



Exploring the Design Considerations for Developing an Interactive Tabletop Learning Tool for Children with Autism Spectrum Disorder

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Abstract. Usability, ease of use and user experience (UX) are crucial quality concerns to develop any learning applications for children with autism. Several design considerations are proposed to design and develop different kinds of learning tools for autistic children but no study was found that explicitly focused to understand the design consideration required to design a tabletop learning tool for children with autism. Therefore, the objective of this research is to reveal the fundamental design considerations for developing a tabletop learning tool for autistic children with enhanced usability and UX. Two studies were conducted following ethnographic study and semi-structured interview, while the interviewing study was replicated with eighteen teachers of autistic children. The study data were analyzed through content analysis. As outcome, this research, firstly revealed a set of design considerations that includes, for example, affordance, intuitiveness, portability, ease-to-use, clear & concise interface, metaphoric design, easy to learn, interactive, visual feedback, multimodal feedback and pictography. Secondly, proposed a design solution to develop the tabletop learning tool based on the revealed design considerations.

Keywords: Autism · Design considerations · Ethnographic study · HCI · Learning tool · Usability

1 Introduction

Now a days, technologically enhanced education has become a priority in all over the world while special education for children with Autism Spectrum Disorders (ASD) is not an exception. The recent research demonstrates that the autistic children eagerly engaged in working with Information and Communication Technologies [1], despite having the limitations like impairment in communication skills and social interaction, and the restricted and repetitive behavior [2]. In [3], Kamaruzaman and Azahari highlights how the ICT based application helps to improve the self-determination of

autistic children. A significant number of research has been conducted focusing to ICT based learning and ASD, which recognizes the effectiveness of a variety of newly emerged learning technologies, however, in most cases, these research represent the development of different kinds of learning tools [4, 5].

Usability is the key quality for any computer systems [6]. One of the primary concerns to adopt a system by the end users is ease-of-use or usability [7]. Some prior studies focusing to HCI and learning technology for autistic children highlights a few design considerations to design effective interfaces for autistic children [1, 3]. A few studies measure the usability of the applications developed for the autistic children, for example, Weiss et al. [8] and Zaman and Bhuiyan [9] evaluate the usability of touch based applications (*Join-In-Suit* and *MumIES*) that were developed for autistic children. A few other studies focused only to develop new applications for autistic kids like Chien et al. [10] developed a tabletop based picture exchange communication system (PECS) for the autistic children to provide the visual and voice support. Only a few articles have been carried out focusing to the design and evaluation principles/guidelines considering the limitations of autistic children [11].

Again, a limited number of research was conducted focusing to the tabletop technology. For example, Weiss et al. [8] developed a multi-touch tabletop application named *Join-In-Suit* and presented the effectiveness of working together (group work) of the autistic children through this tool. Despite of the limited research focusing to the tabletop technology, evidence does suggest that this technology is an applicable technology for autistic kids with great potentials [12]. The design principles used for developing a mobile application will not be appropriate for developing an interactive tabletop learning tool to achieve maximum motivation, engagement and usability for autistic kids. Since no such study has been found that focuses explicitly to explore design considerations to develop tabletop learning tool for autistic kids.

Therefore, the objective of this research is to explore the underlying design considerations to design and develop an interactive learning tool (tabletop) for autistic kids. To attain this objective, this research conduct an extensive empirical study following the ethnographic and interviewing approach. The studies revealed a set of design considerations for developing a usable tabletop for autistic kids to learn the basic education and daily life activities. A design for developing a tabletop learning tools also proposed based on the revealed design considerations.

The rest of the paper is organized as follows. Discussion on related research is presented in Sect. 2. In Sect. 3, study methodology is discussed. The data analysis and findings is demonstrated in Sect. 4. The proposed design of the tabletop learning tool is discussed in Sect. 5. Finally, the discussion and conclusion are presented in Sect. 6.

2 Related Works

A number of research has been conducted focusing to ICT usages and the people with special needs like autism detection [13]; development of assistive tools/systems [14]; and the development of learning and skill development tools [15, 16]. This section briefly introduces the work related to the design, development and usability of the learning tools developed for autistic children.

