The 5-Step Plan

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Empowered Children's Robotic Product Ideas

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Abstract. When children and adults work together as partners throughout the design process in a collaborative and elaborative manner, children come up with a wide range of creative and innovative ideas. The 5-step plan is a holistic approach that empowers children as robotic product designers. Researchers as well as educators can use the approach to introduce children with different interests to robotics and explore their interests, desires and needs regarding interactive technology like robots. In this paper, we describe the 5-step plan and present our findings on children's robotic product ideas from three case studies.

Keywords: Educational robotics; robot design; child-robot interaction

1 Introduction

Hendler separates robots for children into the categories toys, pets, interactive displays, educational robotics, and service robotics [1]. Bertel and colleagues [2] further distinguish between educational robotics (or hands-on robotics) and educational service robots: they argue that research within educational robotics has a tradition for participatory design while "the majority of research on educational service robots is still based on highly controlled experiments in lab settings which cause certain limitations to the transferability and applicability of the results to real-world learning environments". They also imply that Wizard of Oz settings may foster unrealistic expectations and thus cause children to become disappointed when they meet "real" robots. Popular culture also often serves the benchmarks for real-world robot systems and their behaviors [3, 4], which can result in unrealistic expectations, e.g., Veselovská and Mayerová [5] could observe this with children in educational robotics workshops. Eisenberg and colleagues [6] also warn about the effects of ubiquitous educational technologies whereas Resnick and Silverman [7] suggest "choosing black boxes carefully".

The constraints of the employed technology and the study set-up have an important impact upon children's perception and expectations towards robots. What kind of future robotic products would children imagine if we circumvented these constraints and studied their ideas in a creative context combining education and design? In this paper, we explore this question and present our approach – the 5-step plan – along with our findings on children's robotic product ideas from three case studies.

2 Related Work on Children, Technology & Design

Motivation and emotions play an important role in learning. Children are driven to grow and assert themselves, as well as to love and be loved. Considering these drivers, adapting learning activities to children's lives and interests [8], and empowering children to learn through play [9] will motivate them. Various design methods consider growth (learning by doing), diversity (not everyone will arrive with the same set of skills) and motivation. One is Learner-centered Design, which should result in the participants' understanding, create and sustain motivation, offer a diversity of learning techniques, and encourage the individual's growth through an adaptable product [10]. Another is Bonded Design, where children participate for a short but intensive time in activities with adult designers. The techniques include brainstorming to generate new ideas, paper-prototyping design ideas both individually and in small groups, and building a consensus on a final low-tech prototype [11]. Additionally, in Cooperative Inquiry children and adults work together as partners throughout the design process in a collaborative and elaborative manner [12]; this leads to empowered children as well as a wide range of creative and innovative ideas [13]. Finally, Garzotto [14] argues that developing technology in an educational context creates a more holistic view (product focus) underlining a number of benefits: collaboration and discussion skills, project/goal oriented attitudes, and capability of reflection and critical thinking (as well as reflecting on technology) for children; and innovative solutions in the way technology can be exploited in an educational setting.

Resnick and Silverman [7] suggest that the best learning experiences occur, when people are actively engaged in designing and creating things. Schrage [15] also underlines the importance of prototyping and argues that prototypes catalyze discussions among designers and potential users. Yet, prototyping is one phase in "creative improvisation" processes embraced by many highly innovative companies to lead their markets [15]. Design Thinking describes such a process where the designer's perception is matched to people's needs with what is technologically feasible and what is a viable business strategy [16]. The design studio is another method where designers work on complex and open-ended problems, use the precedent and think about the whole, use constraints creatively and rapidly iterate their solutions [17].

3 5-Step Plan

The 5-step plan is an introduction to robotics for children with different backgrounds and varying levels of knowledge. It guides them through the work of real robot experts by introducing them to three important phases of product development: ideation, prototyping and evaluation. Children are encouraged to think as product designers during ideation phase and offered a simple structure to conceptualize a robot from scratch. In this approach, theory and practice are carefully balanced. Children are not constrained by the limits of technology: there are no limits for their robots' capabilities when they start brainstorming. What they cannot build, they describe on paper with words or sketches. In this paper, we focus on the conceptual design (ideation phase). In follow-up sessions – addressing prototyping and evaluation – maker technology can be used to build working prototypes and evaluate them.

The 5-step plan is based on design methods that empower children [13] to address problems that influence their lives. It uses similar methods like Hamidi and colleagues [18] who introduced children from a rural Mexican community to technology by drawing elements from Learner-centered Design, Bonded Design and Cooperative Inquiry. The plan can be integrated into different teaching or research contexts; it can be adapted to different age groups or even to adults who are not familiar with robotics. We have employed the 5-step plan in three different workshops with children aged 7 to 14.

