Designing an interactive educational software involving children as design partners

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Abstract: This paper describes a requirement study to design an interactive educational software for children. The study demonstrates the importance of involvement of children as design partners. Eleven (11) students aged 8 to 12 years from a local government school participated in the study. Educational softwares used in the study were three applications to help children learn mathematics. Observations and survey methods were used to evaluate fun, learning, and ease of use. We used Smileyometer and Fun Sorter as tools for the children to evaluate the applications. We found that the Fun Sorter was a better evaluation tool for children. Results of the study show that children were aware of their needs for learning. They were able to produce creative ideas in designing an educational software for learning mathematics. The children believe that educational software should mainly focus on learning, but at the same time it should be fun and exciting.

Keywords: child-computer interaction; educational software; participatory design.

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1 Introduction

In the last decade, children in the developed world have become significant users of software technology. This has resulted from the investment of government in information technologies for schools, the fall in price of the personal computers, the production of game consoles and related dedicated platforms that have brought software and related products to the attention of children. Ahn et al. (2016) suggested that integrating digital tools into classroom settings may be beneficial for students' learning outcomes. Nowadays, students are having difficulties grasping concepts especially when the e-learning platforms are dull and mostly text-based or unexciting (Kong et al., 2017). Many educational software products are produced to support home learning activities to assist children in their education (Sim et al., 2006). But now, educational software has been introduced to schools to help them attain good grades in government-initiated tests.

Educational software for children should combine fun and education in more initiative ways (Nijholt, 2012). Therefore, technologies for adults need to be tailored for children. In Child Computer Interaction (CCI) community, designing interfaces take into consideration the special characteristics of children as the user group. Children are different from adults with regards to their motivations, desires and expectations (Sim et al., 2006). Children as users deserve products and techniques that are designed for them, with their needs in mind.

Thus, participation of children as social actors, designers and users is important in CCI (Markopoulos et al., 2007). Researchers can explore new opportunities in interactive technology to support the development of varying groups of children, by involving them throughout the entire process of the system development. Through these studies, we can understand and distinguish the design requirements that can affect today's children.

2 Literature review

In most part of the western world, children's voices are heard. As such, there is a new demand for research that focuses on children as actors in their own right (Borgers and Hox, 2001; Borgers et al., 2000). Researchers are recognising that information on children's opinions, attitudes and behaviour should be collected directly from them because proxy reporting is no longer considered good enough (Borgers and Hox, 2001). Read and MacFarlane (2006) gave the following valid reasons for asking children for their opinions on interactive products:

1 Adults and children live in different worlds and for that reason adults may not understand what children want.

2 There is greater awareness from society to involve children as actors rather than observers where children can give opinions about their choice of environment.

3 Involving children in the design and evaluation of their own products is fun and rewarding for researchers, developers and, more importantly, for children.

The role of children related to technology can be categorised into four (4) main profiles: user, tester, informant, and design partner (Garzotto, 2008). For the role of informant, children involve in the design process at various stages such as identifying needs, producing design sketches and giving feedbacks on low-tech prototypes before the real prototype is developed (Druin, 2002). Most of these techniques are inspired by the contextual inquiry approach, such as the cooperative inquiry. The techniques of Cooperative Inquiry (CI) enable children and adults to work together to create innovative technology for children (Druin, 1999). These methods include ideas adapted from cooperative design, participatory design, and contextual inquiry, but are tailored to meet the unique challenges of working with children (Druin, 1999, 2002).

Sim et al. (2006) has conducted a study involving three (3) software products that were designed to prepare children for government-initiated science test. The study is conducted to measure the learning effect, and observations and survey methods were used to access usability and fun. The first software placed the assessment activities within a game context, while the second software presented the material in a more formal and linear structure, without games. The third software asked questions fairly formally abut after a few questions the users were rewarded with a separate, brief game. From the study, the children were asked to rank the three (3) software products on a number of different criteria. We run similar study to understand children's preferences on which kind of applications they are most likely interested.

