What Children Really Contribute When Participating in the Design of Web-Based Learning Applications

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Abstract. Over the past 20 years a vast amount of research has been published on participatory design (PD) with children – especially in the field of educational technology design. The literature reveals many advantages (e.g. giving children voice in design), but also some challenges (e.g. overcoming the power distance between co-designers). What is difficult to find in published results on PD with children, is evidence that the children's design ideas are suitable for development into actual products. Serious educational games (SEGs) have to meet certain requirements. If children participate in the design of SEGs but their designs do not fulfil these requirements, are we still supposed to include them in the final product? Researchers often present examples and descriptions of the prototypes produced by child designers, but they do not always discuss to what extent these ideas are implementable. This paper reports on a study to assess children's contribution to the design of a web based educational application in the form of a SEG. Using a case study, children's prototypes were analysed using a valued framework for SEG design to determine if their designs satisfy the requirements of SEGs. The results demonstrate how children naturally include the elements of the SEG design framework. The findings confirm that involving children in the design of a web based educational game using well-tested techniques for doing PD with children, will result in design ideas that are in line with general requirements for SEGs and are thus implementable.

Keywords: Participatory design · Cooperative inquiry · Children · Serious educational games

1 Introduction

Interaction design and children is a noteworthy field of research within human-computer interaction (HCI). The ACM SIGCHI conference on Interaction Design and Children and Elsevier's International Journal on Child-Computer Interaction include participatory design (PD) with children as a recurring theme. PD actively involves the stakeholders (such as the users) in the design process [5]. Druin [2] is the 'PD with children' pioneer and introduced the Cooperative Design (CI) method. CI involves intergenerational design teams consisting of children (usually between the ages of 7 and 11) and adults designing interactive products for children together, using techniques such as brainstorming and low-tech prototyping.

H. Xie et al. (Eds.): ICWL 2017, LNCS 10473, pp. 185–195, 2017.
DOI: 10.1007/978-3-319-66733-1_20

Academic literature on designing with children mostly reports on the *process* of designing with children rather than on the design *outcomes*. A clear impression of what children's actual contribution to real-world products could be is therefore elusive. The study reported here is an attempt at addressing this gap through a thorough investigation of one CI project during which a web based educational application was designed with the help of children. The designers intuitively interpreted the intended outcome to be a serious educational game (SEG). I analysed the children's design prototypes to establish to what extent they satisfy the requirements of educational game design. Mapping the elements of their designs to the elements included in Annetta's [1] framework for SEG design, revealed which aspects they intuitively incorporate and through what mechanisms.

The paper is organized as follows: The next section introduces related literature focusing on PD with children and SEG design. Section 3 presents the research process – how the PD sessions were conducted and how the outcomes were analysed for comparison with SEG design requirements. I then discuss the design outcomes and their assessment in terms of SEG requirements in Sect. 4 and conclude the paper in Sect. 5.

2 Related Work

2.1 Participatory Design with Children

In PD, the end-users of an organisational or technological system take part in the design and decision-making processes associated with that system. It originated in Scandinavia in the 1970s as a mechanism for workers to influence the design of new technologies for use in their workplace [5]. CI with children evolved from PD to make children part of the teams that design technologies aimed at improving their education and their lives in general [2].

Guha, Druin and Fails' [7] primary motivation for designing with children rather than with adults who are experts on children's technologies, is that no adult really knows what feels like to be a child 'today'. The assumption is then that the technology that results from CI will be more successful or appropriate for children than if it was designed by adults only. Kelly and colleagues [8] describe how the literature on designing for children displays a pattern 'of designing for no use or for local use'. They explain that much of the most cited research on the topic reports on design experiments from which no built product would result or where the product was just for use within a small, closed user group. There is thus a discrepancy – on the one hand we are encouraged to design technology for children with the help of children, but on the other hand, when children had been involved as design partners, it seems that widely used technologies seldom emerged.