Figure 1 shows an overview of the 5-step plan as presented to the children.

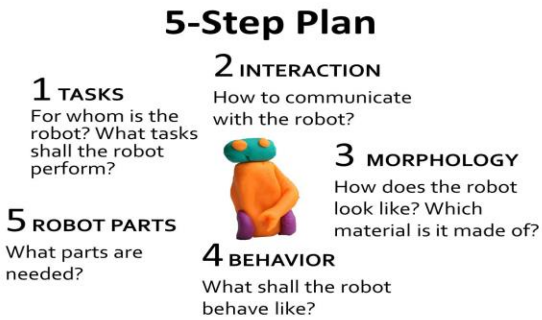

Fig. 1. The 5-step plan

3.1 Pre-Phase

The researchers introduce themselves as robot experts and explain that in this workshop, the children will learn how to design robots while the researchers will learn from their ideas how to build better robots in the future. As a starting point, children are introduced to technology as *"human-made objects, tools, artifacts that help us"* [19]. We expect that children broaden their view of technology as "*something that we build to make our lives easier*" and start thinking critically about it. The definition of robots draws on the definition of technology: *"True robots act autonomously. They may be able to take input and advice from humans, but are not completely controlled by them"* [20]. We teach children the difference between robots and machines, show them different robotic applications that go beyond public knowledge, and guide them towards the concept of autonomous behavior.

3.2 Main Phase

We briefly introduce three incisive stages of a design process (ideation, prototyping, evaluation): *Real robots are highly complex and designed by a team of experts from different disciplines (designers, human-robot-interaction experts, programmers, engineers, etc.). Robot experts consider a few things before they start building prototypes.*

They ask people, sketch, build models, discuss their ideas, and share them with others. This is what we are going to do today. Each of you will think of a robot idea and then build a model to share it with others.

Children are guided step by step through five important topics they need to cover if they are to design a robot like a product designer. Pictures help in grasping abstract concepts, but in order to minimize bias on their design ideas the first four steps are explained without any pictures (see also Figure 1).

Step 1 – Robot Task ("assignment").
The children are asked to imagine a robot for themselves that does anything they want. Every idea is valuable in this phase and not discarded as useless or undoable. Children are rather encouraged to think about a helper and adapt their ideas to this concept.

Step 2 – Robot Interaction.
Known and not yet invented applications are both encouraged equally. Children learn that some of their ideas need scientists who invent new things that are then built into the robots by engineers. *How would you tell your robot what to do? Would you talk to it in a secret language or with signs? Would the robot understand your thoughts? Or would you use an app to control it?*

Step 3 – Robot Morphology ("looks and materials").
We have divided the third step, robot morphology, into "looks" and "materials". First, we introduce four different categories of robot morphology from Fong and colleagues [21]: *Robots can look like machines, like cartoon characters, like animals (zoomorphic) or similar to humans with a head and body (anthropomorphic)*. Second, we talk about different materials robots can be made of, and describe some properties: *They can feel smooth, hard, furry, etc. How would your robot feel like?*

Step 4 – Robot Behavior.
In the fourth step, the abstract concept of autonomous behavior needs to be explained in a manner that children understand. We use two paths: In order to make the abstract word "behavior" more concrete, we describe roles (or personas) with which children identify. *Would you like your robot to be rather like a butler, a teacher, a protector, a pet or a friend?* We also explain that robots have rules to obey and introduce the Three Laws of Robotics [22]; they offer children a first orientation and are more child-friendly than, e.g., the EPRSC / AHRC principles of robotics.

Step 5 – Robot Parts.
This last step brings the previous steps together. The researchers show pictures of mechanic and electronic parts: some are used in every robot; others depend on what the robot does, how it looks like or how it should behave. In the beginning of the design process (ideation), the focus is on the holistic view of a product developer who needs to know what parts are needed but is not concerned with the details.

After this introduction children immediately start building a prototype with modeling clay that they can take home to show family and peers. In an expanded 5-step plan concept with follow-up workshops that move from ideation to prototyping, Step 5 is a starting point to go into more detail by using simple technology (e.g. maker electronics) to work out technically feasible solutions.

Post-Phase.
Once through all five steps, children are encouraged to go back to Step 1 and check if the robot has all parts to accomplish the tasks it was assigned to, then Step 2 to check interaction, then Step 3, etc. Then they start again from Step 1 to check if all fits together. The order of the steps is not as important as the iteration after completing all five steps. When the low-tech prototype is finished, children may present it to the rest of the group. They learn that a robot is developed in iterations and they best start quickly with a simple and cheap prototype to build new ones from the lessons learned.

