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Heuristic Evaluation on Augmented Reality Basic Reading Courseware (AR BACA-MV-SindD) for Down Syndrome Learner

Roslinda Ramli
Fakulti Sains dan Teknologi Maklumat
Kolej Universiti Islam Antarabangsa Selangor
Persiaran1, Bandar Seri Putra, 43000 Kajang, Selangor Malaysia
roslinda@kuis.edu.my

Halimah Badioze Zaman
Fakulti Teknologi dan Sains Maklumat
Universiti Kebangsaan Malaysia
hbz@ftsm.ukm.my

Abstract

The development of Augmented Reality (AR) courseware for down syndrome learner should not only take advantage of the technological advances, but also pay close attention to the usability of the product that meet the target user's requirement. In this paper, *we describe the heuristic evaluation of AR BACA-MV-SindD; a courseware for down syndrome learner in learning basic reading by using Augmented Reality technology. This study employs heuristic evaluation (HE), which is one of the inspection methods. Heuristic evaluation was chosen because it does not involve the end user. Previous studies have shown that more problems can be identified using this kind of evaluation. Several experts from different fields were involved in this evaluation. Based on the evaluation made, several disadvantages of AR BACA-MV-SindD have been identified. In addition, experts have provided some feedbacks to further improve the courseware.* This paper includes a report of a heuristic evaluation which used a five point Likert scale. A questionnaire for this heuristic evaluation consists of three constructs: interface, education and augmented reality technology. As conclusion, the heuristic evaluation can be an effective and efficient way to identify usability problems in the early stage of software development. Thus, usability should be given high priority in the development of AR courseware especially for special needs students like down syndrome learner.

Introduction

Reading is one of the most important subjects in schools, due to the fact that all subjects utilize reading one way or another. Reading is also considered "the heart of education" as knowledge of almost every subject is gained from reading [1]. According to Down Syndrome Foundation President, Prof Madya Dr. Zainiyah in [2], it is found that a few Down Syndrome students can learn to read like normal students. Computer-based technology can positively impact the students with learning disabilities, both in primary and secondary schools [3],[4]. Multimedia software combining audio, graphics, animation, texts and video will help improve motivation and strengthen learning [5]. A number of independent researches also discovered positive shift in behaviors of students with learning disabilities, when technology is made part of the learning process [6],[7]. With the recent new technology that is the Augmented Reality (AR) has been used in education and had demonstrated high

potential to enhance students' learning experience [8]. AR adapts visual learners like Down Syndrome students to easily understand a concept or solve a problem with AR because of its capacity for charts, graphs, models and moving objects in a form of 2D and 3D. 3D models or pop-up images for example allow a student to view an object from different angles. AR Flashcards and AR Magic Book combine augmented reality with flashcards and book to help visual learners really grasp what each card or book represent. AR is a promising technology which allows seamless user interaction between the real and virtual objects. The development of Augmented Reality (AR) courseware for Down Syndrome learner should not only take advantage of the technological advances, but also pay close attention to the usability of the product that meet the target user's requirement. Nevertheless, to ensure the usable and effectiveness of any courseware that is developed, an objective usability assessment must be conducted.

Heuristic evaluation is also called as expert evaluation which is among the easiest methods to learn, and results in problem reports that appear to be better predictors of end-user problems [15] as well as to shape the design of formative evaluations [21]. Nielson in Hix [22], stated that this method is used by the usability experts to identify critical usability problems in the early development cycle, so that design issues can be addressed as part of the iterative design process. Usually 3-5 expert evaluators are necessary to inspect the interface [17]. In this study, the experts in interface design and experts in learning contents are used to evaluate the courseware at the last phase of usability evaluation. Even though this usability inspection method is often used in the final phase of the software development life cycle (SDLC)[19], it is the need to do a software evaluation in an earlier stage, because the design can be improved [20]. The mistakes which have been found at the end or after the software development has been submitted to the users would be costly to correct [19], [21]-[23]. Therefore, to avoid these problems, involvement of users in early development is required [21], [24].