Ferrari and Robin [15] proposed an evaluation framework to investigate the interest and design of an autonomous robotic toy in context of therapy and education for autistic children. They mainly focused to the interactivity (interactions & effectiveness) issues for evaluating the robotic toy. Weiss et al. [8, 17] conducted two usability evaluation studies to evaluate the collaborative gaming applications developed for autistic children run on a multi-user tabletop surface to improve their social competence skills. The study found that collaborative nature and proficient use of the technology (ease-of-use) were the most effective concerns to enhance the usability, engagement and motivation to wards playing and learning social competence skills. Bhuiyan et al. [18] developed a smartphone based system named *MumIES* (Multimodal Interface based Education and Support) for teaching basic education and support to autistic children; while Zaman and Bhuiyan [9] evaluate the usability of this system in terms of usefulness, efficiency, effectiveness, learnability, satisfaction, and accessibility through questionnaires. The evaluation study was replicated with the teachers, parents, carer and autistic kids.

Gay and Leijdekkers [19] presented the design of emotion-aware mobile apps named *CaptureMyEmotion* for identifying the emotions of autistic children using sensors and by detecting facial expression. This study also discussed the development of one emotion-aware android app *MyMedia* to take sounds, videos or photos and simultaneously attach emotion data to them. This apps can be used by the carer, teachers or guardians of the autistic children providing them a new way to learn, and understand their emotions and daily activities.

Shalash et al. [20] developed an interactive game based application including images, scenarios and voice recognition to solve the speech disorder problems of autistic kids. This application was developed for improving the Arabic language of autistic children having 2–9 years old. An empirical study was conducted in [21] to explore two issues: what factors mediate engagement with and effective use of software, and the extent to which students, teachers and parents perceive the software as having an impact in developing social and life skills of the autistic children. This study considered a mobile application that developed for providing cognitive support to autistic people. Study data were collected through classroom observation and semi-structured interviews. As outcome, the study provided a few design guidelines to develop such kind of cognitive support application for the people with special needs. In another study [22], Juhlin et al. developed an augmented reality based teaching tool for minimally verbal children with ASD to improve their language learning and activities.

In sum, the literature survey showed that *firstly*, though a limited number of studies was conducted focusing to design and develop the learning tools for autistic children, but most of them were desktop and mobile based system. *Secondly*, earlier works mainly focused to introduce and discuss the development of various learning tools and only a few articles explicitly focused to the design considerations to make the system/tools intuitive for the autistic children. *Thirdly*, from HCI perspective, though most of the articles highlighted a very few design considerations (like use of images, audio feedback, etc.) but no study was found that provided a complete set of design considerations to develop a learning tool or application for autistic kids. *Fourthly*, a number of articles were conducted focusing to the usability evaluation of the applications developed for the autistic kids, which in turn shows the significance of usability

for developing such system usable/accessible to the autistic kids. *Finally*, no study has been found that explicitly focus to the design and development of tabletop tools for autistic children. Therefore, the focus of this work was understanding the underlying design considerations to develop a tabletop learning tool for the autistic children.

3 Study Methodology

From methodological perspective, an empirical research approach was followed. In this research, two studies were conducted to reveal the possible design considerations for designing and developing a tabletop learning tool for the autistic kids following ethnographic [23] and semi-structured interviews.

3.1 Ethnographic Study

In ethnography study, two educational institutions of the specialized children located in Chattogram region of Bangladesh were visited to observe the daily activities of autistic kids, teachers and other staffs during the school hour. The first institution's named was *Prerona Autism* where eight teachers and ten other supporting personnel were involved to teach and assist the autistic kids. In this school, students can start their education from pre-play and continue up to class eight. The second institution's named was *Dream Star Autism Academy* where ten teachers and eight other supporting personnel were involved to teach autistic kids in this school, to develop their social and basic academic skills. Autistic children can get admission from nursery to class eight.

To conduct the ethnographic study, firstly the study objective of the visit was defined and finding out the suitable places to visit. Secondly, necessary permission was taken and thereby consent paper was also signed from the teachers, parents and institution's head to maintain the research ethics. Thirdly, the institutions were visited by the research team twice in a week and observed their activities for 3–4 h for three consecutive weeks. During the visit, researchers primarily observed - how the students communicate their basic needs with the teachers and within themselves, how they spent their time during school hour, their activities in different places with different situations, how to teach them the basic education and how they try to learn it. During the observation, field notes were taken very meticulously with some photos and short videos.