4 Case Studies

The 5-step plan can be integrated into different participatory design or educational robotics contexts. We were involved in three different educational activities:

1. Children University workshop (July 2013, July 2014): one week in summer children aged 7 to 12 attend science and technology lectures at the university and participate in workshops
2. Robot Design workshop (July 2014): two weeks in summer girls aged 10 to 14 participate in science and technology workshops
3. Classroom workshop series (October 2014): five middle school classes (students aged 11-13) each participated in three consecutive science communication project workshops the first of which was "ideation"

Each of these case studies was done with different children in varying contexts and environments in a capital city.

4.1 Analysis

We evaluated the 5-step plan from three perspectives: (1) Can children with different interests be empowered to define problems that influence their lives and share their ideas through low-tech prototyping? (2) Does the 5-step plan provide them enough structure for their open creative process? (3) Can researchers derive ideas and needs for future robotic products from these contributions without using the actual technology? In this paper, we report on children's robot ideas that we derived from the qualitative data from the 5-step plan templates the children had filled out during the workshops. We combined the data of all three case studies and had 114 children in total. The various robot ideas were categorized into meaningful themes, e.g. robots for different types of playing activities were collected individually in the robot for play category. This categorization led to a quantification of the qualitative descriptions, which we analyzed further.

4.2 Results: Robots kids want

All children had a robot idea to solve a problem from their lives, ranging from cooking robots to protector friends and all of them built a model of their robot from modelling clay. One student even had two ideas and built two models. Many robots (75%) were related to actual problems out of the children's lives (including their family), e.g. being alone at home after school and needing help with cooking or homework, taking care of pets, having entertainment or a playing partner, waking up, or transporting from A to B. The other robots were for people with special needs or special interests (themes with which the children concerned themselves).

In our analysis, we only looked at robots for children that were related to the children's own problems (including their family) and where templates were sufficiently completed, using 83 templates from 38 girls (46 %) and 45 boys (54 %) aged 7 to 14. Table 1 shows which tasks robots should accomplish for children (and their families). Figure 2 shows three examples of children's robot ideas.

Table 1. Most mentioned ten tasks and their occurrences.

Task	Occurrence
Play or entertain	23
Do or help with homework	21
Help or serve or both	18
Help in household	18
Cook or serve food	13
Bring or carry or lift objects	12
Talk or make conversation	9
Be a friend	8
Protect	8
Play music or sing	7

Fig. 2. Examples (left to right) FrühlingS1000 as good friend who sings and cooks (girl, 13), ETI 5 as reusable exploding play robot (boy, 9), pizza-shaped Cronk to tidy up room (boy, 10)

Interaction with speech was mentioned 56 times, followed by mobile phone or tablet app combined with touchscreen (15 occ.), and then keyboard, mind and remote control with seven occurrences each. The most preferred morphology was anthropomorphic (34 occ.), followed by zoomorphic (21 occ.), machine-like (14 occ.) and cartoon-like (11 occ.). In total, 35 children explicitly stated that their robot should be nice or friendly. This statement was very distinctive. We interpret this in two ways: (1) nice and friendly behavior is an important topic in children's lives; (2) these findings affirm Fong and colleagues [21] identification of mostly "benign" social behavior in social robotics, hence social robots usually designed as assistants, companions, or pets. We also saw this in the personas dedicated to the robots: the 51 children who named personas (not describing adjectives) mentioned friend (12 occ.) and butler (11 occ.) most often, followed by pet (7 occ.) and butler & friend (4 occ.). Other mentioned personas (≤ 3 occ.) were different combinations of butler, friend, protector and pet (in sum 13 occ.), and teacher (2 occ.) or play partner (2 occ.).

5 Conclusion

We have introduced the 5-step plan, an approach that (1) empowers children with different interests to work on technology as product designers; (2) provides them with enough structure for their creative processes; and (3) offers researchers a tool to examine children's robot ideas. The 5-step plan is useful for researchers as well as teachers to introduce all children to robotics, not only children interested in becoming engineers or scientists. We contributed our findings about what types of robots children want to the community to demonstrate that the approach can be used to explore the ideas and needs of a wide range of future robot users.

We have already conducted follow-up workshops in the Classroom workshop series where we used simple electronics, so that interested students could work on engineering tasks while the others could choose other topics of their interest, like marketing, design, or human-robot interaction. We report on this in [23]. We have also started a next round of the Classroom workshop series with four new classes. In these workshops, we have introduced the storyboard technique to analyze how well storyboard and 5-step plan complement each other.

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