While Mazzone et al. (2010) has described three (3) different design activities carried out for the design of a music device for children. The study was defined to two (2) main evaluation criteria which is:

1 the capability of the design methods employed in the activity to produce useful results for design and

2 the suitability of the design methods to engage and involve children as active participants

The first activity was to understand children's concept of music playing, elicit their ideas of a music toy and discover how they liked to play with a music application. This study conducted to gather contextual information and design ideas for the music application. The second activity aimed to test one of the initial design ideas of the music education experts for the music application, where different kinds of music are associated with different places or environments. Aimed to capture what type of instruments children of these ages are more familiar with or fond of and wanted to investigate the level of association children make between music and places. The third activity intended to see what type of association children were able to make between music and moods/emotions.

When working with children, it is crucial to get insights on how these users behave in their natural environment. One such method is a modified form of participatory design that involves sketching ideas with art supplies such as paper, cardboard, and glue to create low-tech prototypes during the brainstorming process (Druin, 1999, 2002). Working with children as co-designers can help researchers understand the best ways to design educational resources that facilitate learning about the complex and nuanced concepts related to privacy online (Hartikainen et al., 2016). Previously, studies have found that games and storytelling are effective in teaching children about topics related to Science, Technology, Engineering, and Mathematics (STEM). STEM is important for children's understanding on how real-world complexities shape decision making (Gee, 2007).

Other works that used CI methods is Choose-Your-Own-Adventure that helps children to learn about privacy online. The primary focus in the study was not to develop and test a specific tool, but rather, to elaborate ideas on how to engage children effectively in learning about privacy online using CI methods (Kumar et al., 2018). McNally et al. (2018) held two co-design sessions with children to review and redesign an existing mobile monitoring application where the results benefit designers looking to develop parental mobile monitoring technologies in ways that children will both accept and can actively benefit from.

In the field of CCI it is common to find studies that report the use of survey methods with children. In some of these studies, children were asked to contribute ideas and suggestions for future or partially completed designs (Read and MacFarlane, 2006). Some examples include the use of surveys to detail out mental models of children (Read et al., 2003), or to gather requirements for interfaces (Read et al., 2004). Surveys are usually used in evaluation studies, where children are asked to comment on the attractiveness or usefulness of a product using some kind of product rating (Read et al., 2001).

Once requirements are well developed, it is time to begin developing design ideas and specifications. The most common activity at this stage is the development of prototypes. These are mock-ups of interactive technologies that can be used to obtain feedback from children. Developing design ideas usually begins with low-fidelity prototypes and may involve more basic brainstorming if there is less of a sense of what to build (Hourcade, 2015). Below are few of CI research projects as shown in Table 1.

Table 1 Example of Cooperative Inquire research projects

Prototype technique	*Research example*	*Descriptions*
Sketch	Develop web-based user interface for community website (Chen et al., 2004) Participant aged 10 to11 years old.	Interface develop from this activity is more usable than a popular commercial user interface.
	Develop games for tag to support children's open-ended play (Valk de et al., 2013).	Visual sketch is limited, therefore they are using working prototype for children to try out on actual play.
Storyboard	Use of comics as a way to elicit design ideas from children (Moraveji et al., 2007). Children will fill in the blanks in comics that have beginning and end.	Children produce more ideas than given blank pages to do traditional storyboarding.
	Obtain design ideas through web-based tools (Isomursu et al., 2004).	
Layered elaboration	Develop previous sketches by adding more details or replacing parts without having to redraw (Walsh et al., 2010). Use of layers of transparencies on top of paper sketch to modify it.	Children can elaborate on previous low fidelity prototypes, that made by art supplies.
	DisCo, an online tool to help children and adults to iterate prototypes, annotate them and communicate with each other. (Walsh et al., 2012).	Help geographically distributed design teams communicate with each other.
Card sorting activities	Categorise cards into pre-established categories (Joly et al., 2009) Participant aged 3 to 4 years old.	The method could be used to learn whether children could understand a specific category.
Interactive table top	Development of tangible interaction toys for use on an interactive table top (Marco et al., 2010) Participant aged 3 to 6 years old.	Creation of user profiles, wizard of oz techniques and peer tutoring.
Yes or No questions	Obtained feedback by asking children yes/no questions (Hourcade et al., 2013) Participant are children diagnosed with autism.	They answered through pointing on piece of paper with the word yes or no.

