Measuring Satisfaction on Augmented Reality Courseware for Hearing-Impaired Students: Adjustment Formula form SUS

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Abstract: Satisfaction is an important usability attribute in developing a courseware which involves end users. Measuring satisfaction among hearing-impaired students is different than measuring it among common students because they learn using sign language and have different learning styles. An educational courseware for hearing-impaired students is employed to measure this. The courseware uses the Augmented Reality technology and it is called PekAR-Mikroorganisma. Hence, this article focuses on the methodology of measuring and the attributes that contribute to users' satisfaction. An adaptation of the System Usability Scale was used to identify the satisfaction value. Fifteen hearing-impaired students were employed as a case study. Findings show that the satisfaction level in using PekAR Mikroorganisma is high. It is hoped PekAR-Mikroorganisma can help the hearing-impaired to understand lessons better through the enhancement of their comprehension on abstract concepts.

Keywords: Augmented Reality, Hearing-Impaired, Usability Testing, Visual Informatics

1. Introduction

Augmented Reality (AR) is a low-cost technology that has 3D computer graphics and one special feature known as markers. It allows users to view and manipulate the virtual 3D object in a real-world environment (Azuma, 1997; Milgram et al., 1995; Rosenblum, 2000). In recent years, there have been many developments concerning AR. AR has extremely wide applications across a whole range of disciplines (Yu et al. 2009; Mekni & Lemieu, 2014). Even though AR could be applied to various domains of applications, the technology is projected to have a more significant role in teaching and learning such as visualizing the abstract concepts in Science education (Nischelwitzer et al., 2007; Medina et al., 2007; Liu et al., 2007; Saidin et al., 2015). Besides, several researchers have done works related to augmented reality among the hearing-impaired (Nishioka, 2002; Parton et al., 2005). In addition, previous researches that were conducted in hearing-impaired schools showed that hearing-impaired students had problems in learning and understanding the abstract concepts in science education (Cawthon, 2010; Quinsland & Van Ginkel, 1990; Zainuddin et al., 2009). Moreover, the learning style of hearing-impaired students is different than common students' (Ibrahim et al., 2016; Marschark et al., 2017). Previous researchers have suggested that educators should be concerned with abstract thinking among hearing-impaired children in their study (Silver, 1977; Passig & Eden, 2000).

Heuristic evaluation and usability testing methods are often used in the final phase of the Software Development Life Cycle (SDLC) (Folmer et al., 2003; Holzinger, 2005). Usability testing is different from heuristic evaluation. Usability testing is more formal than formative assessment and it is often referred to as summative testing (Kirakowski, 2005; Ratwani et al., 2017). However, if the software evaluation is done in the earlier stage, the design can be improved (Nielsen, 2000). If errors are found at the end or after the software development has been completed, rectifying the error would then be costly (Folmer et al., 2003; Holzinger, 2005; Gabbard et al., 2002; Sommerville, 2007). Therefore, the involvement of users in the early phase of software development is required to avoid major usability issues (Gabbard et al., 2002; Dünser et al., 2007; Nguyen, L. 2021).

Usability testing among end users is the main criteria in evaluating software interface developed (Abran et al., 2003; Folmer et al., 2003; Plaza et al., 2006; Winter et al., 2007). Testing is intended to assess the operational readiness of the target users to use the software. In this phase, the question that often arises when performing usability testing is whether the developed software is capable of achieving the desired goal (Nielsen, 1993). Therefore, usability testing or usability tasks should provide satisfaction to the users and meet the needs of the target groups.

Usability testing has several advantages and disadvantages. Among the advantages are (a) the involvement of users which allows the designer to identify the problems faced by real users to evaluate the software primarily involving interface (Holzinger, 2005; Nielsen & Landauer, 1993), (b) help users to be more focused and concentrate better in order to identify problems and avoid confusion or misconception of the software (Holzinger, 2005); and (c) assist in improving communication between users and designers (Dhillon, 2004). However, usability testing has also its disadvantages. Among the most frequently mentioned weaknesses are: (a) it is costly and time-consuming (Holzinger, 2005); (b) needs a larger sample size (Faulkner, 2003; Turner et al., 2006); (c) needs to measure the performance of users due to different learning styles (Holzinger, 2005); (d) the process needs to be repeated to produce a better design (Lewis, 2006; Hwang & Salvendy, 2010); and (e) needs full concentration among users (Holzinger, 2005).

