A User Centered Approach in Designing Computer Aided Assessment Applications for Preschoolers

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Abstract: The children of nowadays are growing surrounded by technology. The appropriate use of technology is important in determining their attitude towards it, and education should support the right approach in this sense. Adjusting the teaching and evaluation methods to the current trends is necessary, starting from very young ages. In this paper, we present a User Centered Approach for developing Computer-Aided Assessment applications for preschoolers from our country. We describe our approach and present a case study of applying it, together with discussions about the challenges, lessons learned and future development.

1 INTRODUCTION

Nowadays, more and more children are exposed to technology from their early childhood (Crescenzi and Grane, 2016; Nesset and Large, 2004; Robertson, 1994). In the European Union (EU), there is a growing interest to improve the digital skills of its citizens, so a Digital Agenda has been created and adopted by the member states (International Computer and Information Literacy Study, 2018; Kiss, 2017). It is considered that the improvement of digital skills should be led by the educational system, where more and more focus goes around the digital skills of young people. Currently, it is considered that the children's digital skills are of same importance as literacy and numeracy (Bukova, 2017; Fraillon et al., 2016; UNESCO, 2011).

The educational system in Romania has faced several reforms in the last thirty years regarding curriculum and forms of organization, redefining the objectives of education according to the EU requirements. It is organized in three stages: preschool stage (children aged 3 to 6), school stage (children aged 6/7 to 18-primary, secondary and high school) and university stage. Political, social and economic development following the transition from dictatorship to democracy came with mandatory changes regarding education. Along the way, several measures were taken as a means to improve the teaching-learning process and to obtain better results at national exams and international contests, as well as developing competencies and skills needed to integrate youngsters in different work fields. Thus the need to have digital skills formed from early ages, i.e., preschool stage. ICT classes are organized for the primary school, but no measures address the preschool system, even though every kindergarten classroom is equipped with a PC.

Presently, only primary and secondary school are compulsory, but further legislation in the area states that preschool stage will become mandatory, too. It started with preparing teachers, giving them the possibility to enroll to dedicated courses in order to achieve certain digital competencies, promoting e-learning, and continued with introducing computers, useful devices (cameras, printers) and internet in schools in order to provide resources to improve, ease and increase the benefits of education. It was followed by preparing children, an ongoing process that needs a special attention. Using technology in teaching and teaching children how to learn using it seems to be the challenge of the 21st century in Romania.

At preschool stage, kindergarten time is dominated by discovering the world through games and playing (Piaget, 1970). This stage is the proper start in making acquaintance with using devices in a joyful and pleasant way, in making a transition from listening to a song or a story to pressing a button to listen

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to them, to interact according to rules, and to pay attention to the process of interacting. This brought the idea of building interactive applications to support the teaching activities as well as the learning process and to also cover the entertainment side of the process. Inspired by the idea of building edutainment applications for preschoolers (Guran et al., 2019), we have decided to go a step further, by introducing technology in the evaluation process of preschoolers. In this paper we present our user centered approach in designing Computer Aided Assessment applications for preschoolers.

The paper is structured as follows. Section 2 describes essential aspects of preschoolers' assessment and the characteristics of Computer Aided Assessment. Section 3 presents our view on the design and development process of Computer Aided Assessment of preschoolers together with a case study. The results of applying the proposed approach are discussed in Section 4. Section 5 presents some conclusions and future work ideas.

2 EARLY CHILDHOOD ASSESSMENT

The kindergarten is one of the educational environments with a big impact on the process of development and socialization of the child.

The preschoolers' evaluation is a complex didactic process, that is structurally and functionally integrated into the kindergarten activity. The theory and practice of assessment in education has a wide variety of ways of approaching and understanding the role of evaluative actions. In the kindergarten activity, the evaluation act aims to measure and assess the knowledge and the skills acquired by children during the educational act. At the same time, the evaluation also follows the formative aspects of the educator's work, materialized in the ways of approaching the change, in the attitudes and behaviors acquired by the preschool child through the educational process. Evaluation should not inhibit children or demotivate them. Instead, it should stimulate them to learn better. The knowledge, the skills, and the abilities acquired during that period are reviewed, with the explicit purpose of reinforcing and consolidating the new learned behaviors.