The following sections discuss the initial designing stage of our study in developing educational software with the involvement of children as design partners.

3 Method

The aim of this study is to collect ideas and opinions as part of the designing stage for development of educational software involving children as design partners.

3.1 Participants

Eleven (11) primary school children aged range 8 to 12 years old comprised of boys and girls participated in the study. The sample covered the normal range of ability with some of the children needed help with instructions. Three (3) educational applications for learning mathematics downloaded from Apple Store were used in the study. All of the children never used the application before but they are frequent users of tablets or mobile devices with more than one-year experience. They have learned the topics for at least one year, so the subject matter of the software was largely familiar to them. The children were chosen based on convenience sampling. It is a non-probability sampling technique where subjects are selected because of their convenient accessibility and proximity to the researcher. Prior to the visit, we have informed the parents about their children's involvement in this study. Letter of consent was sent to all parents and was submitted to the researcher on the first day of the experiment. The setting of the experiment is represented in Table 2.

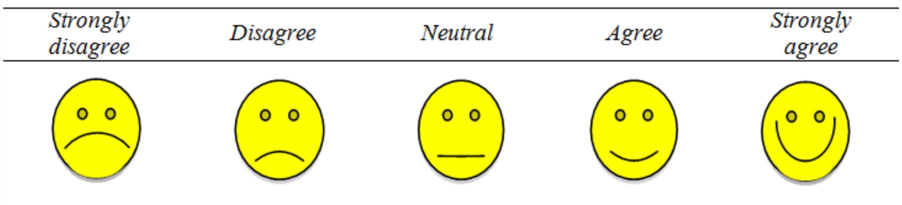
Table 2 Setting of the experiment

Criteria	*Descriptions*
Age	8 to 12 years old
Gender	Both (female and male)
Learning problems (ADHD, Autism etc.)	None
School	Elementary school
Subject	Mathematics (Additional – 2 digit only)
Time	9 am – 12 noon
Venue	Classroom
Experience	Usage of tablet or mobile devices more than 1 year.
Reading ability	Requires minimal help in reading the questions and Instructions
Device	Tablet (Ipad)

3.2 Data analysis method

In this study, the Smileyometer from the Fun Toolkit for children by Read and MacFarlane (2006) was used to measure user's experience. The Smileyometer is specially designed for children whereby it is based on a 5-point Likert scale and uses five smileys (see Figure 1). The answers on the Smileyometer range from 1 (for strongly disagree) to 5 (for strongly agree).

Figure 1 Smileyometer



As for the statistical point of view, we are using descriptive statistics involving mean and standard deviation. The interpretation of mean score is based on scale by Nunnally and Bernstein (1994) as shown in Table 3.

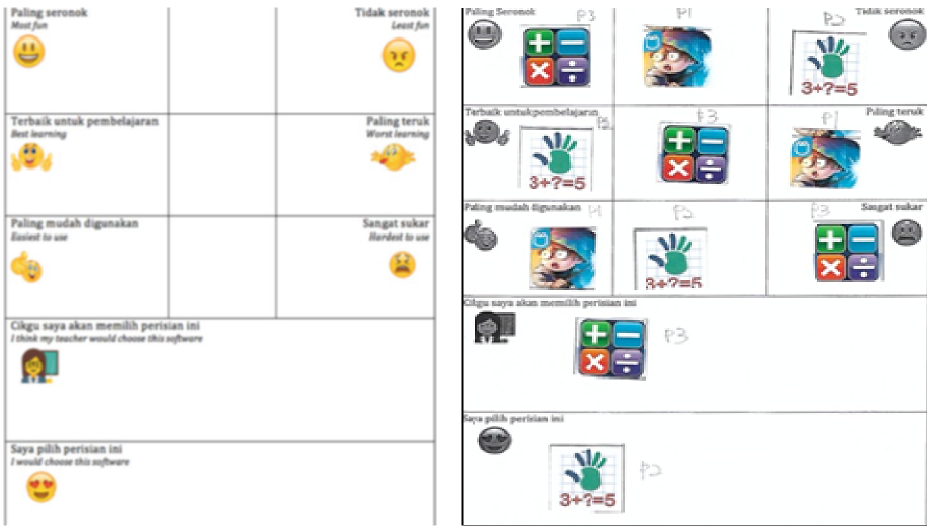
Table 3 Mean interpretation by Nunnally and Bernstein (1994)