3.2 Semi Structured Interview

A total of 18 teachers were interviewed following a semi-structured interviewing approach. Among them 8 female teachers were interviewed from *Prerona Autism*. Their age was 32 ± 4 years having teaching experience from two to seven years. Again a total of ten teachers were interviewed who served in the *Dream Star Autism Academy*. Their average age was 35 ± 3 years and have teaching experience from 6 months to 13 years. To conduct each interview session, a set of questionnaire was prepared related to their biographical data (e.g., age, gender, educational qualification, teaching experience at autistic school, etc.) and their teaching practice at autistic

school. Based on their answers a few additional questions were asked to find out the possible design considerations to develop a tabletop learning tool for the autistic children. Interview sessions were conducted one-by-one. Each interview session recorded and later transcribed for analysis.

4 Data Analysis and Findings

The ethnographic study data and interview responses were analyzed through content analysis to find out the design considerations for developing a tabletop learning tool for autistic children. The analysis revealed a total of eleven design considerations. Each design consideration was found both in ethnographic and interview studies.

Affordance - Affordance refers to provide the clues of operations to be done to execute a task [24]. In interview study, four teachers stated that students hold any object based on their physical appearance like hold the water glass, covering the pen head, playing/solving some puzzles based on their shapes, etc. One of the participants responded as “...*I know I have to press here to power-on the note book because it looks like the start button of a computer...*”. Similarly, through ethnographic study it was observed that students catching different objects and behaving accordingly based on their affordance quality (like organizing toy of fruits in the fruits basket while other type of toys are putting in different baskets). Therefore, the affordance could be considered a design considerations to develop any hardware based interactive systems like design the buttons such a way that they may get an affordance to press on it or to hold an object.

Intuitiveness - It refers to present any object or interface element in such a way that a human can interpret to grasp its referential meaning or purpose without much evidence or rational [25]. Both studies showed that autistic kids understand the referential meaning and do accordingly to those things, objects or behavioral actions that are intuitive enough for them. For example, during the ethnographic study, it was observed that one autistic child showing his finger to an open door image on the photo board, when the teacher asked him by symbolic gesture whether he wants to go to playground or lobby or canteen. Every time he denied by shaking his head and became angry within a short time. The reasons behind this was that the kid did not understand teacher’s response given by symbolic gesture though he was actually intended to go for play. Similarly, during interviews one teacher responded as “...*In many cases we failed to express their [autistic children] exact feeling by showing objects or photos at the first go....and that makes them tempered...*”. Thus the results indicates that any action, objects or interface elements used to communicate with them should be intuitive enough so that they can easily understand its meaning or purposes.

Portability - Three teachers opined about the portability of the learning devices is a major factor to use efficiently by the autistic kids. The ethnographic study also found the similar observation. For example, when a teacher asked seven autistic children to go to the computer corner (as it was a desktop computer system), most of the children did not feel to move to the computer location. Again the setup of the desktop computer was

not suitable for all the children because of the short comings of the children having muscle problem. So, portability is one of the design considerations for the tabletop learning tool to place it anywhere at anytime without much effort.

Ease-to-Use - It refers to the measurement on how a learning tool can be used without much effort. Both studies showed that ease-to-use is the primary requirement to address in developing any system for autistic kids. For example, it was observed during ethnographic study that autistic children were playing with puzzle card were getting disappointed within a short period and involved with another action, because most of the cases they failed to match the puzzle with a first go. Whereas kids playing puzzle game in computer were enjoying. While asking the reason to one of the teachers; she expressed as “...when an autistic children is matching the puzzle with computers s/he needs to use only two arrow keys and easily receive the feedback, while they are playing using the puzzle cards, after placing one block they do not understand any progress and thereby loose the interest...”. Again during the interviewing study, 13 out of 18 (73%) teachers stated the importance of ease-of-use in developing a learning tool.

Clear and Concise Interface - Each and every parts of any device including interface should be clear, simple and concies to understand. A tool will not be useful if there is any confusion about the appropriate usage of any part of it. It has observed that students were playing with some toys where there are some large round shaped buttons on those toys. Most of the children were confused whether those should be pressed or rotated. During the interview session four teachers expressed that clear & concise interface is a must design consideration for developing any tabletop learning tool.

Metaphoric Design - Metaphoric design ensures that the representation of every parts/symbol of the tool is self expressive and has a proper mapping/relationship with the real world object. During the ethnographic study, it was observed that students were playing by utilizing the appropriate usage of the sports materials (football, cricket ball, bat) at the outdoor playground. Again, during interviews, two teachers stated that in many cases like distinguishing between the usage of fork & spoon and wearing foot wear in right pattern autistic children face some challenges. Thereby design with a proper mapping with real world (metaphoric design) phenomena should one of the design considerations.