KidPad is an example of an implemented result of CI [3]. It seems however that the outcome of CI need not be complete, built products. They can also be ideas that inspire adult designers towards better or more innovative solutions implement [11]. Nickelodeon's 'do-not-touch button' is an example of a design element that emerged in a prototype designed by two nine-year-olds and became a prominent feature of the Nick App (www.nick.com) in 2013.

The advantages of CI include giving children voice in design [6, 7] and approaching the design of children's technology from a child's point of view. The challenges include overcoming the power distance between adult and child designers and that children's creative ideas may be impossible to realise [11].

CI traditionally involves children from ages 7 to 11 working with adults. However, Gelderblom [6] reports on CI with young children and teenagers and Yip et al. [12] describe successful child led CI sessions. In the project reported here, I used a combination of child led and teenager facilitated CI.

2.2 The Design of Serious Educational Games (SEGs)

Different frameworks, models and guidelines exist for the design of SEGs. For example, Moreno-Ger et al. [10] propose integration, adaptation and assessment as high level pedagogical requirements for online educational games. Mitgutsch and Alvarado's [9] SEG assessment framework includes six criteria that respectively relate to purpose, aesthetics, narrative, game mechanics, framing and content.

Annetta's [1] well-cited framework for designing SEGs includes six elements. This hierarchical framework has 'identity' as the core element. Annetta's comprehensive explanation of each element makes it an appropriate tool to evaluate early prototypes of a SEG. The six elements are:

- Identity: A SEG should convince players that they are unique individuals in the game environment. This is best achieved through unique avatars that user select themselves.
- Immersion: This is achieved if players see themselves as the main character in the game and feel completely present in the virtual world. Good feedback supports immersion by giving players a clear sense of where they are in the narrative.
- Interactivity: This can be achieved through social communication with other players or non-player game characters. Immediacy is important– that is, the interaction must reduce the player's perceived distance from other players or game characters.
- Increased complexity: There must be multiple levels of complexity. Players must continuously progress and be rewarded for performance or in-game decisions. The aim must be to maintain 'pleasurable frustration'.
- Informed teaching: Data about the player's progress and achievement in the game must be recorded over time to assess student understanding.
- Instructional: A SEG should foster learning. There should be clear opportunity for mental development to occur during game play. Designers should understand cognitive information processing and use it as a guide. Scaffolding must be available at the right time and in the correct form.

In the study reported here, children's prototypes of a web based educational game were analysed to determine to what extent they adhere to the above, generally accepted requirements for SEG design.

3 Research Methods

Case studies allow a researcher to obtain a rich analysis of a phenomenon. A case study was suitable to identify the contribution that child designers make to real world products when they participate in the design thereof. Using one CI design case, I studied all the design ideas generated by children in depth and then assessed these ideas according to the requirements of a SEG design framework.

3.1 The Case

The case I investigated was the design of a web based platform for the Edublox reading and learning clinics [4]. Edublox is a South African company that specialises in cognitive training, reading, spelling, comprehension and mathematics [4]. Edublox programs, in the form of face-to-face sessions as well as computer based exercises, develop skills that underlie reading, spelling, writing and mathematics. Many of the Edublox exercises involve a set of coloured blocks that children have to manipulate and organise to improve their memory capacity and logical thinking skills.

In 2016, Edublox decided to develop a comprehensive web based platform that will allow them to expand their client base. I was approached to assist with the design of the web application that would incorporate their existing computer based exercises as well as additional aspects that had previously only been offered through face-to-face sessions. The new web based interface was designed over a period of three months with the help of an intergenerational design team.

3.2 The Participating Designers

The design team included seven children, two teenage facilitators and a professional graphic artist. The children and teenagers were divided into three groups for the design task (see Table 1). Group 1 consisted of three boys, one of whom had previously designed with me and since they seemed comfortable in the context, I decided they could lead their own design. The other groups each included one designer with previous design

Table 1. The participating designers.

