Research-based design and research through design: a case study of the improvement in the user experience of an autism caregiver using ICT.

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Abstract

There is a long history in design study of focusing on designers, but this does not connect well with industry and the end products of design. With the emerging importance of user experience (UX), we argue that what is needed is a new kind of design study that focuses on users, relates to the end products, and results in mutual benefits for research and practice. It is both “research-based design” and “research through design”. The design process of iCAN was used to demonstrate a new kind of design study that combines both design research and design practice. iCAN is an app used in the place of traditional tools to assist caregivers in developing the cognitive and communication skills of children with autism. The three phases of the process were UX Research, UX Design, and UX Testing. They demonstrate the inter-connection between design research and design practice, and also demonstrate the features of the new kind of design study. We believe that this is the future direction of design studies, and has benefits for both design researchers and practitioners.

Keywords
User Experience; Assistive technology; Autism; Caregivers; User Interface.

Introduction

Background

There has been a long history of design studies exploring design thinking using case studies, interviews, and protocols; however, it wasn’t until recently that we found some limited design studies specifically focused on users. The emphasis of user experience (UX) in products, processes, and systems from industry fosters the need to understand the users’ experience in design studies. Two kinds of research on user experience can
be found. One is UX research that focuses on the vague front end of the design process in order to understand the need and expectation of users. The other is UX testing, which focuses on examining the usability of the products. The results of UX research contribute to the design of new products, whereas UX testing helps with the modification of a design in an iterative cycle.

For products with physical components, such as electronic appliances, the resources for modification are expensive, and so hardly any modification of the design occurs following user experience testing. On the contrary, the modification of software applications is rapid due to the relatively low cost of programming. The iterative cycle between UX design and UX testing is multiple and agile. Therefore, the results of UX testing is closely connected to design practice. This result has inspired us to produce a new kind of design study that combines both design research and design practice. We believe that it may be the first step in a new direction for design studies.

We carried out a design process based on our proposed method in order to demonstrate the details of the design study and its specific differences. The case is iCAN, a teaching assistant app for children with autism. It started with UX research and concept design, which was then followed by a multidisciplinary collaboration between designers and ICT professionals to produce numerous working prototypes. UX testing was carried out to examine the usability and UX of iCAN, and to further improve its functionality. After four cycles of UXD and UXR over three years, we established the business model of iCAN and put it on the market. The UX research and testing resulted is a full-fledged product, and thus we use this process as an example of this new kind of design study. Below describes the background knowledge, the method used, results of the example, and discussion of the new design study.

**Literature review**

According to "The Diagnostic and Statistical Manual of Mental Disorders IV (2000), DSM-4th", the diagnostic criteria for Autistic Disorder (No. 299.00) are: (A) Qualitative impairment in social interaction. (B) Qualitative impairments in communication. (C) Restricted repetitive and stereotyped patterns of behavior, interests, and activities.

Some research mentioned caregiver's stress, Lecavalier (2006) found that parents of children with autism seem to experience even more stress than parents of children with other disabilities. Davis & Carter (2008) found that parental mental health is an important consideration in the study of parenting stress, and that parental depression has a strong correlation with parenting stress. Moreover, mothers of children with ASD typically report higher levels of depression than fathers.
The Picture Exchange Communication System (PECS) is a unique training program, as shown by Bondy & Frost (1994). It primarily uses picture cards, which have a picture and description to illustrate an object, an action, or an emotion. The effectiveness of PECS lies in children with autism being able to use these picture cards to make sentences. Therefore, they can express to their caregivers what they need or how they feel.

Law, Roto, Hassenzahl, Vermeeren & Kort (2009) defined User Experience (UX) as “the overall experience, in general or specifics, a user, customer, or audience member has with a product, service, or event”. Jesse (2006) found that for customers to feel that they have a good relationship with a company’s service, they must first feel that they have a good relationship with the product, and that begins with the user experience. Hassenzahl & Tractinsky (2006) showed that UX is associated with a broad range of fuzzy and dynamic concepts, including emotional, affective, experiential, hedonic, and aesthetic variables.

