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The Design of Mobile Numerical Application Development Lifecyle for Children with Autism

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Abstract

Children with autism require special attention during the teaching and learning process. The use of information technology in special education can assist the teaching and learning process become more effective. Many applications were developed to enhance the social skills and communication skills of the children with autism as they are known with social and communication impairments. However, numerical skills are also important to prepare the children for lifelong learning. Yet, the children with autism are struggling with normal learning methods. For that reason, a mobile numerical application is proposed to assist the children with autism to acquire numerical skills. The development of the numerical application adapted ADDIE lifecycle which consists of five phases; analysis, design, development, implementation and evaluation. This paper objectively discusses a design phase for development lifecycle of mobile numerical application, developed for the children with moderate and mild autism who are learning basic numbers, basic shapes and size of objects. The design phase of the numerical application uses the deliverable from the analysis phase which had been completed previously. This paper discusses the learning theories, learners and usability which have been incorporated in designing the numerical application. Heuristic evaluation had been conducted with three evaluators to improve the user interface of the mobile numerical application. The results from the heuristics evaluation show all the evaluators agreed and strongly agreed with all heuristics. Constructive suggestions were also obtained from the evaluators. The development phase of the mobile numerical application would be carried out in future.

Keywords: Autism, mobile numerical application, ADDIE lifecycle, design phase, heuristic evaluation

1.0 INTRODUCTION

Autism is also known as Kanner's syndrome, discovered by Leo Kanner in 1942 [1]. The word autism is a compound of two Greek words, 'aut', which means 'self' and 'ism', which implies 'orientation or state' [2], and therefore reflected the condition of the children who keen to be alone. The number of children with autism increases and it is identified as the fastest growing neurobiological conditions in the world [3], thus the demand for specialized educational services has grown in relatively with the increment in numbers.

Autism is a lifelong disability that cause difficulties with social interaction, social communication and social imagination [4]. Autism is characterized by inability of children to develop relationship with people, a delay in speech recognition and non-communicative use of speech after it developed [5]. There are three well-known characteristics of children with autism, known as triad of impairments include communication, social interaction, and patterns or restricted of repetitive behaviors [6].

The well-known triad of impairments has inspired researchers to conduct studies related to the three impairments. Most studies that have been conducted to improve their social and communication skill, but lack of study on numerical skills have been conducted for the children with autism. Typically-developing children, generally acquire basic concepts of numbers through social interaction [7]. Since the children with autism are having difficulties in social communication, they might facing difficulties to acquire the basic concepts of numbers. The children with autism were believed to count up in different way and this may affect their level of self-determination [8]. Yet numerical skills are also important for their lifelong learning. As stated in a study [9], basic numeracy skills are required on daily basis in many settings in a children's life and the skills provide foundations for more advanced numeracy skills. It has been documented that counting skills are essential prerequisites that can lead to an independent adult way of life [10]. Hence, it is important to develop effective strategies for teaching them the basic numeracy skills.

There are several levels of autism as stated in a research [11], where the authors divided the level of autism based on IQ level into average, borderline, moderate, mild, severe and profound. The children with autism also have problems in their learning process, based on their severity. This study focusses on children with moderate and mild autism who are learning basic numbers, basic shapes and size of objects.

The cause of autism is still unclear and currently there are no cure [6]. However, the use of Information and Communication Technology (ICT) in teaching and learning can alleviate the autism symptom severity. ICT is a powerful tool in supporting education for children with disabilities [12], including children with autism. The successful use of ICT application enable classrooms to be more inclusive, physical environments be more accessible, teaching and learning content and techniques more in tune with the learners' needs [13]. Many applications were developed to enhance the social skills and the communication skills of the children with autism, such as iCAN [14], ECHOES [6], BIUTIS [15]. Counting Angry Bird is an iPad-based video modelling package developed to teach number one until seven to a five years old child with autism [9]. A counting skill application has been developed for children with autism to assist them to learn number one until seven [8]. Most applications are developed using visual approach and deployed in mobile devices which are used as medium of learning.

Objectively, this study is to discuss the design phase of a mobile numerical application development lifecycle. The mobile numerical application that will be developed, is to assist the children with autism in learning basic numbers one to ten, basic shapes (circle, triangle, rectangle and square), and size of objects (long/short, big/small, and many/few). Heuristic evaluation has been conducted to evaluate the user interface for the application. The heuristic evaluation involved mathematics teachers from special education schools.