2.1 Preschoolers' Assessment in Our Country

In our country, at the beginning of each school year the first two weeks are used for collecting data about the children, called *the initial evaluation*. Teachers observe the children during different moments of the daily program and talk to the children and their parents in order to build an image as accurate as possible on each child psycho-somatic development, knowledge, understanding and skills. The same provision applies to children enrolled during the school year. A two-weeks *final evaluation* is recommended, but not mandatory, in order to assess the overall progress of each child during the school year or during all preprimary education years. Based on the results of the final evaluation, teachers determine the educational strategy to be applied the next school year and/or make recommendations for the children ready to enroll in primary education. The curriculum promotes the idea of encouraging children and helping them to develop a positive self-image, and to gain confidence in their own abilities and individual progress at one's own pace (EURYDICE, 2019). Currently, the summative evaluation of cognitive skills is paper-based, an evaluation session consists in three or four evaluation fiches that must be filled in by the child, with content from the curricula domains studied during the evaluated period.

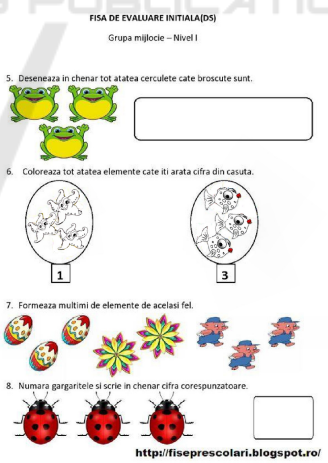

Figure 1: Paper-based evaluation example.

In Figure 1 an evaluation fiche is presented. The tasks from the fiche are: to draw the number of lines equals to the number of frogs, to paint the number of elements indicated by the number in the rectangle, to mark the sets of identical elements and to write down the digit corresponding to the number of ladybugs.

2.2 Computer Aided Assessment

Computers have been successfully used to assess older children and adults, and there is much research comparing computer-based testing (CBT) to traditional paper-and-pencil testing (PPT) with older students and adults (Sim and Horton, 2005; Sim et al., 2014). While for adult users (e.g. faculty students) there are advanced approaches in building adaptive computer-based assessment tools (Chrysafiadi et al., 2018; Krouska et al., 2018; Troussas et al., 2019; Troussas et al., 2020), there are only a few attempts in studying the appropriateness of computer-based testing with typically developing preschool children. In (Barnes, 2010) it is shown that preschool children can successfully perform computer-based testing. The main issue that was discovered is the children's lack of digital skills that brought difficulties in performing the test. In this paper we describe our approach in designing, implementing and evaluating a computer aided assessment system for middle group preschoolers (4-5 years old) from our country. The intended users are preschoolers who have participated in teaching activities with the support of edutainment applications. Practitioners from software design and education can benefit from the insights on the user centered design process, content, dealing with mistakes, tasks, and evaluation that we have performed during this case study implementation.

3 OUR USER CENTERED APPROACH

To design successful Computer Aided Assessment applications, people with different backgrounds should participate. We consider that at least people from the following domains should be involved: education (i.e., cognitive and developmental psychology), design (i.e., interaction, industrial, UX, game), and software engineering, together with preschool children and their parents. As the final users of our intended product are preschoolers, many constraints on the design process occur. We consider that applying User Centered Design (UCD) we have the opportunity of building an appropriate evaluation tool. Still, the UCD process needs adaptation, such as the final users to be present or at least represented during all the stages. In the following we describe our UCD approach in designing a Computer Aided Assessment application together with a case study.

3.1 Participants

Two preschool education experts (kindergarten teachers), three software designers (Software Engineering master students), one interaction designer, five children (two boys and three girls, aged 4-5 years) and three parents participated in the design and evaluation process.

3.2 Users' Needs Identification

To understand clients' requirements and to get to know our real users we have conducted user studies through observation and interviews with preschoolers and kindergarten teachers. We have started the design process with the design team meeting the kindergarten teachers. In this meeting the teachers have presented the requirements for the evaluation software, stating the following:

- the software application should not require internet connection (as it is not always available);
- it should not require additional software licenses;
- it should not require installation;
- the children shall be capable of using it without the help of an adult;
- the application should be built around a story/game;
- the test shall not take longer than 10 minutes;
- the children shall be able to see, hear and answer 15 questions from topics they have studied during the year;
- children shall have an audio helper providing instructions at each step;
- along the whole test, the children shall be able to interact with the interface by clicking buttons and by hovering over an audio helper;
- a child's progress through the test shall be displayed at each step;
- at the end of the test the result will be displayed;
- a time limit for each question will be allocated;
- children will have the option of requesting additional help by hovering over the audio helper;
- the application will not collect any personal/private data and will comply with the children privacy policy;
- the tasks children are required to perform should cover all the domains from the preschool curricula (if it is not possible, then most of the domains).