The methodology of usability can be divided into several types (Ivory & Hearst 2001). There are five types of methodology namely testing, inspection, inquiry, analytical modelling and simulation. Formative and summative assessments are more suitable for testing, inspection, and inquiry. Meanwhile, analytical modelling and simulation are more suitable for use in engineering approaches such as analyzing the performance of a computer system. There are several types of question-asking protocol in using this methodology. For instance, the tester will be assisted by a tutor, who will help on a one-to-one basis between the tutor and users via questions asked related to the usability testing (Mahrin et al., 2009). Thus, this kind of methodology is suitable to be applied or when the analytical modelling and simulation are difficult to implement or even inappropriate (Kato, 1986).

Therefore, the purpose of this article is to identify the satisfaction level among 15 hearing-impaired students in using the PekAR-Mikroorganisma courseware. This is done by employing the adapted System Usability Scale (SUS) (Lewis & Sauro, 2017).

2. Methods

In this study, there are five attributes used in evaluating the courseware by the end-users. The attributes are learnability, efficiency of use, usability error, effectiveness and satisfaction. This article however, focuses only on the satisfaction attribute. The qualitative research method adopted was the usability engineering methodology. The type of usability engineering was question-asking protocol, which is a type of testing class methodology (Ivory & Hearst, 2001). The researcher would like to identify the hearing-impaired students' satisfaction level using the PekAR-Mikroorganisma courseware. The pilot study was conducted previously among three hearing-impaired students. Based on the pilot study, the instrument used was modified according to these students' responses. Before the pilot study was conducted, the heuristic evaluation (HE) was carried out among experts in two iterations (Zainuddin et al., 2011). The courseware and instruments were modified according to the experts' suggestions and from the interaction with the hearing-impaired students during the pilot study.

Therefore, in determining the satisfaction level, the researchers employ the SUS after the selected students used the courseware.

2.1 Participants

The participants were 15 hearing-impaired students (5 male and 10 female) from two special education schools for the hearing-impaired in Kuala Lumpur. Due to the nature of hearing-impaired students who are a protected group, limited numbers of participants were allowed to take part in this study. Among them were between 12 and 13 years old who were considered as high achievers compared to their counterparts as classified by their teachers. Even though they should be in secondary school, the hearing-impaired students only reach standard five (5) at this age. All of them were chosen by their teachers according to their communication ability and only had a single disability (hearing-impaired). Before the observation, consents from the hearing-impaired students' were obtained. The whole interaction and observation were handled by the researcher, assisted by the teacher.

2.2 Research Instrument

Only one set of questionnaire and pictorial likert scale cards were used throughout the observation and interaction with the students. The questionnaire was titled as Hearing-impaired Students Satisfaction on Courseware. The questionnaire was adapted from the SUS (Brooke, 1996; Lewis & Sauro, 2017). Besides, SUS is also suitable for a small number of participants (Brooke, 2013; Calancea, et al., 2019; Krueger, L. J., et al., 2020). In the questionnaire, there were 16 items (14 positive and 2 negative). Items numbered 10 and 14 were negative, the rest were positive. According to the original SUS, the alternated item is to avoid the response biases, but in this research only two items were negative. The sentences were minimized and the word selection was easy for hearing-impaired students to understand. This was because the speech and delivery methods for hearing-impaired students were different from the common students (Mohammadi et al., 2010). The changes mostly derived from the negative item. This was due to the difficulty of the teachers to explain and the students to understand the negative items. All the items are demonstrated in Table 1.