Section 2 discusses briefly on each of the five phases of the mobile numerical application development lifecycle. Section 3 describes the design phase of the development lifecycle. Section 4 confers the results from the heuristics evaluation that have been conducted.

2.0 MOBILE NUMERICAL APPLICATION DEVELOPMENT LIFECYCLE

The mobile numerical application development lifecycle is adapted from ADDIE lifecycle. ADDIE is a product development concept, appropriate for developing educational and other learning resources [16]. There are five phases involved in the development of the mobile numerical application; analysis, design, development, implementation and evaluation; as illustrate in Figure 1. Each phase in the ADDIE lifecycle consists of input and the output or deliverable produced.

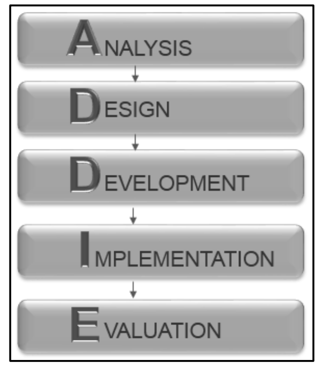

Figure 1 Phases adapted from ADDIE Lifecycle

Analysis phase is a very important step in the mobile numerical application development lifecycle. As illustrate in Figure 1, the analysis phase consists of various activities. The deliverable of this phase will be used in designing the numerical application. In the analysis phase, a series of user experience study have been conducted using available numerical application, named as MathDS [17] in National Autism Society of Malaysia (NASOM) in Bagan Ajam and NASOM in Ipoh. Interview sessions have been conducted with the teachers from NASOM and teachers from special education school. The purpose of the interview session is to understand the current teaching method. To ensure the content of the numerical application will suit the requirement of teaching and learning process, current teaching modules from the Ministry of Education also have been reviewed. On top of that, literature from other researchers have been studied in order to understand the characteristics of the children of autism, the learning theories that fit the children, multimedia techniques that suitable for the teaching and learning process for the children, numerical skills that are appropriate for the children and the methods of teaching that coincide the children learning. As a result, a conceptual model for the mobile numerical application has been developed, as presented otherwise. [18].

The design phase starts with the conceptual model that has been developed in the analysis phase. As shows in Figure 2, from the conceptual model, an instructional design model for the numerical application has been developed, together with the storyboards and the navigation flow. The purpose of instructional design model is to provide the structure of the mobile numerical application that will be developed. Storyboards are series of pictures for the purpose of pre-visualizing the flow of the application. Whilst the navigation flow is to provide the navigation throughout the application. These prototype designs will be used as guidelines in the development of the numerical application prototype.

Third phase is the development phase, as described in Figure 3. The prototype designs will be used as guidelines in the development stage. The development of the working prototype is an iterative process where the working prototype will be evaluated by the expert in the field, for example the teachers from the special education school and also teachers from NASOM. The working prototype will be revised and enhanced until the expert satisfies with the enhanced working prototype.

The fourth phase is the implementation stage, as demonstrates in Figure 4. Implementation strategies will be developed during this phase. Target users will be identified, tools for evaluation will be constructed and user's guideline will be developed throughout this phase. Target users need to be identified and guidance consents are required to conduct the testing. Tools for effectiveness evaluation and also user experience study will be designed in order to get accurate evaluation. User guideline is essential in order to ensure the teachers and the children's guidance able to use the prototype effectively.