Developing AR technology using the concept of three-dimensional (3D) is different from the traditional evaluation interface [36], [37]. The difference between 3D interface and traditional interface are in terms of physical environment aspects and a sense of presence in that environment. As a visual learner, the interface for Down Syndrome learner should be designed that suit their usage. Therefore, in this study HE was used to evaluate the interface, pedagogy and AR environments.

The objectives of this study are to:

(i) identify the design problem in developing courseware AR BACA-MV-SindD.
(ii) identify the problems in The Heuristic Evaluation Questionnaire for Courseware AR BACA-MV-SindD (HEQ-AR BACA-MV-SidnD) for further improvement.

Review of relevant literature

Augmented Reality

The first AR interface was developed by Sutherland in the 1960s (Sutherland, 1965). However, it was not until the early 1990s that the term "augmented reality" was coined by Caudell and Mizell (1992). Caudell and Mizell were researchers at Boeing Corporation, who dedicated their time towards developing experimental AR systems to train workers installing wiring harnesses in planes. Later, Milgram and Kishino (1994) described a reality-virtuality continuum that spans from the real environment to a pure virtual environment as shown in Figure 1. AR lies near the real world end of the line, with the predominate perception being the real world augmented by computer generated data. *Augmented virtuality* (AV) is a term created by Milgram (Milgram & Kishino, 1994) to identify systems which are mostly synthetic, with some real world imagery added, such as texture mapping video onto virtual objects. MR consists of AR and AV. However, the definition by Azuma (1997) is widely accepted as a "benchmark" to describe AR and MR. Azuma described the three characteristics of an AR environment: it combines real and virtual objects, is interactive in real-time, and is registered in three dimensions. This definition of an AR system is extended by the definition of an

MR system as an interactive system that combines digital and physical entities. Kondo (2006) assumed that MR is similar to virtual reality technology that combines interactive three-dimensional computer graphics with the real world. Figure 2 shows an example of AR scene in which a user is holding a cap. The user can view a 3D virtual cap and hear the word of cap by the system.