Easy-to-Learn - Teach anything to the autistic children is challenging, so the learning tool should be easy to learn. The operation procedure of any tool should not be complex. Almost 50% of the autistic children were observed that they learn puzzle game through computer quite early than through the puzzle card since playing puzzle game in computer was comparatively easy for them. Again, during interviews, a teacher stated that “...the tools which are easy to operate are more used by the autistic children..”, said by them.

Interactivity - Interactivity refers to the ability of a system to respond to a user's action (or input). During the ethnographic study, it was observed that autistic children are attracted to those tools which have some feedback upon some action taken by them. During interviews, four teachers stated that autistic children like the games like puzzle game in the computer because, after each matching some points awarded to the users.

Thus the tabletop learning tool need to be interactive to make it attractive to the autistic children.

Multimodal Feedback - It was observed during the ethnographic study that autistic children were attracted to those toys having some sound (piano, flute) or movement (car, train) or changes of color. It was observed that all the kids were using toys those have vibration, movable properties or sound. Similarly, four of the teachers stated about this issue during interviews. For example, one teacher responded as “...*sounds, music, vibration or changing colours are naturally attract the autistic children..*”. Thus, including multimodal feedback in the learning tool will be an appealing feature for the autistic children.

Visual Feedback - This reflects the relative visual changes or reactions after each action. Both the studies found that visual feedback helps autistic kids to understand whether the taken action is right or wrong. Six teachers stated this issue during the interviews. One teacher stated as “...*children always wait for the real time feedback. ...*”. Similarly in ethnographic studies, it was found that autistic children were using a touch screen named *Diamond Touch* and after each touch (to any particular icon in a scenario) kids wait for the next scenario. So, visual feedback can be a design consideration for developing tabletop learning tool.

Pictography - This refers to the pictorial representation of any seen. It was quite challenging to teach the autistic children through words, while this can be easier with some colorful pictures or symbols. During ethnographic studies, it was observed in a class of grade one, where three teachers were taking class on daily life activities, and nine autistic children were showing the pictures which information/facts appropriate for that activity. Thus, pictography can be a design consideration to develop a usable tabletop learning tool for autistic children.

5 Proposed Design of the Tabletop Learning Tool

A design proposal is showed in Fig. 1 for developing a tabletop learning tool for the autistic children based on the revealed design considerations. The proposed system will include four modules. The modules are discussed briefly in the following sub-sections.

5.1 Module 1 (Learning Alphabet and Constructing Words)

The purpose of this module is to learn the alphabets and afterwards constructing simple words. To attain this objective, a number of keys will be designed for the alphabets and labeled from A to Z. The keys will provoke autistic children to press and thus follow the *affordance*. For example, if a user press a key labelled ‘A’, in the output screen/interface the alphabet ‘A’ will be displayed with a picture and text of an object (whose name start with the pressed alphabet) along with voice annotation like ‘A for Apple’ (see Fig. 1). This functional design address the *interactivity*, *pictography* and *visual feedback*. By hearing the voice annotation, the user will type the name of the picture. Depending on the accuracy of user’s typing, the system will provide voice

feedback as ‘right answer’ or ‘wrong answer’; which in turn will satisfy the design consideration of *visual feedback*, *multimodal feedback* and *intuitiveness*. The layout will be designed to attain *ease-to-use*, *easy to learn*, and *clear & concise interface* design considerations. Thus, this module will address the following revealed design considerations: *affordance*, *intuitiveness*, *ease-to-use*, *clear & concise interface*, *easy to learn*, *interactivity*, *multimodal feedback*, *visual feedback*, and *pictography*.

5.2 Module 2 (Appearing Test on Alphabet and Constructing Words)

The objective of this module is to learn the usage of the alphabets and constructing the words by themselves (autistic children). To attain this objective, similar to module 1, a set of keys labelled with alphabets will be designed to provoke autistic children to press or type. This will address the *affordance* design consideration. Two options will be incorporated to test the user learning progress. First option will be MCQ. If “A” is pressed then MCQ will start. Ten questions along with options will come one by one. This will address the *interactivity*, *intuitiveness*, *metaphoric design* and *visual feedback* design considerations. A user’s need to choose any of the options by pressing the alphabet A, B, C or D. If the answer is correct the score on the upper right corner will increase. At the end total score will be shown like ‘Total score: 70/100’. Again, if the quiz option is selected (by pressing the ‘B’) then ten questions will come one by one. Just beneath the question the user’s need to write the answer in one word. If the answer is correct then the score on the upper right corner will increase. Similar to the MCQ option, at the end total score will be shown. Again, this module is designed clearly and concisely so that other design considerations like *easy-to-use*, *easy-to-learn* and *clear & concise interface* features are addressed properly to ensure the easy use and learning by considering the limitations of the autistic children. In sum, this module will address following revealed design considerations: *affordance*, *intuitiveness*, *ease-to-use*, *visual feedback*, *easy to learn*, *multimodal feedback*, and *clear & concise interface*.