Table 1. Item in questionnaire

Category	Num	Table Head
Overall	1	Like to use the software?
	2	Want to use it anymore?
Interface design	3	Background colour is beautiful?
	4	Can understand the buttons?
	5	Can see the word?
	6	Beautiful picture?
	7	Like video microorganisms spread?
	8	Like the video for making bread?
Sign Language Video	9	Is the video size big enough?
	10	Sign language faster?
Augmented Reality Environment	11	Like to use the webcam?
	12	Beautiful 3D model?
Marker Cards	13	Markers cards are beautiful?
	14	Very small marker card?
	15	Easy to understand the text on the marker card?
	16	Like marker card books?

The Smiley Faces Assessment Scale was adapted from the previous study (Wong & Geilani, 2004) and it was used as a pictorial likert scale in a card form. This smiley faces assessment scale by (Wong & Geilani, 2004) was preferred by children compared to other smiley faces (Yahaya & Salam, 2008). In general, smiley faces were used since the hearing-impaired students could understand them easily compared to the normal likert scale. The Data Analysis Model for Usability Testing: Satisfaction Attribute is shown in Fig. 1.

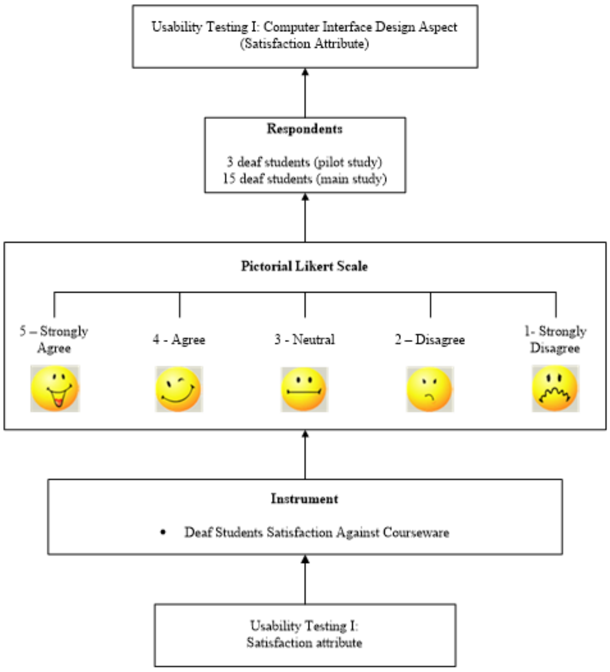

Fig. 1 Data Analysis Model for Usability Testing: Satisfaction Attribute.

In this study, the augmented reality technology was used in developing the courseware. The content was taken from the Curriculum Specifications Science Year Six (Kementerian Pendidikan Malaysia, 2014) and Science Textbook Year Six (Kementerian Pendidikan Malaysia, 2015). In Fig. 2, Fig. 3 and Fig. 4 are interface examples of the PekAR-Mikroorganisma courseware.

Fig. 2 The Introduction of PekAR-Mikroorganisma

Fig. 3 The Main Menu and Learning Module of PekAR-Mikroorganisma

Fig. 4 Example of AR environment in courseware in module 2

The first screen in the courseware is the main display screen which can be seen in **Fig. 2**. The display starts with the name of the application which is PekAR-Mikroorganisma. “Pek” stands for Pekak or in the Malay language it means the deaf. “AR” is augmented reality and Mikroorganisma means Microorganism. A multi-coloured interface with pictures of mushrooms was used. This represented one of the topics featured in the courseware. The concept of design was simple and had meaningful information and was based on the concept of aesthetic and minimalist design that was taken from principle number eight of usability testing (Nielsen, 2001). The selection of text used was simple, clear and appropriate for the students (Bueno et al., 2007). This screen was created to motivate students to always be ready in using the application. This was based on the operant conditioning theory by Thorndike (1913) regarding the law of readiness. Scaffolding strategies or guidance was also applied to the main display screen interface such as in giving clear instructions to users. The “Seterusnya” or Next button was displayed to guide hearing-impaired students to start the activities available in this courseware. When the students moved the mouse over the button, the word "Next" would be displayed. However, on the next screen, the word "Next" would be deleted. This was based on the temporary scaffolding principle, guiding students and giving them the confidence to be independent. In the entire courseware Bahasa Melayu was used. This was based on the second principle of usability testing, which emphasizes the matching features between the system and the real world of users (Nielsen, 2001). Based on the second visual design principle by Avgerinou & Ericson (1997); Heinich et al. (1996), colour balance was also applied. Therefore the harmonious colours were used to attract the attention of the targeted students.