	Participant	Age	Gender	Role
Group 1	P1	10	Male	Novice designer
	P2	12	Male	Novice designer
	P3	12	Male	Designer
Group 2	P4	10	Female	Designer
	P5	10	Female	Novice designer
	P6	18	Female	Facilitator/Designer
Group 3	P7	9	Female	Designer
	P8	10	Male	Novice designer
	P9	15	Female	Facilitator/Designer

experience, one novice designer and a teenage facilitator. The facilitators had been involved in several CI projects, some conducted at the University of Maryland's Kidsteam with Allison Druin – the originator of CI.

3.3 The Design Task, Materials and Procedure

The design sessions were conducted in a university based design lab with ample space for children to sit on the carpet to build their prototypes. Following Druin's [2] CI process, we started with everybody sitting in a circle on the floor. We went round the circle for introductions and to answer the question 'What is the brain?'. The 'question of the day' is meant to direct the focus of activities to the design task and stimulate ideas related to the task.

Next, I explained who our client was and what the design task entailed. A representative of Edublox who was present then described in detail what their different programs involve. For the next 30 min she put volunteers from the team through some Edublox exercises while everybody else observed. This familiarised them with what they were about to design.

After a quick snack, each group received a large 'bag of stuff' [7] to be used for prototyping. Different sized sheets of board and paper were available on a communal table. Figure 1 shows part of a group's 'bag of stuff' content.

Fig. 1. Prototyping materials (i.e. 'bags of stuff')

They had an hour to work on their prototypes with no interference from the adults. Each group then presented their designs to the whole team. We recorded the presentations and the questions and discussion that followed.

To conclude the session we sat in a circle again and reflected on the design experience. I thanked them and we played games and enjoyed more snacks until their parents arrived to collect them. The complete session lasted almost three hours.

Prior to the design session parents were given detailed information on the project and they had to sign a consent form that allowed us to record the activities for the purposes of design only. No video or audio material by which any child could be identified may be published or even made available to Edublox, and all reports refer to the children as P1, P2, et cetera.

3.4 Data Collection and Analysis

The data consisted of the low fidelity prototypes created by the designers; recordings of the group presentations; recordings of the discussions and questions that followed the presentations; and detailed notes of all design elements and ideas that emerged from the prototypes and discussions.

I used the above data sources to compare the design outcomes to the six elements of Annetta's [1] SEG design framework. This involved considering the six elements one by one and for each going through all the data sources and noting down any related design idea or feature. I carefully studied these notes to determine which the SEG requirements are fulfilled (and how) and which not.

4 Design Outcomes and Their Relation to SEG Requirements

The results are discussed by describing the children's design prototypes and then relating these designs to Annetta's [1] six elements.

4.1 The Design Prototypes

Design Group 1: This group planned a five week program with three 15 min challenges per day. In the first week players escape from the enemy's castle and then have to find their way home. Levels are unlocked once a day only so that 'you don't rush through everything and forget it'. Depending on how many challenges you complete in 15 min, you gain points that represent cash units.

The challenges take the form of the Edublox exercises recreated within the fantasy world. One designer created a 3D implementation of an Edublox exercise as a physical add-on (Fig. 2, right). It communicates with the game, so when the challenge calls for

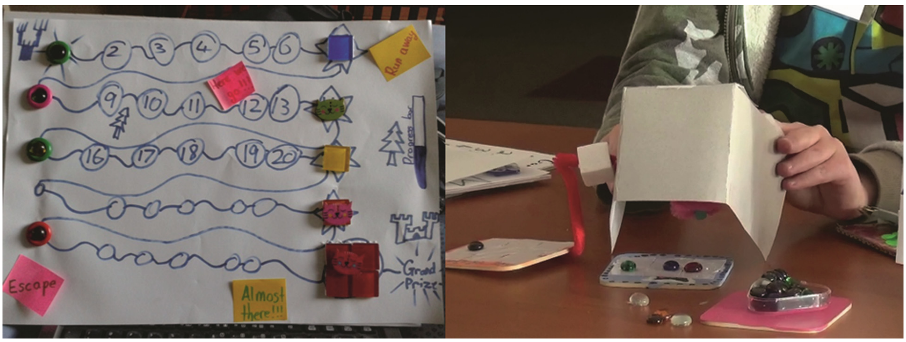

Fig. 2. Part of Group 1's prototype.

that particular exercise, the player can play the physical game and the results will be transferred into the online game.