5.3 Module 3 (Daily Communicator)

The purpose of this module is to provide a means to express the basic common daily needs of autistic kids as they cannot express their needs verbally. This module will include a number of basic needs into several categories as follows: (a) the emotion category will include the emotions/symbol of great, good, happy and sad mood; (b) the working category will include the reading, writing and puzzle matching; (c) the activity category will include song, art and gym; and (d) various foods’ symbols to ask for which food he/she wants to eat. For each need, a button will be designed and each button will be appended with intuitive symbol/picture to provide a realistic mapping of its purpose (meaning) with the real world phenomena. For example, to express a helping request to drink water, a button will be designed under various food’s category where a symbol/picture of water in a glass will be appended. When the user will press the button the light of the symbol will be on and the system will generate corresponding voice request to draw the attention of the teacher/assistants. This feature will thus address the *intuitiveness*, *interactiveness*, *pictography*, *affordance* and *metaphoric design*.

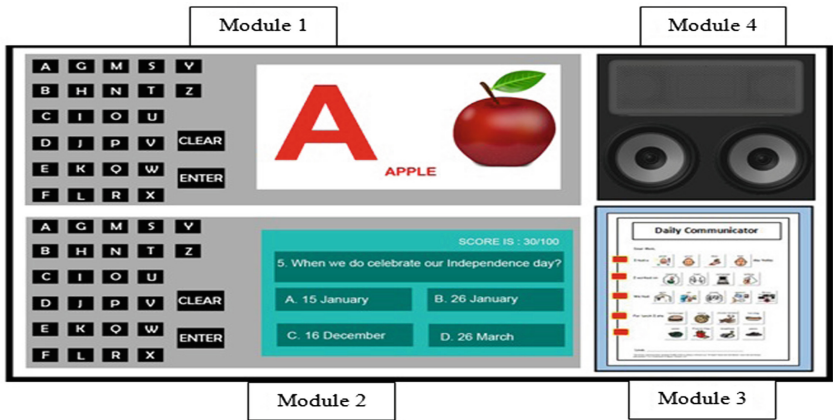


Fig. 1. Proposed design of the tabletop learning tool

5.4 Module 4 (Playing Rhyme and Music)

As music and rhymes have a great impact to the autistic children and in some cases also used to provide mental therapy, this module is designed to play any music or rhyme from external source (like pendrive or memory card). In this module, speaker with display is installed, where external source can be attached by port. There will be some intuitive buttons to play or change the rhyme or the songs. This module will address the following revealed design considerations: *affordance*, *interactivity*, *multimodal feedback*, *intuitiveness*, *easy-to-learn* and *easy-to-use*.

6 Discussion and Conclusions

This research provides a total of eleven design considerations for developing a tabletop learning tool for autistic children to learn basic education and to express their daily needs. A design solution for developing a tabletop learning tool for autistic kids based on the revealed design considerations is also proposed here. Though some of the design considerations are already exist in literature, but many of the design considerations revealed through the research are new to design the tabletop learning tool for the autistic children; that includes, *affordance*, *intuitiveness*, *clear & concise interface*, *metaphoric design* and *multimodal feedback*. Again, literature survey showed that most of the existing design considerations are for developing desktop, web and mobile based tools. None of the earlier work focused to design any tabletop learning tool. Therefore, the revealed design considerations are new and innovative to develop a tabletop leaning tool for the autistic children.

The research has a few limitations as well. Firstly, though the revealed design considerations were revealed through empirical studies but these were not validated yet. Secondly, the study data were analyzed through a qualitative approach. As the result of the qualitative analysis depends on individual’s experience, view, knowledge

and most importantly the target. The future work will focus to develop and evaluate the concrete version of the tabletop learning tool to validating the effectiveness of the revealed design considerations.

Declarations

Ethics Approval and Consent to Participate – We confirm that ethical approval has taken by the ethical committee headed by the Research & Development Wing of Military Institute of Science and Technology (MIST) for conducting this research. We also declare that we have taken written consent from each participant to participate in this study.

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