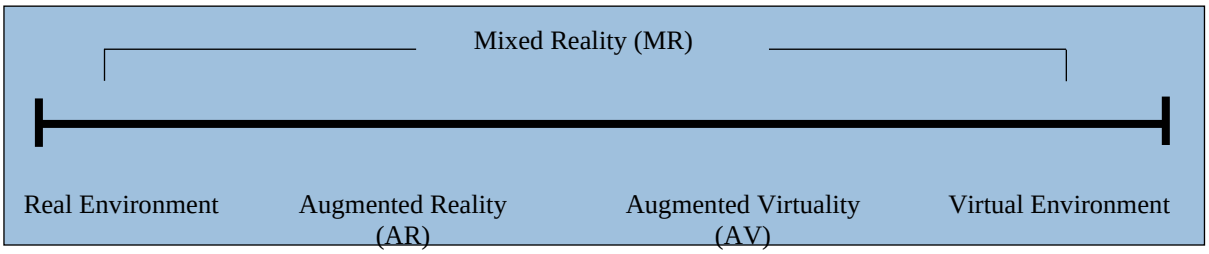

Figure 1: Milgram reality-virtuality continuum

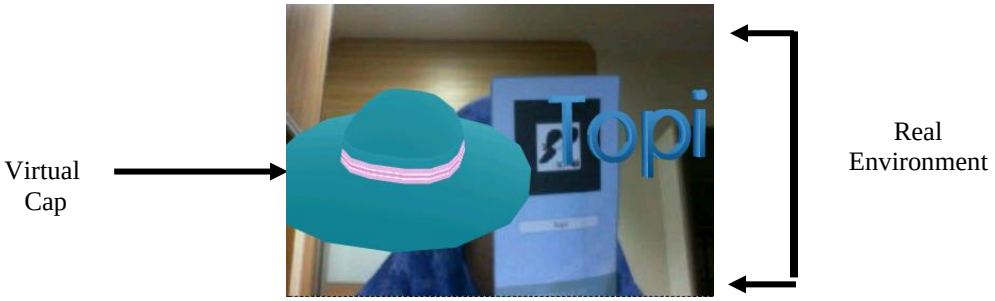

Figure 2: Augmented reality scene

Heuristic evaluation

Heuristic evaluation (HE) is also known as discount usability engineering and it is one of usability inspection classes [12], [13]. This method uses a small number of experts to evaluate the interface and document software errors based on the usability design principles [14]-[17]. Each of the experts assesses the software interface separately. When the evaluation was done, all results of the usability interface will be collected and reported. In addition, heuristic assessment can improve the validity of the construction during the software development [18].

Research Methodology

The research methodology adopted in this study was the usability engineering methodology. The type of usability engineering was HE which was a type of inspection classes methodology [13]. In this study, the researcher tried to identify problems in interface that had been developed for improving the design of courseware and improving the HE questionnaire. This process was to provide information in second iteration. Therefore, the experts were employed to discover the usability problems on interaction of the AR BACA-MV-SindD courseware and HE questionnaire.

Respondents

This study was conducted with 5 evaluators, who evaluated the courseware. All evaluators had the experience of more than fifteen years in their respective areas. Their expertise was chosen according to their experience in their field. The list of evaluators and their expertise can be seen in Table I. Four of the evaluators were female (80%) and one was male (20%). The evaluators had to filled up the

questionnaire during evaluating the courseware individually. They had also been asked to provide feedback on the courseware. Most of them have had more than fifteen years of experience in education courseware inMalaysia.

Table 1: The Specialization and Department of Experts

Evaluator	Specialization	Department/University
A	Human Computer Interaction	Universiti Teknologi MARA (UiTM)
B	Gamification, Augmented Reality, Flipped Learning, MOOC, Multimedia for Disabilities	Universiti Teknologi MARA (UiTM)
C	Augmented Reality, Reading Disabilities, Educational Technology	Universiti Teknologi Malaysia (UTM), Kuala Lumpur
D	Problem Based Learning, Instructional Design, ICT, Interactive Multimedia and Video Tutorial in Teaching and Learning	Universiti Perguruan Sultan Idris (UPSI), Perak
E	Multimedia in Education, Computer in Education.	Universiti Kebangsaan Malaysia (UKM), Selangor

Research Instruments

Three instruments and a courseware called AR BACA-MV-SindD were used in this study. The instruments were two forms and one questionnaire. The two forms were: (i) Courseware Problem Report Form (CPRF) and the (ii) Suggestion for Improving the Questionnaire Form (SIQF). The questionnaire was The Heuristic Evaluation Questionnaire for Courseware AR BACA-MV-SindD (HEQ AR BACA-MV-SindD). The questionnaire consisted of three constructs: interface, education and AR environment. Items in each construct were measured in five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).To identify the problem of the courseware, the CPRF was used. The CPRF was adapted from [18], [39]. In this study, web based environment was used in developing the courseware. The hardware required a notebook, web cam and AR markers. The related software in developing the AR BACA-MV-SindD courseware was:

- Autodesk 3D Studio Max 2009 for 3D modeling.
- Papervision 3D (library) was used to bring 3D object into Flash.
- Adobe Photoshop for marker object.
- Build AR for generate marker.
- Adobe Premier/Adobe After Effects for video editing.
- Soundbooth for sound editing.
- Adobe Flash; was used for AR coding (ActionScript 3).
- FLAR Toolkit (Flash Augmented Reality Toolkit); was used as the engine.
- Dreamweaver was used to build HTML scripting.
- EasyPHP 5.3.6.0; was used for side server scripting.

In the developing the courseware, the content was taken from the Malay Language Curriculum Special Education Disabilities [JPK 2003]. In Fig. 3 and Fig. 4 below are interface examples of the

AR BACA-MV-SindD courseware. Fig. 5 illustrates an example of AR environment in the courseware.