Mean score	*Interpretation*
1.00–2.00	Strongly disagree
2.01–3.00	Disagree
3.01–4.00	Agree
4.01–5.00	Strongly agree

We also used The Fun Sorter which requires the children to rank the three educational applications in order of preference in to three (3) separate criteria; fun, ease of use, and how good they were for learning (Read and MacFarlane, 2006).

Our intention was to record the children's opinion of the applications or activities and to evaluate their engagement. Each child was given a form with three (3) empty boxes for each question (see Figure 2 (a)) and 'stickers' with pictures of each application. Figure 2 (b) shows a sample of completed Fun Sorter form done by one of the children.

Figure 2 (a) Fun sorter (blank), (b) Completed fun sorter

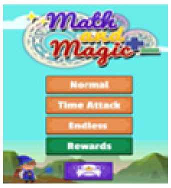
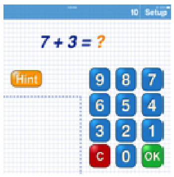


(a) (b)

3.3 Procedures

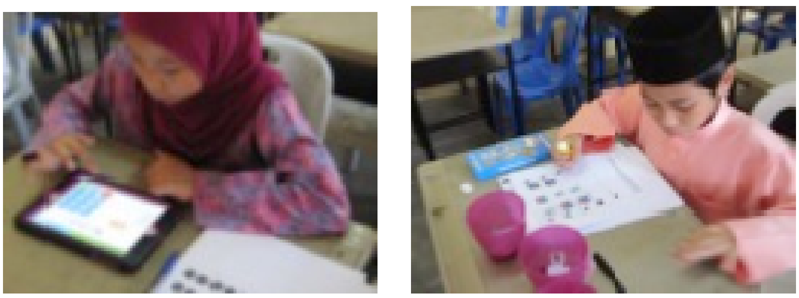
Activity 1: The objective of Activity 1 is to determine design preferences based on the selected educational applications. Three (3) different types of application were used in this activity (P1, P2 and P3). P1 designed the assessment activities within a game context, P2 presented the material in a more formal and linear structure, without games, and P3 presented questions formally, but after a few questions the users were rewarded a brief game (Sim et al., 2006). The educational software was selected based on criteria selected for the activities. All three (3) applications are available in Apple Store, which can be downloaded for free from any Apple products. The three (3) applications are designed to teach children to learn mathematics in engaging ways. The three (3) applications selected in this activity are presented in Table 4.

Table 4 Selected educational application

P1 Game Context	P2 Without games	P3 Brief Game
		

The study was carried out at a school, in a room close to the children's classroom. Two similar tablets were used to conduct the study. The children were called from their classroom in groups of two and were directed to designated table with tablets. The researcher sat in front of the children and explained the task to them. The researcher observed and recorded down the children's reactions and engagement with the tasks. The children were given 2 minutes to get familiar with the application and another 5 minutes to complete the task as shown in Figure 3(a). They were then asked to rate the application using Smileyometer. Over the course of three (3) days, every child used each of the applications once. For each application, the researcher recorded any usability problems, facial gestures and comments to establish level of fun.