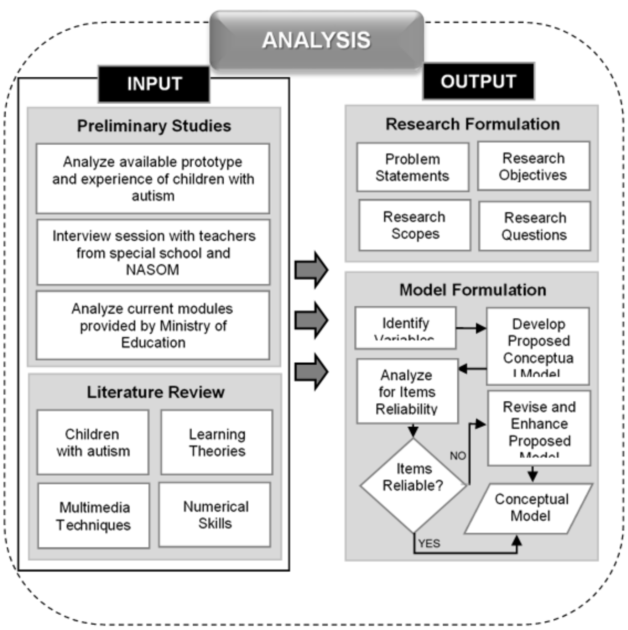

Figure 1 Analysis Phase

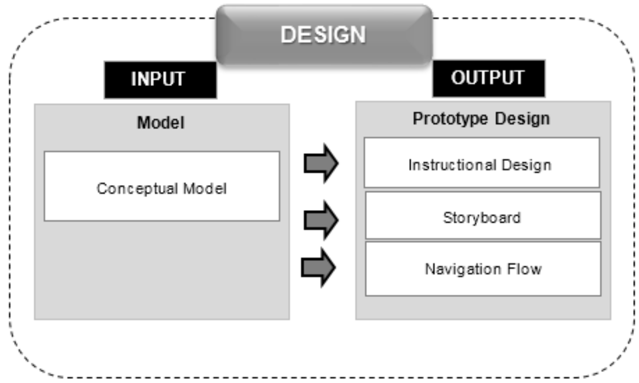

Figure 2 Design Phase

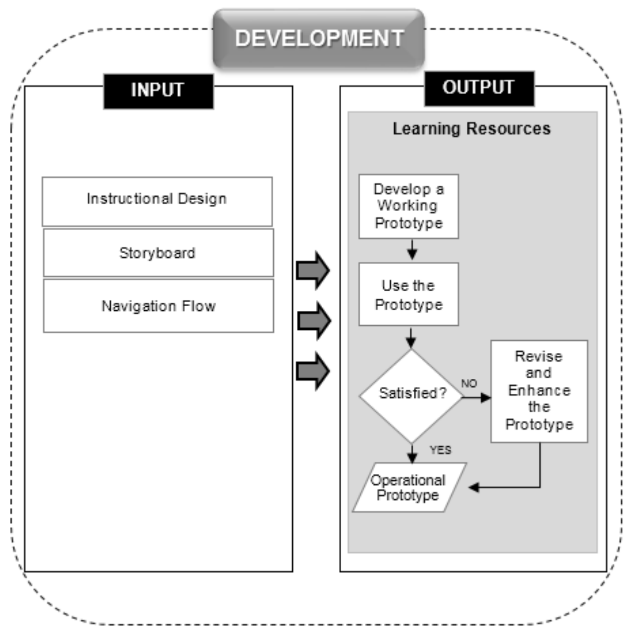

Figure 3 Development Phase

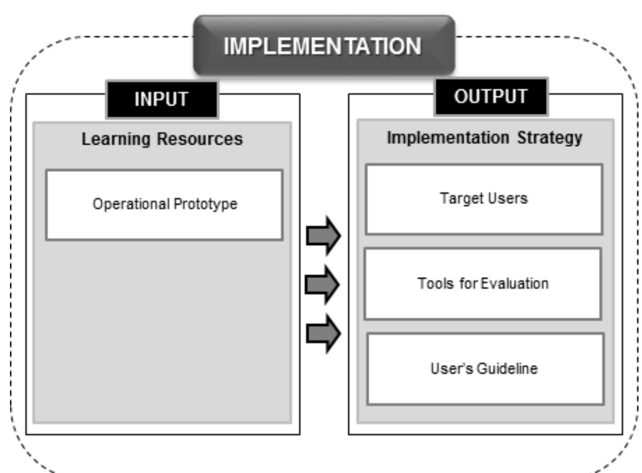

Figure 4 Implementation Phase

The final stage is the evaluation process. During this stage, the working prototype will be used in the evaluation process. A series of effectiveness evaluation and user experience study will be conducted at NASOM and also at special education schools. For the effectiveness evaluation, series of pre-tests and post-tests will be accomplished. Tools that have been developed during the implementation phase will be used to evaluate these the effectiveness evaluation and user experience study. The results will be analyzed using statistical analysis.