Figure 2: Field study at the kindergarten.

Figure 3: First window in the evaluation application.

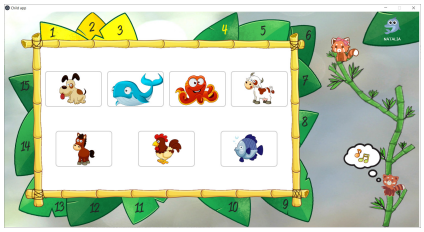

Figure 4: Status and progress view in the application.

During the interviews with the kindergarten teachers, information about the evaluation goals, methods, and current situation has been gathered. Afterwards, the design team has visited the kindergarten in order to meet the final users of the system (see Figure 2).

The design team members have played with the children, asking them questions in order to get an initial idea on their knowledge from different curricula domains. Then, the children have been invited to play on a laptop using the mouse, such that the digital skills of the little users have been observed. At the same time, the members of the design team have studied the curricula and Bloom's taxonomy of learning objectives (Bloom et al., 1956) to accommodate with real users capabilities and limitations.

3.3 Design Alternatives and Prototyping

In the next step, the design team has proposed design alternatives which were evaluated only by the kindergarten teachers. In this step the kindergarten teachers, playing the role of the *surrogate* for the real users, provided feedback on the narrative chosen by the design team to envelop the evaluation process, on the proposed characters, and most important, on the tasks proposed for the evaluation goal. Based on the teachers' feedback, the design team has started creating the executable prototype. The prototype was conceived as a quiz, exposing question and answer exercises or sorting tasks, wrapped in game specific features. The software encourages children into solving the quiz by using means of games and interactive exercises, to support them to engage, explore and think. The interface is self-explanatory and designed in a way that would enable the children to use it without adult supervision. An audio guide provides information and instructions along every step of the interaction, as an alternative to the fact that preschoolers are not yet able to read the questions on their own. We wanted to ensure that the users would receive help at all times, without having the teachers instruct them into using the application. The scenario, designed to encapsulate the evaluation tasks, exposed a red panda, called Tibi, that had to solve a set of tasks with child's help (see Figure 3). If the child correctly solves a task, Tibi will climb higher in the tree, thus getting closer to his friend, Lin, which lives on the top of a tree (see Figure 4, on the right hand side of the screen). Each successfully solved task benefits from an advance in climbing the tree for Tibi and, also, a bamboo leaf. In the end, if all tasks are successfully completed, the two friends meet and share the bamboo leaves. If some tasks haven't been completed, Tibi won't get to Lin, but it will still receive a basket of bamboo leaves (a bamboo leaf for each correctly solved task).

While taking the test, a user knows at each step his/her current status (the leaves surrounding the test window, corresponding to the answered questions, change their colour from green to yellow) and actual progress in the game, as Tibi climbs higher in the bamboo tree from the right side of the screen with each correct answer (see Figure 4).

The application does not allow a child to give up when more challenging questions appear. After a time limit of 45 seconds, if the child fails to deliver an answer, a hint is presented to him/her (see Figure 5, where the first image that should be selected is marked by 1). At the end of the test, after the child finishes going through all of the tasks, the application displays the result (number of tasks correctly solved, together with a basket of leaves representing their performance in the test, consisting in one bamboo leave for each correct task), as a form of reward. The reward is different based on how well the children answered the questions (see Figure 6 and Figure 7).

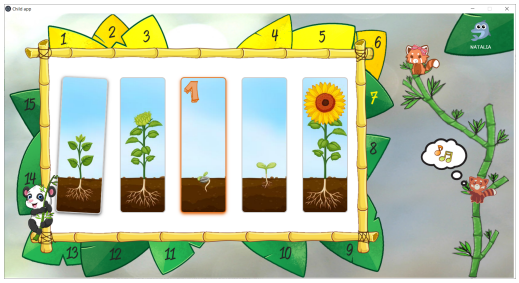

Figure 5: A hint in solving the task.