Figure 3 (a) Children using the application (b) Children completing the fun sorter



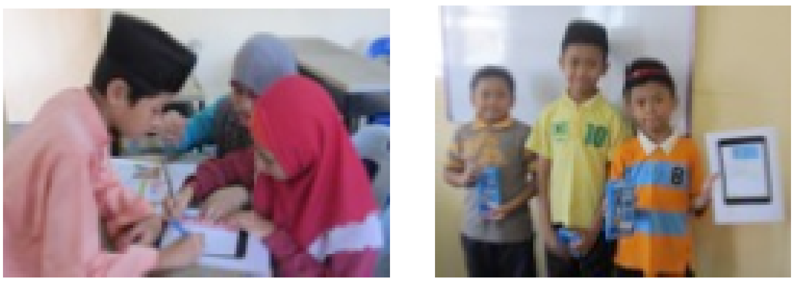
(a) (b)

Once the children had tried all the applications, they did the final evaluation using the Fun Sorter. The Fun Sorter required the children to rank the three (3) applications in order of preference on three (3) separate criteria: fun, ease of use and how good they were for learning (Read and MacFarlane, 2006). The method used here was to give each child a form with three (3) boxes for each question, and some stickers with pictures of the applications.

They were asked to rank the three (3) applications by sticking three (3) stickers on to the boxes in appropriate order as shown in Figure 3(b). All the children did this activity successfully after a brief explanation. They could distinguish the criteria and specify which of the three (3) applications they like, and which one in their opinion, the class teacher would choose.

Activity 2: The objective of Activity 2 is to gather contextual information and design ideas for children educational software. During this activity, we also investigated the level of association of children with technologies. The children work collaboratively during the design process. The children were divided into groups of three. At the beginning of this activity, samples of educational applications were shown to help children understand the objectives of Activity 2. The purpose of introducing these samples is to trigger design ideas from the children. The children were asked to design educational application for the Mathematics. No functional constraints were given: the children were free to imagine any application they like and sketched their ideas using art and craft materials provided. A few children needed more time to get started and some needed the researcher's help to express what they would like. They were given 15 minutes to discuss and design their ideas before presenting it to the class as shown in Figure 4(a) and Figure 4(b). All the children completed this activity successfully and presented their ideas clearly.

Figure 4 (a) Children designing the application (b) Children presenting their ideas



(a) (b)

4 Results

Activity 1 involved children selecting three (3) different types of applications: game context, without game and brief game. The results from the Smileyometer data are presented in Table 5. Majority of the children selected the 'strongly agree' option. Thus, the results show small variations based on their response because children get excited and very enthusiastic when involved in technology-based activities. This enthusiasm among young children has been noted earlier in previous studies (Sim et al., 2006).

Table 5 Mean analysis for user experience

Questions	*P1 Mean*	*P2 Mean*	*P3 Mean*	*Mean Int.*
1. Easy to understand	4.09	4.64	4.27	Strongly agree
2. Interesting and fun	4.18	4.18	4.09	Strongly agree
3. Can help in school	4.64	4.45	4.55	Strongly agree
4. The questions are easy to answer	3.73	4.18	4.00	Agree
5. Finished the task easily	3.73	4.27	4.18	Strongly agree
6. The symbols are not confusing	4.09	4.18	4.18	Strongly agree
7. Interesting interfaces	4.45	4.09	3.91	Strongly agree

On the other hand, Fun Sorter was the most effective in getting true response from children as they understand the concept of ranking. The children were asked to rank three (3) educational applications based on different criteria. Table 6 shows frequency for each application ranked first by the children.

Table 6 Frequency of each application ranked first by children

Children's ranking	*P1 (Game)*	*P2 (Linear)*	*P3 (Brief Game)*
1. Most fun	2	6	4
2. Best for learning	3	4	4
3. Easiest to use	5	4	2
4. Teacher's choice	1	4	6
5. Own choice	4	6	1

Results indicate that highest number of children chose application P2 under category 'Own choice' ($fP2 = 6$) which correlates with 'Fun' (highest frequency for 'Fun': $fP2 = 6$). This shows that 'Fun' is the most important criterion in children's assessment of an educational application (Sim et al., 2006). Unexpectedly, P2 is the children's favourite pick for 'Own choice' and 'Fun' since it is a linear game. We would have thought that the children would choose game-based P1 since it is more exciting and challenging.