Kientz & Hayes etc (2006-2007) proved that some computer features can help autistic children learn. These included repetitive teaching and the use of visual images with sound effects. Adler-Block & Bernhardt etc (2007) showed that in many studies, if appropriate computer-assisted training is conducted, it can improve the speaking ability, cognitive ability, and social communication skills of children with autism. Hailpern, Karahalios etc & Halle. (2009) proposed the Spoken Impact Project (SIP) system for the study of five "low-functioning autism patients". They discovered that when sound effects combine light with shadows and images, it can enhance the low-functioning autism patients’ willingness to engage in spontaneous oral expression. This breakthrough in the field of Human Computer Interface (HCI) and autism was not easy to achieve.

**Method**

The method consists of three design phases, as shown in Figure 2, which include User Experience Research (UXR), User Experience Design (UXD), and User Experience Testing (UXT). The process is both research-based design (Mayer, 1999) and research-through-design (Zimmerman, Forlizzi, & Evenson, 2007).

![UX Design Process Diagram](image)

*Figure 1: User experience design process.*
**User Experience Research (UXR)**:

We used qualitative interviews to understand the teaching experience and problems of caregivers, which included the parents and teachers of children with autism. UXR can help in finding the problems associated with the user experience of the current product. During this phase, the results of UXR are transformed into concept design, which are then fulfilled by UXD, and subsequently verified by UXT.

**User Experience Design (UXD)**:

Research results were organized so as to develop a conceptual prototype and design a new teaching material (assistive app) for caregivers and children. In the design process, it may be necessary to make a few slight modifications to the design, and so users are allowed to engage in repeated testing, with the user experience of caregivers being incorporated. By the end of this stage, the assistive app – iCAN – had been fully developed.

**User Experience Testing (UXT)**:

The caregivers of children consisted of parents and special education instructors. We examined the different burdens of the caregivers when using "traditional teaching materials" and using "iCAN". During the four-week deployment, each caregiver participant was interviewed. The interviews consisted of both individual and semi-structured formats, where participants were asked to discuss how they utilized the system.

Additionally, caregivers were provided with a questionnaire using the five-point Likert scale, which asked them to provide feedback on the effectiveness of using iCAN compared to the conventional PECS method that they had previously been using. Finally, a paired sample t-test was used to compare their questionnaire responses. During the UXT process, the hypotheses of UXR were examined. This forms the basis for scientific research. The hypotheses comes from users’ needs and the results contribute to the product, which is then needed by the users. In turn, this forms the basis for product development. As a result, this new process is a combination of design research and practice, and the process is both research-based-design and research-through-design.

**Result**

In this section, we use the development of iCAN as an illustration of the new kind of design study. Children with autism can’t fully express themselves because of an impairment in their brain development. Caregivers often use picture cards and other teaching materials to teach these children. This allows children with autism to develop communication and cognitive skills. Caregivers require more patience and love to teach children with autism because of the greater inconveniences caused by current teaching materials, which caregivers have to spend a lot of time and effort making.
One of the most effective pedagogical techniques for assisting children with autism in better adapting to social life is the Picture Exchange Communication System (PECS), a tool developed by educational experts in order to assist autistic children in communicating with others. PECS needs to match the teaching material to the use, but the usability of traditional teaching material is both complex and time-consuming including things such as taking pictures, printing, clipping, decorating the cards…etc., and the management and retrieval of picture cards becomes inconvenient.

**User Experience Research (UXR):**

We interviewed two caregivers: one of the caregivers was a special education instructor and the other was the mother of a ten year old boy (severe autism, no verbal skills). The ten year old boy doesn't like using traditional teaching materials or picture cards, and caregivers feel that using them is very inconvenient. We identified several current problems:

1. **Learning:**
   Caregivers need to help children with autism develop their cognitive and communicative abilities, but current teaching processes spend a lot of time in simply finding the picture cards, which results in the lack of sufficient patience to learn. In order to smoothly teach children pronunciation and sentence structure, a simple and clear classification system is needed to improve learning efficiency.