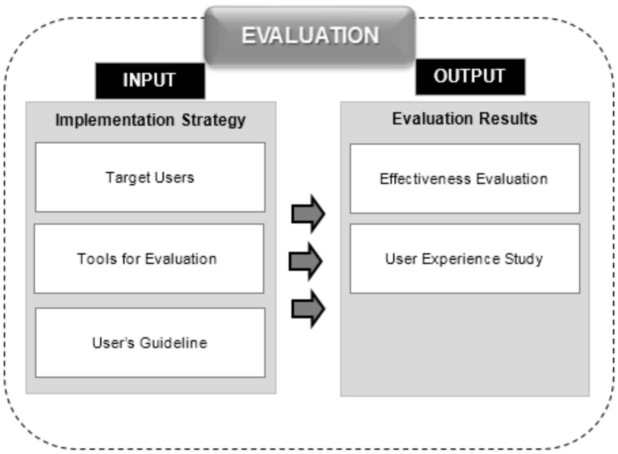

Figure 5 Evaluation Phase

3.0 THE DESIGN PHASE OF MOBILE NUMERICAL APPLICATION DEVELOPMENT LIFECYCLE

This section discusses primarily on the design phase of the mobile numerical application lifecycle. This section presents the study of design principles and requirements for the mobile numerical application.

Learning theories describe how learning essentially occurs [19], explicate on how the children accept, obtain, process and retain the information during the learning process. It is very expedient to employ suitable teaching theories to ensure the effective used of the application. There are several types of learning theories, however only two suitable learning theories to be incorporated in the development of the numerical application; cognitive, and behaviorism, as determined during the analysis phase earlier [18].

Cognitive learning theory cogitates that learning process involves active use of the children's long term memory to multimedia elements into logical construct [20]. Mayer's Cognitive Theory of Multimedia Learning allows the children to use both auditory or sound and visual or image channels in the learning process [21]. Thus, both sound and images will be incorporated in the numerical application to ensure effective learning process.

Figure 6 shows the example of using both sound and images. The children will be introduced to the basic numbers one to ten. The screen will display the number and the respective number is audible concurrently. The children can click on the replay button at the bottom right of the screen to repeat the learning session or they can proceed to the next number by clicking the next button at the bottom right of the screen. The repetition process will help the children to memorize the basic numbers learned.

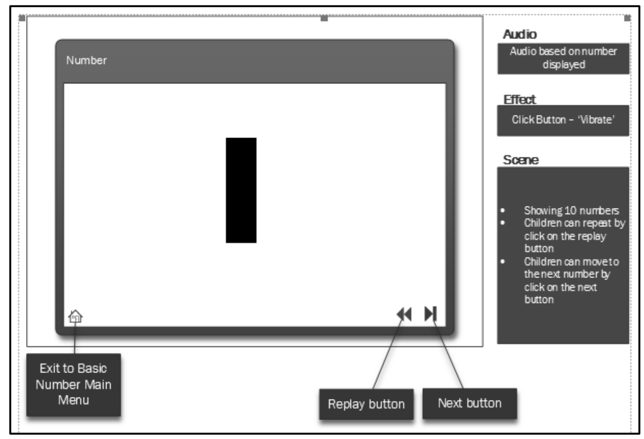

Figure 6 Example of number recognition

Behaviorism is a worldview that operates on a principle of stimulus-response and environment strengthened learning and behavior [22]. Behavioral theory is used to predict that children who are reinforced for correct responses will increase their motivation to perform well. The numerical application will include both positive and negative reinforcement to encourage the behavior of the children. For positive reinforcement, cheerful audio such as clapping hand together with attractive graphical image such as fireworks when the children have successfully completed each practice module to attract them to continue using the application. In contrast, for negative reinforcement, sad face with audio encouraging the children to keep on trying.

Learners and usability are two attributes that should be considered in developing the mobile-based learning application [23]. Learners, or for this study is the children with autism, is a very important attribute that need to be understood and analyzed. The children cognitive level and their familiarity with the mobile devices should be studied before developing the mobile application. Evaluating the children's attitude before developing the mobile application is substantial to ensure the ease whilst using the mobile application. Usability is a significant attribute to define the quality of user interface design and the user's experience during the interface interaction [24].

According to Nielson [25], consistency is one of the most important usability characteristics. Therefore, the user interfaces for the mobile numerical application are designed with this characteristic. For example, as shown in the storyboards in Figure 6.

Figure 7 and Figure 8, the exit button, is situated at the same location at all screens located at the bottom left of the each screen. As for the replay and next buttons, all are situated at the same location on the bottom right of the screen. Title of the screen for all interfaces are located at the top left of the screen. The consistency feature is very important for the children with autism to avoid confusion during the learning process which will lead to frustration on the children to continue using the application.