They have a progress map that serves to keep track of the players' progress (Fig. 2, left). As they complete levels the circles change colour and messages of encouragement pop up.

Players are represented by unique avatars that they design themselves and they can use cash units accumulated to 'buy' accessories for their avatar.

Design Group 2: They created a 'story game' that takes place in a fantasy forest (or any other fantasy setting). They placed a lot of emphasis on the reward system and on viewing progress. Players complete a 45 min exercise session per day to qualify for rewards. Timing was a prominent feature here. Rewards include time to play games, prizes and coins that can be used to accessorize 'Ed' – an in-game character that guides players through the game and provides help when required.

Like Group 1, they have a progress map (Fig. 3, right) that indicates the levels reached. Every time you go a level up you get 100 coins. This is the 'fun' progress map for children. There is also a 'serious page' for parents that shows the child's progress in the form of charts.

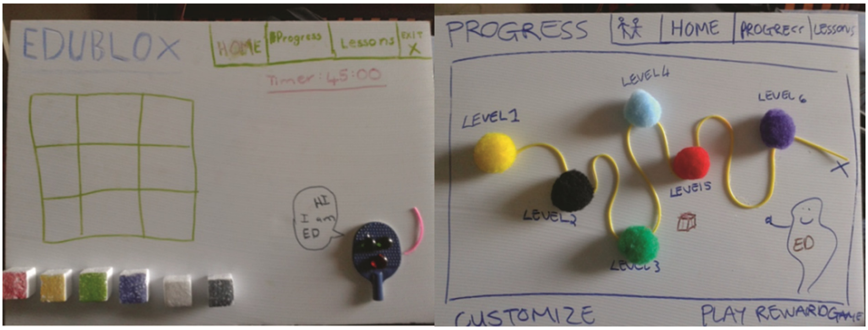

Fig. 3. Part of Group 2's prototype.

A webcam records the child while playing so that the parent need not be with the child to see if they cheat. When parents note that children lose motivation, they can send little mystery prizes that will appear as additional rewards.

The Edublox exercises (e.g. Figure 3, left) are separate from the fantasy world, but performance in the exercises determine what children can do in the fantasy world. They appear like on-screen replicas of the face-to-face versions.

Design Group 3: Figure 4 shows parts of their design. They immersed the games in a social media-like environment rather than a game world. On the Home screen players choose a name and an icon that represents them, as well as a language. Once logged in, a screen with four parts appear: Games, Progress, Time, Instructions. The Games link takes a player to the Edublox exercises that they designed as on-screen replicas of the face-to-face versions. There is an 'Earth' icon that will connect a player with other players. Play can happen in three ways: 1. Race other kids; 2. Time yourself; 3. Normal (no timer).

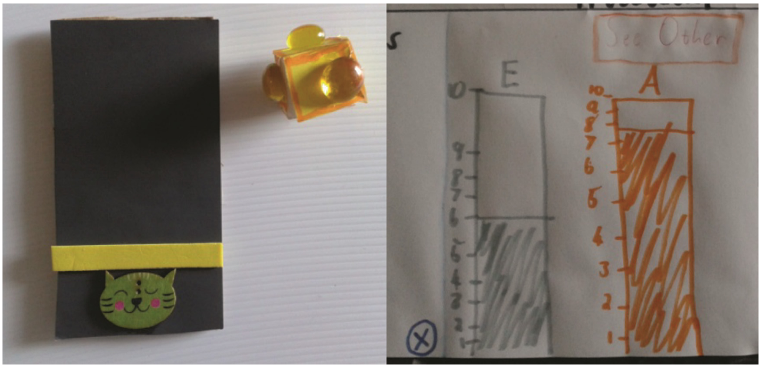

Fig. 4. Part of Group 3's prototype.

The Progress link brings up a screen with a bar chart-like visualization that indicates the player's progress against that of other players (Fig. 4, right). Players have the choice to hide their progress from other players.