Figure 3: Main Menu of AR BACA-MV-SindD

Figure 4: Learning Module of AR BACA-MV-SindD

Figure 5: Examples of AR Environment in Courseware

Research procedures

HE was used to evaluate the courseware involved in this study. The evaluation process was taken place in the evaluators' environment. Each expert spent one to two hours examining product at least twice. The steps involved in the process were:

(i) Identifying the number of expertise.
(ii) Identifying the suitable evaluators.
(iii) Arranging for an appointment with the evaluators (place and time).
(iv) Filling up the profile by evaluators in the HEQ AR BACA-MV-SindD questionnaire (part 1).
(v) Gathering of the whole interactive interface manipulation and idea on the interface of the courseware by evaluators
(discussing with researcher and researcher fill up the courseware problem report form-CPRF).
(vi) Filling in the questionnaire by experts in the HEQ AR BACA-MV-SindD questionnaire (part 2 and 3).
(vii) Making suggestion in improving the questionnaire by evaluators (SIQF).

The process of evaluating the courseware by the experts is illustrated in Fig. 6.

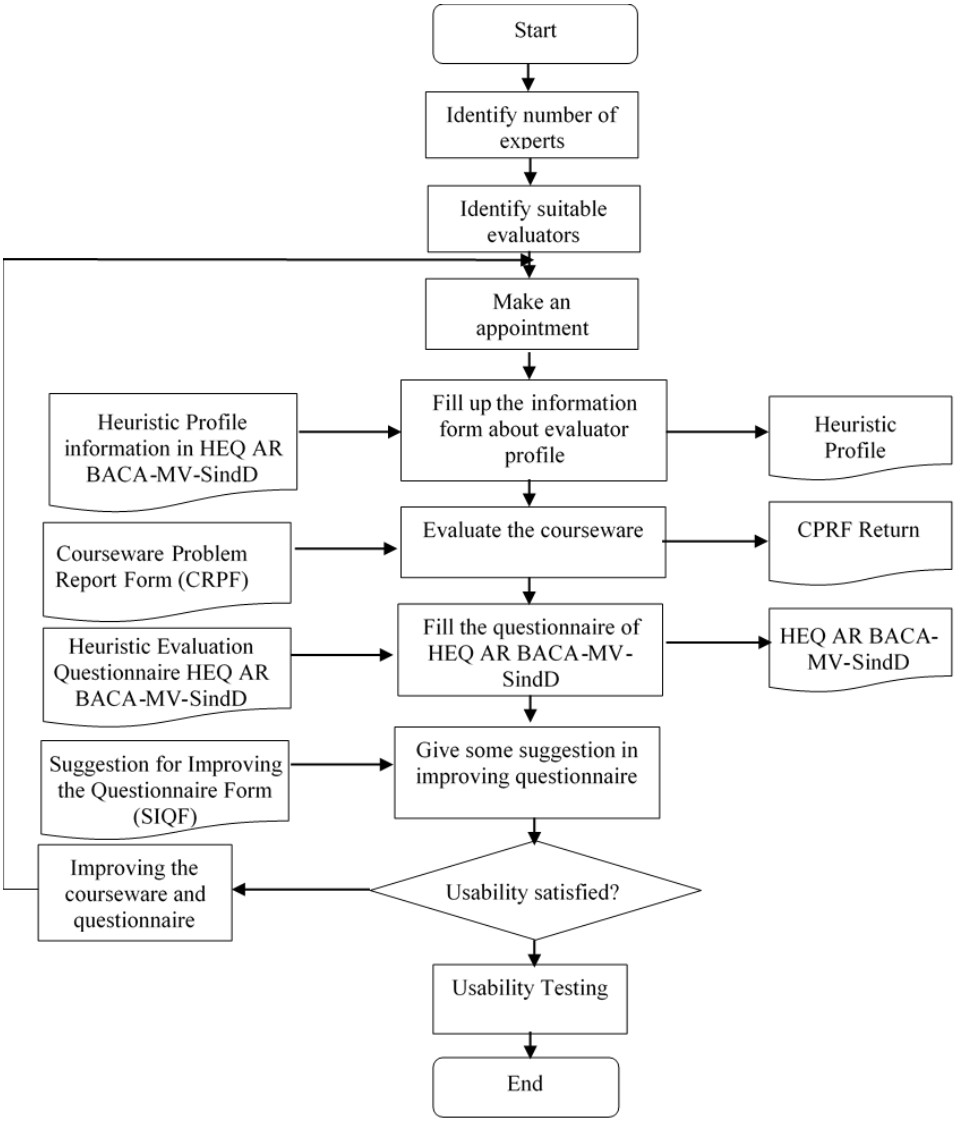

Figure 6: The process of heuristic evaluation of AR BACA-MV-SindD courseware

Findings

The findings of evaluation of AR BACA-MV-SindD courseware from the Courseware Problem Report Form (CPRF) are depicted in Table II. Finding from the Heuristic Evaluation Questionnaire (AR BACA-MV-SindD) was divided into three constructs which were; (i) interface design in Table III, (ii) educational design in Table IV (iii) Augmented Reality interactive design in Table V.

Table 2: Experts' Opinions For Usability

Parts	Suggestions
Interface Design	Increase time for reading text Include more exit button