Fig. 3 illustrates the Main Menu and the Learning Module in the courseware. The interface design is standard in which the entire screen uses various elements such as text, images and video to provide meaningful visual information to the targeted students. However, the text used is simple and limited. This is because based on previous studies, it has been found that texts play an important role in addition to the use of sign language for students who have different hearing ability (Bueno et al., 2007). Navigation buttons or icons in the main menu are designed using visual information and assisted by verbal information represented by a sign language translator. This definitely affects the learning process of these students (Panselina et al., 2002). Furthermore, based on the first principles of visual design, by Avgerinou & Ericson (1997); Heinich et al. (1996), the navigation buttons are designed sequentially so that they can be easily seen by these students. The verbal information is provided due to the application of the dual-cognitive theory. The buttons on this main menu are used to navigate to the next menu based on the selection of the participants and this is in agreement with the principles of educational application development (Quinn, 1996) that emphasizes icon-based representations of texts to facilitate special needs students to navigate an application. In addition, the use of sign language translator is loaded in this screen as shown in Fig. 3 Based on the ability of the targeted students, these signals can be controlled and can be repeated by them. They are able to follow through the sign language by the translator because the speed of the movements of the sign language is suitable with them.

The second module is known as Introduction to Microorganisms. In this sub-module, students are exposed to the concept of microorganisms, which are living things. It emphasizes that microorganisms cannot be seen with the naked eye. So, microscope is used to see the microorganisms. Hence, the concepts of breathing, moving and growing are explained through AR activities. The text used is limited. This is based on the cognitive load theory that proposes students with different abilities or impairment have short-term memory (Lundy, 2002; Samar, 1999). Besides, there is also the main navigation button that is "Ulang" or Repeat which is created to allows students to repeat the animation displayed. However, based on the cognitive theory of multimedia learning (Mayer & Moreno 2003), the animations used should be limited because too many animations can reduce the focus of targeted students. The concepts of repetition, user control and freedom are applied based on the requirements of HCI through experts' evaluation (Nielsen, 2001).

2.3 Research Procedure

The method of identifying the satisfaction level is the question-asking protocol. The evaluation process was taken place in the Special Education School (Hearing-Impaired). This was due to the familiarity of the hearing-impaired students with the environment. Each of the hearing-impaired students spent about 30 minutes answering all questions. From the previous studies, the use of questionnaire is not suitable for students with different hearing ability. This is because they require longer time to answer questions compared to the common students (Nielsen, 2001; Alsumait & Al-Osaimi, 2009; Tanaka et al., 2005).

Based on the observation, teachers took a relatively long time to read and explained the instruction using sign language and the likelihood of the targeted stuents to misunderstand or misjudge the asked questions was high. To make them understand the questions, the teacher had to repeat them in sign language. The details of the research procedure are stated below:

(i) The researcher and teacher described the pictorial likert scale (via sign language) to the students

(ii) The students were tested on their understanding of the likert scale

(iii) The questionnaire was used to measure selected usability attributes of the hearing-impaired students (using the Hearing-impaired Students Satisfaction on Courseware Questionnaire)

(iv) The hearing-impaired students indicated their answers based on pictorial likert scale

(v) The researcher recorded all the answers pointed by the hearing-impaired students

The process of identifying the satisfaction level in using the courseware is illustrated in **Fig. 5**.