A Help button appears in the form of a golden block (Fig. 4, left) that moves around on the screen. Clicking it will 'call a parent for help' on a phone-like device through which parents can also observe what the child is doing. A Time screen shows how much time you have left and a Feedback link will tell players where they did things wrong.

4.2 Mapping the Children's Design Ideas to the SEG Design Model

The features included in the children's designs were mapped onto the six elements of Annetta's [1] framework. Table 2 summarises the results. Besides the absence of *interactivity* in Group 1's design, every element is present in all three designs. *Identity* and *increasing complexity* are thoroughly represented in all three designs. Two groups guarantee *immersion* with interesting fantasy worlds, a story line and elaborate, immediate feedback mechanisms. Group 3's social media-like, competitive environment is also likely to support *immersion,* and scores high on *interactivity.* Group 2 also does well in terms of *interactivity*. With regard to *informed teaching*, all groups keep track of progress through the game in ways that would make it possible for parents or educators to analyse their performance. Group 1's design lacks scaffolding elements, which means they did not fulfil the requirements related to *instruction*.

Table 2. Mapping the design elements onto Annetta's [1] desired SEG elements

	Group 1	Group 2	Group 3
Identity	Player creates own avatar and points earned in the game can be used to accessorize the avatar	The design is set in a fantasy forest. A 'persona' can be adapted using 'money' earned	The player chooses an 'icon', a name and a language. No fantasy world was used
Immersion	All activities are performed within fantasy narrative. Constant feedback and encouragement appears on a progress map that clearly communicates the player's progress in the game	Players can change the fantasy game setting. Ed guides players. He can be customized using money earned, so each player's Ed is unique. Progress maps provide clear feedback on progress	A social media-like platform where players interact and compete. Their character represents their real selves rather than an in-game avatar. Parents can provide feedback/help at any time
Interactivity	No social interaction with other players or any indication of communication with in-game characters	Ed is always there to interact and help. There is indirect interaction with parents who can plant mystery prizes and follow play through webcam	Parents have a mobile device that connects with the game to observe child's play from afar. A floating button will get help from the parent
Increasing complexity	Very clear instructions on how levels of difficulty are unlocked (one a day) at the correct pace to support real learning	Progress maps indicate different levels achieved. Rewards can be games, prizes or money if certain goals are achieved	On the progress screen, bar charts show players' level of achievement compared to other players'. Timing is used to increase difficulty
Informed teaching	Data about players' progress are collected and displayed in the form of a progress map, levels completed and points earned	There a 'serious' progress page where adults can see how children are progressing. All game play is recorded for parents to view later	Progress is recorded per exercise and can be viewed in the form of a bar-chart like visualization
Instructional	Four of the first five elements are included in the design. They did not mention any specific scaffolding mechanisms in their design	The first five elements appear in the design. Players must play 45 min to get any reward. Ed provides scaffolding	The first five elements appear in the game but some in limited form. A Feedback link is available where players can see where they went wrong in the exercises

5 Conclusions

The aim of this study was to determine whether the designs produced by children when they participate in the design of web based games for learning, can make a real contribution towards the implemented application. Through a CI case study I showed that the six elements of Annetta's [1] framework for SEG design all appear in at least two of the three prototypes and that three of the four most important elements (identity, immersion and increasing complexity) are prominent in all the prototypes.

The children received no guidance from adults in this design task, only a demonstration the face-to-face Edublox exercises. We expected their prototypes to be representations of these exercises, but they offered more – they intuitively designed web based SEGs. Two groups focused on immersing the exercises in a game world with a storyline and reward system that would motivate users to do the exercises as a means to thrive in the fantasy world. The third group embedded the exercises in a social media-like environment where interactivity is the main feature, but they also used interaction and competition with other users (elements of SEGs) as motivators.

Without any formal knowledge of, or training in the design of SEGs, these young designers displayed a natural ability to design an online game that incorporates what design experts have established as requirements of SEGs. The application was released in March 2017. In continuation of the research reported here we will now investigate the final, implemented application to determine to what extent the children's designs determined the final product.

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