2. **Teaching Burden:**
   A large number of picture cards and repeated pronunciation increases the teaching burden of caregivers because they need to break apart the original set of picture cards every time. Caregivers hope that children are able to conduct learning and reviewing independently. Thus, the solution should have the function of saving of sentences, and repeated playing in order to inspire independent learning.

3. **Creation:**
   The general approach of picture card production with traditional teaching materials involves computer printing, clipping or decorating the cards, laminating the pictures, and applying hook tape on the back of the cards. These processes exacerbate the burdens of caregivers by longer duration of time (Figure 2).

![Figure 2: The left figure shows several picture cards, the middle figure shows a large number of picture cards, and the right figure illustrates that the creation of picture cards is both complex and time-consuming.](image-url)
During this stage, we interviewed several caregivers and found that the major problems experienced all revolved around the picture cards. The picture cards are widely adopted in the teaching of autistic children. However, preparing and putting numerous cards in order is neither easy nor quick. To suit the needs of different children, the caregivers have to create new picture cards, which is time-consuming. According to these UXR findings, we aimed to reduce the burdens resulting from making and preparing picture cards. In the next stage, user experience design, we changed the form of the teaching material of paper card that into an app which is run on tablets.

**User Experience Design (UXD):**

We designed a new user experience for caregivers which includes features such as a clear category system, the ability to make sentences, save sentences, quickly create picture cards, search…etc. It also includes some special user experience details for children such as a colorful category, real figures (traditional picture cards have cartoon figures), a clear interface, sound feedback…etc. Caregivers thought that the use of a tablet device for teaching children was a good idea because traditional teaching materials are very heavy and require the handling of a lot of picture cards. If they use a tablet device, teaching will become easier.

We cooperated with a programmer to develop a new assistive app, called iCAN (Figure 3). iCAN is an app that aims to improve the verbal expression and cognitive development of children with autism. It resolves the inconveniences of traditional aids for communication learning, for example, the inconvenience of carrying them and the complexity of producing them. To alleviate the burden of caregivers, the main functions include the storage of a large number of communication cards and combinations of sentences, the recording of frequently used sentences, and the addition and editing of new cards. With our categorization system and picture card exchange system, iCAN makes the learning and teaching process effective, efficient, and satisfactory.

Figure 3: iCAN. (Download link: [http://bit.ly/1aoGLC9](http://bit.ly/1aoGLC9))
1. Sentence Production:
Caregivers need to prepare a lot of picture cards to teach children how to both communicate and pronounce words correctly. However, by using the iCAN search and picture card sentences function, you can save time looking for picture cards, and pressing the sound button may facilitate the child's ability in speaking practice (Figure 4).

2. Commonly-Used Sentences:
In the past, users had to disassemble a set of handmade picture card sentences and assemble a new set of sentences, which meant less opportunity for children to practice. One function of iCAN can save the sound of set sentences to help children repeatedly practice and play, which in turn helps caregivers avoid spending a lot of effort on repetitive teaching tasks (Figure 4).

3. Making Digital Picture Cards:
The process of making traditional picture cards requires a lot of time and effort. Through the tablet app iCAN, caregivers can add new cards by taking pictures with the camera on a tablet PC, or by importing from its albums. These special features allow for more time to be spent on nursing children and other things (Figure 4).

Figure 4: The left figure shows the main function interface for sentence production, the middle figure shows the main function interface for commonly-used sentences, and the right figure shows the main function interface for making digital picture cards.

**Detail of User Experience Design:**

1. Method of choosing the picture cards:
Some children with autism experience difficulty in selecting picture cards to make sentences because of problems with finger muscle development, and so we designed two methods of picture card selection in iCAN: press and hold and drag. This way, children with different abilities are all able to use the app.