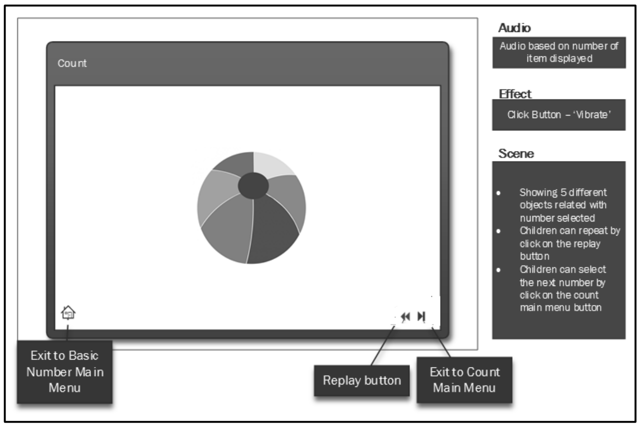

Figure 7 Example of counting skill

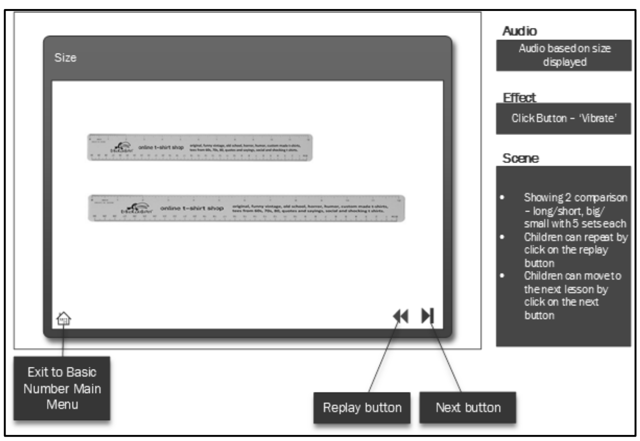

Figure 8 Example of size recognition skill

User-friendliness is another important attribute in designing the mobile application. For the mobile numerical application, the user interface will be designed with the user friendly attribute by using icons that have been widely used in other applications. The use of icons also intend to reduce textual instructions or information, and replace with graphical instructions or information. This is to motivate the children to continually participate in the learning process as mentioned in a study that children with autism may easily learn and remember information that is presented in visual (graphical) format [8]. Table 1 shows the example of icons used in the designing of the numerical application.

The content of the mobile numerical application must be designed based on the need of the children with autism. The contents are adapted from the modules given by Ministry of Education. The application consists of two main modules, pre number and basic number. Pre number module consists of basic shapes and also differentiating sizes between two objects. Basic number module consists of recognizing basic numbering from one to ten and counting the numbers. The numerical application will allow the children to select between two languages, English Language or Bahasa Malaysia Language. These two languages are the medium of instruction mainly used in schools in Malaysia. The content will be divided into two parts, learn and practice.

Table 1 Button/Icon used

Button/Icon	Instruction
	Exit to Main Menu
	Replay Button
	Next Button
	Exit Button

Figure 9Figure 9 shows the storyboard for selecting the modules from the numerical application.

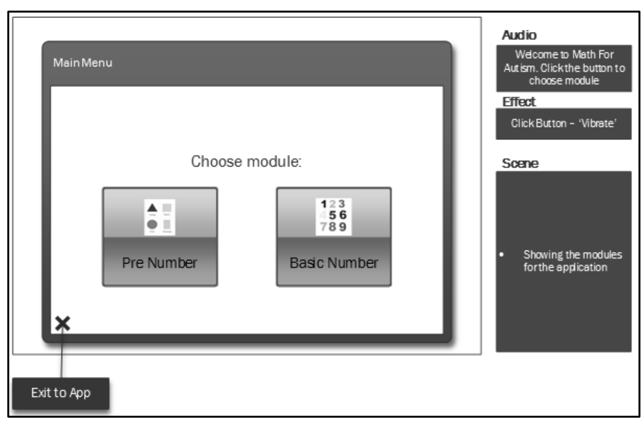

Figure 9 Modules in the Numerical Application

Even though there are many available applications on the market for children to acquire numerical skills, there are few new features introduced in the numerical mobile application. The mobile application is designed with repetitive criteria after taking into consideration of the children's learning difficulties.