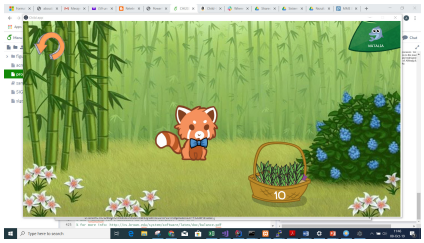

Figure 6: Evaluation end page when children failed to correctly answer all questions.

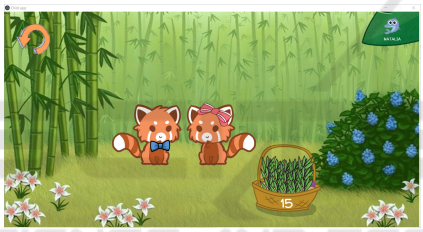

Figure 7: Evaluation end with all tasks successfully completed.

3.4 Evaluation

Evaluation of the prototype with real users has been performed in the kindergarten. The children had the opportunity to choose if they would like to interact with the application. First, a boy and a girl decided to test the application, than another boy and two girls have interacted with it (see Figure 8).

We allowed for evaluation goal to let more than one child interact with the application in order to simulate the think-aloud protocol used for adult users. This way, we have extracted information about the children's thoughts on the game they were exposed to. In the end, the children have been rewarded with stickers with the characters of the narrative and diplomas with elements from the evaluation game.

Data Collection and Analysis. We captured video and audio recordings during the play-testing sessions (see Figure 8) and during the satisfaction evaluation. We also took observational notes during the evaluation session. With the help of the video and audio recordings, and handwritten notes, we prepared a focus group with the children's parents. We were interested in how the children described their experience in their familiar environment.

Figure 8: Play-testing sessions with real users.

Results. During the play-testing sessions we have focused on children's performance. We have been interested in the number of tasks the children solved correctly, but also the number of tasks that needed hints to be presented in order to be solved. Four children have actively participated to the test. One child has only observed his colleagues interacting, but did not want to participate. From the 15 tasks the children had to perform, one child has successfully completed 14, the others a number between 10 and 13. We have observed that children encountered difficulties in tasks where the interaction steps were very specific. For example, when the children needed to sort some objects in ascending or descending order, they selected the largest and smallest object, but did not know how to effectively select the elements in the required order. Although hints were provided (by marking the first element from the solution, as shown in Figure 5), we have observed that children did not manage to perform better. We consider that a small video tutorial will improve their performance.

In order to have an image of children satisfaction, we have used post-interview sessions where questions like *Would you like to show to your best friend this game?* or *Would you like to play again this game?* have been addressed. All children have answered that they had a good time playing and two of them did take the test again. As we know that children are very willing to satisfy adults, we wanted to validate their answers by asking them to fill in a *dragonmeter* (see Figure 9). The dragonmeter is similar to a smiley-ometer (Read and MacFarlane, 2006), but children in this group are using it in their everyday activities to express emotions. The dragonmeter presents the following emotions: brave, calm, sad, happy, bored, furious. Three children have chosen the happy dragon, and two children have chosen the brave dragon. To

Figure 9: Dragonmeter example.

add more details to our understanding of children's view of their experience with the evaluation software, we have involved their parents in a focus group. We asked the parents to describe what the children told them about the activity. Three parents agreed to participate to the focus group. All the parents reported that the children have mentioned the fact that there was a *game* with a *red panda*. The children have mentioned different objects (geometric shapes, animals, fruits) and some of the tasks they had to perform. They were very enthusiastic about the stickers and diplomas they have received after the session. The parents have mentioned that the children were very enthusiastic about their experience. They have also mentioned they would like to participate in further similar activities. Their only concern was about the period of time the children were exposed to the computer. Although we have ensured them that from our experience they did not sit in front of the computer more than 10 minutes, they were sceptic, as from children enthusiasm they believed the children would never stop playing. From all these assessment methods, we have drawn the conclusion that children had a great time interacting with our assessment application. They did not mention anywhere that they had been evaluated or tested.

4 DISCUSSION AND LESSONS LEARNED

Designing for children is different than designing for other stakeholders, as there are additional constraints brought by their physical and psychological development. In the following we will present how the usual software design phases need adaptation such that the clients and the final users of the system participate in the design process. Also, implementation of functionality that requires no supplementary effort when the users are adults, brings the necessity of design and implementation decisions when the users are small children who cannot read or write.