The children commented that game-based educational applications can distract their focus in learning. They also gave feedbacks that it was more fun using application for learning purposes than conventional method using text books. There is also a correlation between children's assessment of how 'good the product for learning' (fP3 = 4), 'Fun' ($fP3 = 4$) and 'Teacher's choice' ($fP3 = 6$). A possible explanation for this observation is that children like to use an application in the classroom that is fun and good for learning which they believe teachers would choose.

Activity 2 involved children using their own ideas in designing an educational application. All of them completed the activity successfully and presented their ideas. Samples of children's design are shown in Figure 5.

Figure 5 Design ideas from the children

During the activity, some comments and ideas from the children were recorded as listed below:

1. *Content*

Comment 1: "*Content should be straightforward*".

Comment 2: "*Do not have too much 'games' so that I can focus on learning*".

Comment 3: "*The game should help me understand the topic, while having fun at the same time*".

Comment 4: "*The difficulty of questions should be gradually increased when I progress to the next level*".

2. *Interactive multimedia*

Comment 1: "*Not too much music or video in the background*".

Comment 2: "*Music that is too loud will make me lose my concentration, or might forget what I had learned from the game*".

Comment 3: "*The graphic should be interesting enough for children, for example using talking animal characters or superheroes*".

3. *Ease of use*

Comment 1: "*Touch screen is more convenient and less movement for me compared to desktop or laptop*".

Comment 2: "*Prefer to use tablet compared to mobile phone because the screen is bigger so it is easy to read questions or tips*".

4. *Other ideas*

Comment 1: "*Give marks/points as motivation for players to repeat the game to improve their marks*".

Comment 2: "*The questions should be random so that they will not give the answer straight away*".

Comment 3: "Provide *tips or guidelines while answering the questions when encounter any problems*".

5 Discussion and limitation

From the experiment conducted we have identified the following criteria that should be considered when designing educational software:

a) Educational software should focus on educational values, but at the same time it should be fun and exciting. Children should be allowed to answer questions randomly especially when they are running out of time. The educational software should let children focus and learn any topic of the subject. Winning should not be the main focus if it is game-based.

b) Questions should be related to the topics or subjects they learn in school. Tips and guidelines should be given when they have difficulties in answering questions especially when they use the application at home.

c) Ease of use matters to children. From our observation, pressing small or fancy icons caused difficulty to children.

d) Educational software should not have too many graphics or animations, too wordy or loud music.

We have also found a few limitations that can be improved for future developments. We found out that children aged below 10 are easily distracted and they are impatience during Activity 1 and Activity 2. From the observation, these happened due to the following:

a) Younger children needed more time and explanation to get started without biasing their ideas. But they tend to be more creative and original.

b) Filling in questionnaire may appear as boring or stressful task for them, therefore we should consider the kind of tasks we plan to carry out with children especially young children who has difficulties in verbally expressing their ideas.

6 Conclusions

Educational software is a powerful tool for effective learning which can give positive impact on children. Throughout the entire software development process, children need to participate, not just as user, but also as social actors and designers. In this paper, we presented a study on design requirements which involves children aged between 8 and 11. The study involved three (3) educational software which were designed to help children to learn mathematics in engaging ways.

From the study, we found that we get better response from children when using the Fun Sorter as evaluation tool than using Smileyometer. The findings also show that involving children in the design stage is crucial to ensure that the educational software is fun and enjoyable for them. Children were able to produce creative ideas. They knew and were aware of their needs for learning. We also found that they preferred educational software which stresses on learning. However, improvement in terms of user experience such as fun, exciting, entertaining, helpful, motivating or rewarding are also important. In summary, children deserve products that are designed for them, with their needs and capabilities in mind.

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