Educational Design	Use suitable text and sentence for down syndrome. Text with more than 5 is not suitable for down syndrome. The reward given is not suitable
AR Environment	Increase time such as 5 seconds to view 3D virtual object

Construct reliability

Content validity were used to determine the reliability of the 29 items, three constructs questionnaire which involved expert evaluation (heuristic evaluation). In order to test the validity of the questionnaire instrument, the aspect of perfection of instrument content was conducted by five (5) expert panels in the relevant field. Some edits are based on comments and feedback from expert panels which they filled in the feedback form. Heuristic testing instrument for AR BACA-MV-SindD AR is called SSPH-AR BACA-MV-SindD.

Interface

Table 3 shows the result of experts' opinion for interface design. 27 out of 29 statements in interface attributes were rated at the highest level either score 4 (agree) or score 5 (strongly agree). Except one statement by the expert rated on the score 3 (moderate) that is the reward is attractive and suitable to the target user. This shows that almost all the interfaces design are suitable for down syndrome students. However, 20% of the respondents were disagree that the text of the sentence is suitable with the target user. The remaining 60% of the respondents were not sure. Observation shows that down syndrome students were difficult to follow a long sentence reading, especially sentences that are more than four words. Expert teachers' assessment also shows the same. Thus, the modification is made to the text of the sentence in the story so as not to exceed four (4) words to meet the needs of DS students. Meanwhile, the others attribute of AR BACA-MV-SindD education application prototype interface was maintained.

Table 3: Experts' Opinions For Interface Design
(1 = Strongly disagree to 5 = Strongly agree. N = 5)