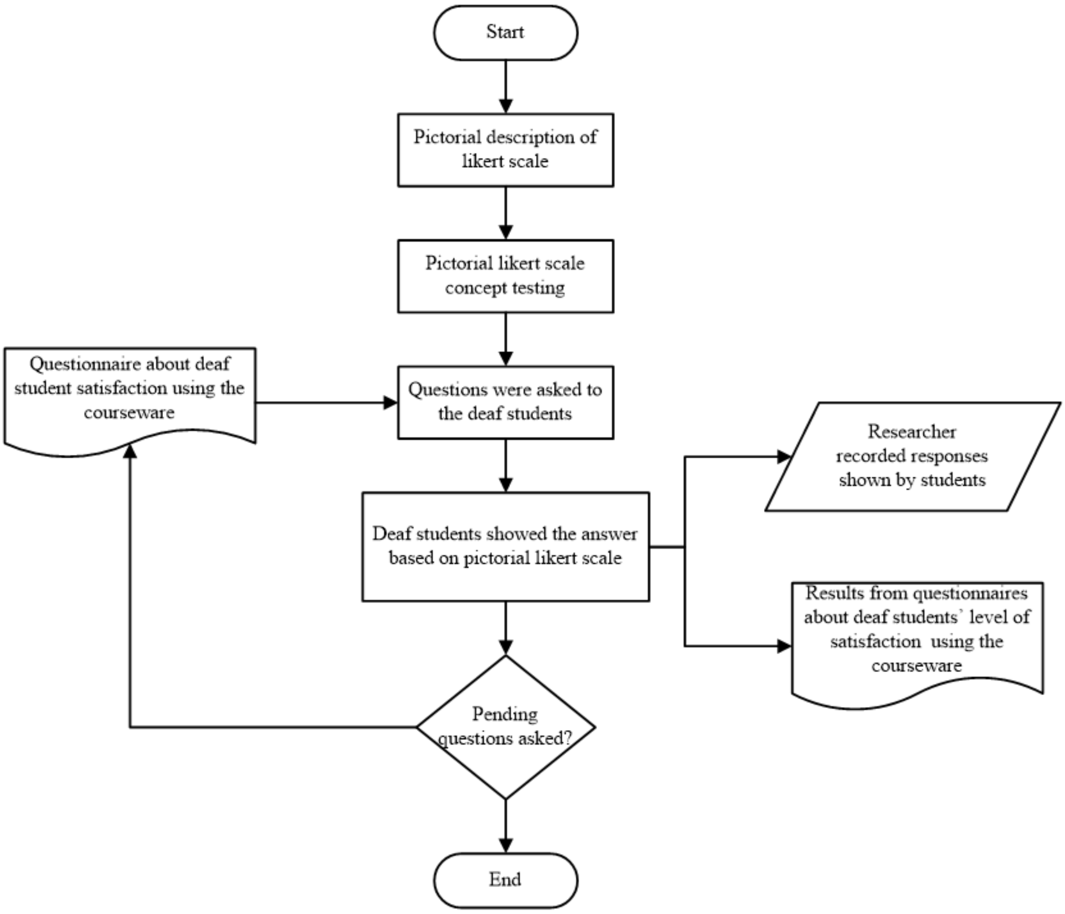

Fig. 5 The process of measuring satisfaction of PekAR-Mikroorganisma courseware

3. Results and Discussion

For PekAR-Mikroorganisma, the score contribution for each item ranged from 0 to 4. In calculating the SUS score, firstly, the sum of the score of each item was obtained. For the items representing the positive score, they were determined by minus one, while for the negative items, it was minus five. Therefore, the positively worded items which are 1,2,3,4,5,6,7,8,9,11,12,13,15 and 16, the score contribution was position minus 1. For negatively worded items which are 10 and 14, the contribution was minus five. Total marks for the SUS scores ranged between 0 and 100. Therefore the adjustment formula to get the maximum possible SUS to score with 16 items would be 16*4 = 64, so to convert to a score on a 0-100 scale, every value of the SUS score have to multiply by 100/64 = 1.5625. An example of the SUS calculation represented for participant One is depicted in Table 2. Meanwhile, the SUS score and value for each participant's satisfaction in using PekAR-Mikroorganisma courseware can be seen in Table 3. Thus, the average satisfaction value of SUS is 87.8 per cent.