Each learning activity in all modules will exploit five different objects. For example, in counting skill module, there will be five different objects used to convey each number (one to ten). This is to assist the children to understand better by providing more than one example. Most numerical application do not embedded the repetition criteria. The children with autism are easily distracted [26–28], hence plain background of the interface design is recommended to avoid distraction of children's attention. In contrast, display items should be bright and attractive.

3.0 RESULTS AND DISCUSSION

This section discusses the use of heuristics methods to evaluate the user interface design, educational design and the content of the numerical application.

Heuristic evaluation is an informal method of usability analysis where a number of evaluators are presented with an interface design and asked to comment on it [29]. For this study, the objective of the heuristic evaluation is to improve the user interface design of the mobile numerical application, evaluate the educational design and to confirm the content of the application matched with the needs of the children with autism.

A heuristic evaluation involves a small set of specialist evaluators who explore the interface of an application and associate usability problems they identify with a set of usability guidelines [30]. Nielsen recommended that the heuristics evaluation is done between three to five evaluators [31], independently of each other. In this study, the heuristics evaluation involved three evaluators, all are mathematics teachers from special education school. The evaluations were conducted independently of each other. The evaluation was conducted using a paper prototype.

The heuristic proposed by Nielsen, Quinn and Albion were adapted in this study, as shown in Table 2. Interface design heuristics identified by Nielsen [32] were adapted to evaluate the interface design of the numerical application interface. Educational design heuristics were adapted from Quinn [33] to evaluate the whether the numerical application are interesting and provide support during learning session. Content heuristic to evaluate the content included in the numerical application were adapted from Albion [34]. The heuristics were presented to the evaluators on a form using Likerts scales rated from 1 to 5 (1=strongly disagree, 4=disagree, 3=neutral, 4=agree, 5=strongly agree) and space for comments.

All evaluators rated agree and strongly agree for all heuristics. The evaluators also proposed few constructive suggestions for improvement in the comment's space provided. Evaluator 1 suggested the use of only animal picture in the learning materials, claimed that the children with autism are attracted to animal more than other objects. However, these suggestions are contradict with evaluator 2 who agreed with the use of varieties group of objects as shown in the paper prototype, since the children's interest are varies. Evaluator 2 and evaluator 3 suggested the module for numbers are changed to introduce number zero to nine. Currently the module introduces number one to ten. The reason given is due to the number of digit for number zero to nine, all are single digit numbers. Number ten is a two digit number and the focus is different. Currently the teaching process is done using traditional method, without any intervention of information technology.

Table 2 Heuristics Evaluation

Interface Design Heuristics	
Consistency and standards	The interface layouts, and button/icons used are consistent
Visibility of system status	The application provide timely feedback
User control and freedom	Users will be able to exit from modules or from application during lessons
Use aesthetic and minimalist design	The application provides attractive overall design and only display relevant information
Educational Design Heuristics	
Context meaningful to domain and learner	The learning activities in the application are interesting and able to engage learner
Activities scaffold	The application provides support for learner's activities
Content Heuristics	
Establishment of context	The graphics/images used create a sense of immersion
Relevance of reference materials	The learning materials are relevant and at a level appropriate to the learners
Materials are engaging	The presentation style and content of the application encourages the learner to continue use the application
Presentation of resources	The application presents useful resources for the learning activities
Overall effectiveness of materials	The application are likely to be effective in learning activities

4.0 CONCLUSION

The beginning of the paper discussed on the development lifecycle that is adapted from ADDIE lifecycle. The mobile numerical application development consists of five phases; analysis, design, development, implementation and evaluation. This paper focused on the design phase of the mobile numerical application development lifecycle. The design of the user interfaces is a vital phase since the children will be able to have better understanding on the learning materials by implementing suitable user interface. Heuristics evaluation had been conducted using paper prototype to evaluate the user interfaces, educational design and the content of the numerical application. There were three evaluators involved, and all are mathematics teacher from special education school. The results showed the evaluators agree and strongly agree for all heuristics. Few constructive suggestions were also obtained from the evaluators.

As conclusion, the user interfaces, educational design and the content of the designed mobile numerical application were agreed as suitable for numerical learning of the children with autism. Still, the design of the user interface and the content needed to be revised based on the constructive suggestions provided. Next phase will be the development of the mobile numerical application.

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