No	Statement	Strongly disagree	Dis agree	Not sure	Agree	Strongly agree	Mean
1	Screen design is user friendly	0.0%	0.0%	0.0%	20.0 %	80.0%	4.80
2	Screen size is suitable for users	0.0%	0.0%	0.0%	40.0 %	60.0%	4.60
3	Icon size is suitable for users	0.0%	0.0%	0.0%		100%	5.00
4	The menu option has a meaning that is readily understood	0.0%	0.0%	0.0%	40.0 %	60.0%	4.60
5	Icon design reduces student memory burden	0.0%	0.0%	0.0%	20%	80%	4.80
6	The letters are used clearly	0.0%	0.0%	0.0%	20%	80%	4.80
7	The font type used is appropriate for the user	0.0%	0.0%	0.0%		100%	5.00
8	The font size used is appropriate for the user	0.0%	0.0%	0.0%	0.0%	100%	5.00
9	The word is easy to read	0.0%	0.0%	0.0%	0.0%	100%	5.00
10	The sentence used is clear	0.0%	0.0%	0.0%	0.0%	100%	5.00
11	The pictures used are interesting	0.0%	0.0%	0.0%	0.0%	100%	5.00
12	The pictures used are related to the word	0.0%	0.0%	0.0%	0.0%	100%	5.00
13	The pictures used are related to the sentence	0.0%	0.0%	0.0%	0.0%	100%	5.00
14	The narration of delivering software content is clear	0.0%	0.0%	0.0%	0.0%	100%	5.00
15	There is sound suitability with pictures and animations	0.0%	0.0%	0.0%	0.0%	100%	5.00
16	Intonation sounds is suitable with sentences	0.0%	0.0%	0.0%	20%	80%	4.80
17	Intonation of the sound of the story presentation is interesting	0.0%	0.0%	0.0%	0.0%	100%	5.00
18	The sound effects used in the software are appropriate	0.0%	0.0%	0.0%	0.0%	100%	5.00
19	Users like the animation in the application	0.0%	0.0%	0.0%	0.0%	100%	5.00
20	The animation is functioned.	0.0%	0.0%	0.0%	0.0%	100%	5.00
21	Animation is suitable with audio/voice	0.0%	0.0%	0.0%	0.0%	100%	5.00
22	The buttons for exploring is easy to use	0.0%	0.0%	0.0%	0.0%	100%	5.00
23	Easy to enter and exit from any activities	0.0%	0.0%	0.0%	0.0%	100%	5.00
24	Easy to exit	0.0%	0.0%	0.0%	0.0%	100%	5.00
25	The interactivity is consistent	0.0%	0.0%	0.0%	0.0%	100%	5.00
26	The facility to repeat words/sentence/activities is easy.	0.0%	0.0%	0.0%	0.0%	100%	5.00
27	The text is suitable with target user	0.0%	0.0%	0.0%	0.0%	0%	3.00
28	The reward is attractive and suitable with user	0.0%	0.0%	40%	60%	0%	3.60
29	Like and comfortable over the prototype	0.0%	0.0%	0.0%	0.0%	100%	5.00

Education

Table 4 shows the results of experts' opinions for educational design. All participants, expressed their aggrement that the composition of content is clear. All participants except one, either strongly agreed or agreed that the content delivered is easy to understand. Even though 80% of the respondents were either strongly agreed or agreed that the learning support through interaction with student activities, the remaining 20% of the respondents were not sure. However, all participants either agreed or strongly agreed that learning using AR techniques was an enjoyable experience. For the statement of "Suitability of content with meaningful context", all of the respondents expressed their agreement.

Table 4: Experts' Opinions For Educational Design
(1 = Strongly disagree to 5 = Strongly agree. N = 5)

No	Statement	Strongly disagree	Dis agree	Not sure	Agree	Strongly agree	Mean
1	The composition of content is clear	0%	0%	0%	80%	20%	4.20
2	The way the content is delivered is easy to understand	0%	0%	20%	60%	20%	4.00
3	Suitability of content with meaningful context	0%	0%	0%	40%	60%	4.60
4	Learning support through interaction with student activities	0%	0%	20%	60%	20%	4.00
5	Students enjoy learning using AR techniques	0%	0%	0%	80%	20%	4.20

Augmented Reality

Table 5 shows findings for the experts' views on Augmented Reality Interactive Design of AR BACA-MV-SindD. All respondents either agreed or strongly agreed that AR BACA-MV-SindD was easy to use. Almost all respondents except for one, either agreed or strongly agreed that using AR technology could motivate students. The majority (80%) agreed that they could easily handle markers on AR environment. However, for the statement "the appropriate time taken for the response system on markers" the majority (80%) respondents expressed their agreement, the remaining 20% of the respondents were not sure. All participants agreed that marker displays 3D objects visual clearly and realistic. The majority of the participants expressed a strong aggreement that can easily handle the web camera. All respondents reacted positively that markers help recognize the visual of real objects in students daily life and also agreed that markers allow students to manipulate 3D objects using fine and gross motor movements on hand.