4.1 Considerations on the Software Engineering Process

Requirements. The process of gathering information about their characteristics and needs must be adapted. Spending time with the children in their familiar environment provides useful information about their interests, their skills, and their knowledge. The entire activity of requirements gathering should be organized as a play activity, to encourage children participation and to help them connect with the design team members. When the goal of the designed product is educational, further assistance from the educational experts needs to be integrated in the process. They can provide information about the developmental stages of children, their knowledge on a specific domain and further educational goals. Parents are valuable stakeholders in the design process, as they can provide their view on children' knowledge, interests and interaction skills.

Alternative Designs. In order to evaluate the alternative designs, there are two possible options: creating abstract representations of the design solutions and involving an educational expert only to provide feedback, or implementing executable prototypes of the designed solutions such that the preschoolers are able to give feedback. Although it is more comfortable to interact with the educational experts (adults) to identify possible interaction problems, there are some aspects that cannot be predicted by the education experts. Task formulation accepted by the adult users might be misinterpreted by the children. For example, if a task required the children to count the number of objects on the screen, the children always answered verbally, without interacting with the interface. Such situations cannot be identified without observing a child interacting with an executable prototype.

Prototyping. As we have previously mentioned, the most appropriate approach when working with such small children is to merge the design alternatives and prototyping step. This means that more development effort is involved in the early project steps, but the children can participate to a larger degree in the design process. Involving children in the process is essential, as we consider that the acceptance and engagement of children in interaction is determinant on their task performance.

Evaluation. Evaluation of computer assisted assessment evaluation tools requires multiple aspects to be taken into consideration. An evaluation from the education experts is needed to validate the content, navigation, and task sequences. The evaluation with the children is required to provide information about their

interaction with the product, their satisfaction in interaction and their understanding of the product. As evaluation with preschool children is influenced by their willingness to satisfy the adults, the use of multiple methods to identify their opinion is needed. As such, parents should be involved in the evaluation step to provide information on how the children have described their experience about using the products. Automatic evaluation methods to identify children' emotions during the interaction can also provide meaningful insights.

4.2 Discussions on Implementation Challenges

4.2.1 Error Handling

New challenges occur when trying to create evaluation software for preschoolers, as there are no guidelines in this domain. When paper-based testing is performed, the kindergarten teacher observes the children' reaction and provides immediate support and help. When using a computer aided assessment system that is intended to be used by children without adult intervention, the designers should try to integrate in the software the part of the kindergarten teacher support. Taking the decisions on how long to wait for an answer, how to provide feedback, how to keep the children focused, how many hints to provide and how to count the performance (when children needs guidance) is very challenging. A lot of time was spent on deciding how to handle the situation when the child gives the wrong answer. Giving multiple chances to answer a question seemed to be the right approach. But then, a new question aroused: how many times should the application show the same question? We decided that after an incorrect answer, the application should present the child the same question, together with a hint. If the child gives another incorrect answer, the application goes to the next task. If the child does not answer the question in 45 seconds, than the application automatically goes to the next question. A better approach for this problem would be to identify the child's emotion and to guide the interaction based on it (if the child gets frustrated then hints would be provided to solve the task, if the child is bored a new audio message should be presented to make him/her gain focus again).

4.2.2 User Authentication

Another essential aspect in developing assessment tools is the authentication procedure. As the preschoolers cannot read or write, is very difficult to identify the user taking the test. Our approach was to take the symbols (avatars) from their objects in the classroom, and it seemed to be an appropriate one (see Figure 10). Still, you cannot be sure a child would not use (intentionally or by mistake) another child's identifier. Another solution we envision is to use algorithms for face recognition that will correctly establish the user taking the test.

Figure 10: Authentication window.

5 CONCLUSIONS AND FUTURE WORK

In this paper we have presented our experience in building and evaluating computer aided assessment applications for preschoolers. We have presented and analyzed the difficulties we have encountered during the design process. In the future, we will focus on the following aspects:

- creating a larger repository of questions;
- assessing the validity of the developed computer aided assessment tool;
- developing and integrating an automatic face recognition module to precisely associate test results to the child taking the test;
- improving the satisfaction evaluation by using an automatic tool that identifies emotions on children.

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