2. Category column design:
Children with autism use visual memory or color to remember something or somebody. We added color and little pictures to the category column, which can help children to select a category. This design detail proved effective in later testing.
3. Method of page change:
If we use “slide” to change the page, it will conflict with the action of dragging the selected picture card. We therefore designed a change page button for the interface.

4. Pointer for recording volume:
Users don’t always know the sound volume when they record a new picture card. Therefore, we designed a volume pointer. This lets users know how to control the volume to ensure that every picture card has the same volume.

5. Hide category columns and sentence columns:
We designed automatically hidden buttons for category columns and sentence columns for better focus of children when using.

6. Adjust size of picture cards & display a single picture card:
Caregivers recommended that the function to adjust size and change the number of cards displayed might help children to identify cards easily. If an autistic child does not have good cognitive abilities, they can switch the display of larger picture card in order to have a better understanding and prevent interference from other picture cards (Figure 5).

![Figure 5: This child is using the "Display a single picture card" function during the learning process.](image)

The final stage was user experience testing, where we installed iCAN on the tablets and let caregivers use them. After experiencing iCAN, we interviewed the caregivers to see whether iCAN was beneficial.

**User Experience Testing (UXT):**

For the design of our study, our system was used over a four-week period by the caregivers of eleven children with ages ranging from 5 to 16 years of age, who had been diagnosed with autism ranging from moderate to severe, and had demonstrated low to minimal verbal skills. The caregivers of the children consisted of eight parents and three special education instructors ranging from 26 to 60 years of age (Table 1). All the participants in our study had prior experience using PECS, and were asked to use our iCAN system from anywhere between two to five times a week. We were particularly interested in investigating three specific research issues: (1) The Willingness of Children with Autism to Learn.; (2) Reducing the Teaching Burden.; (3) Reducing the Burden of Producing Picture Cards.
1. Willingness of Children with Autism to Learn:

The iCAN system helps to stimulate children’s learning through the playback of recorded sounds associated with the picture cards. It engages the tactile sense, through the tapping and dragging of digital artifacts such as the picture cards within the interface, and the visual sense, through the vibrant graphical display and simple and clear classification system used to organize sentences. The caregivers have expressed to us that they observed significant changes in their children after they used iCAN. More specifically, the children were more expressive and able to communicate their needs more clearly. Moreover, the caregivers also stated that they noticed significantly improved verbal abilities in their children (Figure 6).

Table 1: Overview of the study’s participants. (Parent 1 = P1; Teacher 9 = T9)

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Figure 6: Impact on the children’s behavior. (1= Strongly Disagree ; 5= Strongly Agree; T-test, * indicates p<0.1  , **p<0.005 , and ***p<0.005)
P4: After a couple weeks using iCAN, the length of the sentences that he speaks has increased. In the past, I would ask him about what he wanted to eat many times, and he would only reply with a single syllable, but now he will click on the picture cards or sentences in iCAN or even say a sentence...like "I want to eat fries", which never happened before.

In other words, iCAN is an inviting and appealing environment for children to learn in, and children can tactically interact with the visuals of iCAN as they process its audio feedback for a tangible experience.

2. Reducing the Teaching Burden:

The iCAN system appealed to children since they enjoyed clicking on the picture cards on the tablet screen through the iCAN interface. The children were also attentive to the interface’s voice feedback, as the repetition of the words to the children by the interface enabled them to improve their learning progress.

