understanding of the process.

The game mechanics and aesthetics should be designed so as to offer a familiar rule-bound structure, which smoothly guides children along design and helps them become aware of its stages in relation to the given environment.

4.4. Player Roles

In SNaP-framed design, roles for players were partly bound by the game mechanics, which helped make children own their ideas, clarify adults' roles in design, and reflect with others with specific roles. Without clearly specified roles, adults can greatly influence children's design activities even without meaning it. The mechanics of the toolkits for supporting design could thus be used to specify or negotiate the roles of all participants so as to embed them clearly for all into the design process, as in the case of SNaP-framed design. Adults' roles, in particular, should be defined according to children's varying requirements and benefits. For instance, in in-presence workshops with SNaP, adults' role was part of the game rules and guided seemingly by these, so that scaffolding was gradually decreasing as per children's learning of design, one of the expected benefits of their participation in design. Their learning was assessed by triangulating and processing different data, e.g., learning questionnaire data and the evolution of children's smart things over time [4].

Player roles should be defined in relation to design roles, so as to clarify responsibilities and tasks in design, e.g., playing the expert of a design heuristics. In particular, the role of adults should be adapted to the requirements of children and their expected benefits in design, e.g., engagement and learning in smart-thing design.

4.5. Reflections for and by Children

Toolkits should have lenses that help children critically reflect on specific aspects of the things under design, in relation to the environment and technology-related risks. For instance, SNaP has different reflection lenses, e.g., related to the consistency of the smart thing under design for the chosen mission or safety-related risks for the environment or people for which/whom the smart thing is designed. Lenses should come with questions and probes that help children reflect critically and elaborate on their solutions. Moreover, reflection lenses should adaptable and embed children's own reflections in design.

Tangible and adequate reflection lenses, with questions and probes, should be embedded in playful toolkits for children, in relation to "things" of the environment and risks technology can bring therein, besides able to capture children's own reflections in design.

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