Table 5: Experts' Opinions For Augmented Reality Interactive Design
(1 = Strongly disagree to 5 = Strongly agree. N = 5)

No	Statement	Strongly disagree	Dis agree	Not sure	Agree	Strongly agree	Mean
1	The Application of AR BACA-MV- SindD is easy to use	0%	0%	0%	80%	20%	4.20
2	The use of AR technology can motivate students.	0%	0%	20%	60%	20%	4.00
3	The time taken is suitable for the system to response to marker.	0%	20%	0%	80%	0%	3.60
4	Easy to handle the marker in AR environment.	0%	0%	20%	60%	20%	4.00
5	The marker displays the visual of 3D virtual object with clear and realistic.	0%	0%	0%	80%	20%	4.20
6	Can control the camera easily.	0%	0%	0%	100%	0%	4.00
7	The marker can help in recognizing the visual of real object in students daily life.	0%	0%	0%	100%	0%	4.00
8	The marker enable the students to manipulate 3D object using the movement of psychomotor on hand	0%	0%	0%	60%	40%	4.40

Discussion and Conclusions

The main purpose of this study was to identify the design problems in developing courseware of AR BACA-MV_SindD and to identify the problems in the heuristic evaluation questionnaire for courseware AR BACA-MV-SindD (HEQ-AR BACA-MV-SidnD) for further improvement. The AR BACA-MV SindD was developed using AR technology to provide DS children to engage in reading process and especially in learning sight words. Purposive sampling was adopted in this study, involving 15 down syndrome children as participants with mild down syndrome symptom. A majority of the DS children are able to do the process of touching, dragging and dropping in their daily activities and are able to play simple computer games as tetris, PacMan and Mario. The participants were considered as innovative because they are willing to try new technology such as AR. Since Down Syndrome children are special needs children, this research found IT experts to determine the design problems of AR BACA-MV SindD courseware. In order to determine the design problems in developing courseware of AR BACA-MV SindD, the study used five experts from different IT related background.

For the second objective, which is to identify the problems in the heuristic evaluation questionnaire for courseware AR BACA-MV-SindD (HEQ-AR BACA-MV-SindD), content validity was used to determine the reliability of the 29 items and three constructs questionnaire which are interface, augmented reality and education.

The results for interface design show that almost all the interfaces design are suitable for DS students. There was 27 out of 29 statements in interface attributes were rated at the highest level either score agree or strongly agree of the AR BACA-MV-SindD courseware. This indicated that the experts found the courseware is suitable for DS students. The experts perceived that the suitable interface can contribute to the advancement of the DS children academic performance. This result was similar to the findings reported in previous research by Davis (1989) and Venkatesh et al. (2003). However,

experts found that reward is not attractive and suitable to the target user; and sentences that are more than four words were difficult to the DS children. This meant that the AR BACA-MV-SindD courseware should improve on rewarding interface and use not more than four words in order to increase the DS children enjoyment and self-confidence during the interaction session.

Education domain focus on educational design. All experts were agreed that the composition of content is clear and easy to understand, the Suitability of content with meaningful context and DS children enjoy learning using AR technology.

For AR technology domain, respondents (experts) ware either agreed or strongly agreed that AR BACA-MV-SindD was easy to use. All participants agreed that marker displays 3D objects visual clearly and realistic. All respondents reacted positively that markers help recognize the visual of real objects in DS children daily life and also agreed that markers allow DS children to manipulate 3D objects using fine and gross motor movements on hand. AR is the most important construct affecting DS children' intention to use the AR BACA-MV-SindD courseware in the future. In order to ensure that AR courseware are widely accepted, it is important for AR courseware developers to work closely with subject matter experts such as DS teachers in order to produce a courseware that is useful for this special needs children. AR technology can give more engagement to the special needs children with real life experiences and environment. This makes special needs children more enjoyable in the edutainment world.

There are three limitations of this study. Firstly, this research was conducted using only 15 DS children as participants for usability study. Secondly, only five national experts for heuristics evaluation, which is not involved the international experts. Future research could replicate the study with more participants with other special needs children such as dyslexic and autism with greater representativeness in terms of location, gender and ethnicity. Thirdly, the results involved only descriptive statistics. More analysis such as simple correlation, simple linear regression analyses, advanced regression analyses could be implemented to better assess the nature of the relationships between the augmented reality, interface and education.

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