Moreover, we observed children repeating the words after hearing them vocalized through iCAN’s interface, which allowed them to gauge the accuracy of their pronunciation. Caregivers also expressed that the recorded voice also produced more consistency compared to vocalizing pronunciations to the children on the spot, thus better accommodating the children’s learning (Figure 7):

![Figure 7: Results relating to the caregivers’ teaching burden. (1= Strongly Disagree; 5= Strongly Agree; T-test, * indicates p<0.1, **p<0.005, and ***p<0.005)](image)

T2: iCAN provides voice feedback. I ask them to speak and then let them click on it to hear the sound, so they would know whether their pronunciation is correct. I think iCAN improves their initiative.
Another feature that appealed to caregivers was iCAN’s ability to store words and sentences. Caregivers can save these words and sentences in iCAN to enable children to practice them at a later time. Children can then review picture cards with saved words and sentences that caregivers wish for the children to reference in conjunction with the recorded pronunciation, and the children are both visually and aurally stimulated as they repeat the recorded sounds.

One mother shared with us that her child had originally been unable to express verbally. She utilized iCAN to repeatedly play back the sentence so that her child could rehearse the pronunciation. After a couple weeks of use with the system, the mother further shared that her child approached her bed one morning and said to her, “Mommy, wake up!” This anecdote was one of many wonderful reports that we received from the families of children with autism who used our system, as caregivers expressed their joy at hearing their children communicate with them at greater lengths.

3. Reducing the Burden of Creating Picture Cards:

Although picture cards have served as an essential learning tool for children with autism, we discovered through our interviews with the caregivers that the process involved in utilizing picture cards with children has elevated the stress levels of the caregivers. Purchasing ready-made picture cards that already exist on the market is an alternative to creating the cards from scratch, but caregivers stated that customizing picture cards specific to a particular autistic child has proven to be more effective. In the pursuit of more effectively assisting children with autism in developing their communication skills, we are left with a problem: caregivers are spending too much time in making these tangible picture cards. Fortunately, the development phase of our study demonstrated that iCAN can significantly reduce the time needed to produce picture cards using the PECS approach (Figure 8):

![Figure 8: Results relating to the burden and complexity of teaching material preparation by caregivers. (1= Strongly Disagree; 5= Strongly Agree; T-test, * indicates p<0.1 · **p<0.005 · and ***p<0.005)
**PO:** The design of iCAN is so much better than the old-style picture communication board; otherwise, I would spend most of my energy and time making the picture cards, which was the most exhausting part.

**T2:** With iCAN, I can teach things closer to daily life and closer to real-time. Otherwise, it will take time to find a suitable image, or I may need to take a photo with a digital camera, and then print it out, cut it out, laminate, etc. iCAN is faster... it can display the picture immediately on screen.

**Discussion**

The development processes of iCAN are threefold: UXR to determine the required functions for the design process and the hypotheses for the design research in UXT; UXD to generate the working prototypes for the design process and the actual means by which hypotheses would be tested; UXT to reveal the existing design problems for further modification of the design and to test the hypotheses through the design. The cycle between UXD and UXT should continue until a satisfactory solution is found. Along the way, many design research proposals may be formulated.

This is a new kind of design study. It requires both qualitative design research in the beginning of the design process and quantitative design research at the end. It combines both design research and design practice, and they mutually contribute to one another for better design and better research. This kind of research can fully utilize the well-developed research methods of the design studies community, and can contribute to the industry and design practice of society.

The enabler of this method is the development of the software industry. The relatively low cost of software modification enables the cycle between UXD and UXT to happen quickly. Furthermore, the high possibility of the completion of the software/app by the researcher/designer enables this new kind of design study to be carried out in schools and under the limited resources of academics.

**Conclusion**

The current design process is human-centered design, emphasizing both theory and practice. With the development of low cost programming, the whole process can be shortened to fulfill the needs of a research project. Therefore, we can have a new kind of design study that combines both qualitative and quantitative design research and results to obtain both better research-based design and better research through design. This paper illustrates the possibilities and process of this new kind of design study with the design process of an app aimed at assisting the teaching of autistic children. We believe that in the future, this may be one of the best design study practices. Furthermore, with the development of rapid prototyping, the lower cost of modifying physical products will enable the application of this new design study to products other than software. All kinds of design may use this method.
References