Table 2. Example of SUS calculation for first participant

Num	Table Head	+ve/-ve	Student Answer	How to calculate?	SUS Score
1	Like to use the software?	+ve	5	5-1	4
2	Want to use it anymore?	+ve	5	5-1	4
3	Background colour is beautiful?	+ve	5	5-1	4
4	Can understand the buttons?	+ve	4	4-1	3
5	Can see the word?	+ve	5	5-1	4
6	Beautiful picture?	+ve	4	4-1	3
7	Like video microorganisms spread?	+ve	5	5-1	4
8	Like the video for making bread?	+ve	5	5-1	4
9	Is the video size big enough?	+ve	3	3-1	2
10	Sign language faster?	-ve	1	5-1	4
11	Like to use the webcam?	+ve	5	5-1	4
12	Beautiful 3D model?	+ve	5	5-1	4
13	Markers cards are beautiful?	+ve	4	4-1	3
14	Very small marker card?	-ve	2	5-2	3
15	Easy to understand the text on the marker card?	+ve	5	5-1	4
16	Like marker card books?	+ve	5	5-1	4
SUS Score					**58**
Value of SUS (%)					**(58/64)*100=90.6**

Table 3. Hearing-impaired students' satisfaction using the courseware

Participants	SUS Score	Value of SUS (%)
Participant 1	58	90.6
Participant 2	50	78.1
Participant 3	54	84.4
Participant 4	61	95.3
Participant 5	55	85.9
Participant 6	47	73.4
Participant 7	51	79.7
Participant 8	57	89.1
Participant 9	54	84.4
Participant 10	62	96.9
Participant 11	58	90.6
Participant 12	62	96.9

Participant 13	56	87.5
Participant 14	57	89.1
Participant 15	61	95.3

According to previous studies, the success rate of usability consumption of all participants that was more than 50 per cent was considered high (Nielsen, 2001). Meanwhile, other researchers who used the adjective rating scale from the original SUS which used the traditional grading scale of 87.8 per cent was considered as B grade (Bangor et al., 2009). This was due to the usability error that occurred and was addressed post the pilot study. Based on the observation, it can be said the participants enjoyed using PekAR-Mikroorganisma especially in interacting with the AR environment. It has also been discovered that the adapted SUS assessment conducted (Anam et al., 2020) and the development of the interface design of PekAR-Mikroorganisma were compatible with the targeted users since they were included in the beginning of the courseware development (Roberts & Fels, 2006). This findings are useful information to software developers in designing any AR courseware for students with different hearing ability. Futher studies on different topics using the adjustment of SUS are therefore recomemended to help students with different learning abilities or special needs in understanding abstract concepts.

4. Conclusion

In a nut shell, the development of PekAR-Mikroorganisma courseware has to a certain extent, collapsed the wall that has been existed for a long time among students with different hearing ability in acquiring and understanding abstract concepts. Acquiring and learning knowledge is a great challenge for some of them; what more with acquiring and learning abstract concepts. With the use of AR technology, these students are able to grasp abstract concepts better by having different learning experience than the conventional teaching and learning method and thus, enable them to achieve more in academic performance. In assessing their satisfaction using PekAR-Mikroorganisma, adaptation was made to the SUS. The adaptation was crafted due to their ability that is limited in understanding negative statements (Pirozzo, S. et al., 2003). The findings show that the level of satisfaction is 87.8 per cent. This indicates a high level of satisfaction (Nielsen, 2001) and according to the traditional grade scale, it is rated as B grade (Bangor et al., 2009). Hopefully, PekAR-Mikroorganisma can be an alternative tool for students with different learning abilities or impairments to acquire visual literacy and abstract concepts more effectively. It is also hoped that is courseware will help teachers to improve learning outcomes and promote self-learning among the special needs students (Papanastasiou et al., 2019).

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