Measuring Satisfaction on Augmented Reality Courseware for Hearing-Impaired Students: Adjustment Formula form System Usability Scale

Norziha Megat Mohd Zainuddin[1*], Nurazean Maarop[2], Wan Azlan Wan Hassan[3]

[1][2]Razak Faculty of Technology and Informatics,
Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra,
54100 Kuala Lumpur, Malaysia
norziha.kl@utm.my
nurazean.kl@utm.my
[3] Faculty of Communication, Visual Art & Computing,
Universiti Selangor,
45600 Bestari Jaya,Selangor, Malaysia
wan.azlan@unisel.edu.my
*Corresponding Author

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 average satisfaction value of SUS in using PekAR *Mikroorganisma* is 87.8 per cent, and it consider as high or B grade. It is hoped PekAR-*Mikroorganisma* can help the hearing-impaired to understand lessons better through the enhancement of their comprehension on abstract concepts. The teaching and learning using AR able to assure equity in education for the students in understanding certain topics. The study suggested the used of AR for hearing-impaired students for various level up to the higher education.

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 two 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	Questions
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 Figure 1.
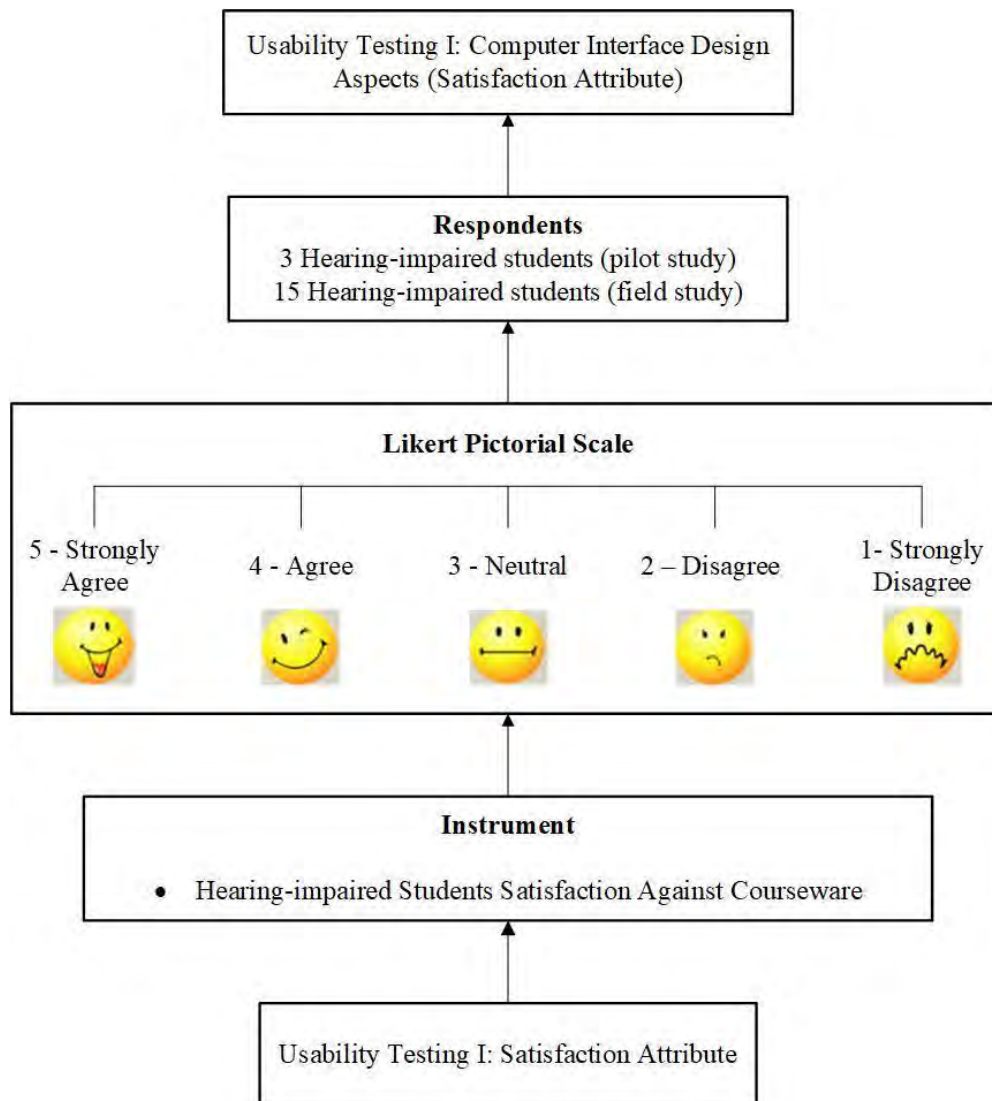

Fig. 1 Data Analysis Model for Usability Testing: Satisfaction Attribute

In this study, the augmented reality technology was used in developing the courseware. The content was taken from the Curriculum Specifications Science Year Six (Ministry of Education Malaysia, 2014) and Science Textbook Year Six (Ministry of Education Malaysia, 2015). In Figure 2, Figure 3 and Figure 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 hearing impaired. "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 Human Computer Interaction 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 (Krasavina, Y. et al., 2022; Nielsen, 2001; Alsumait & Al-Osaimi, 2009).

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 Figure 5.
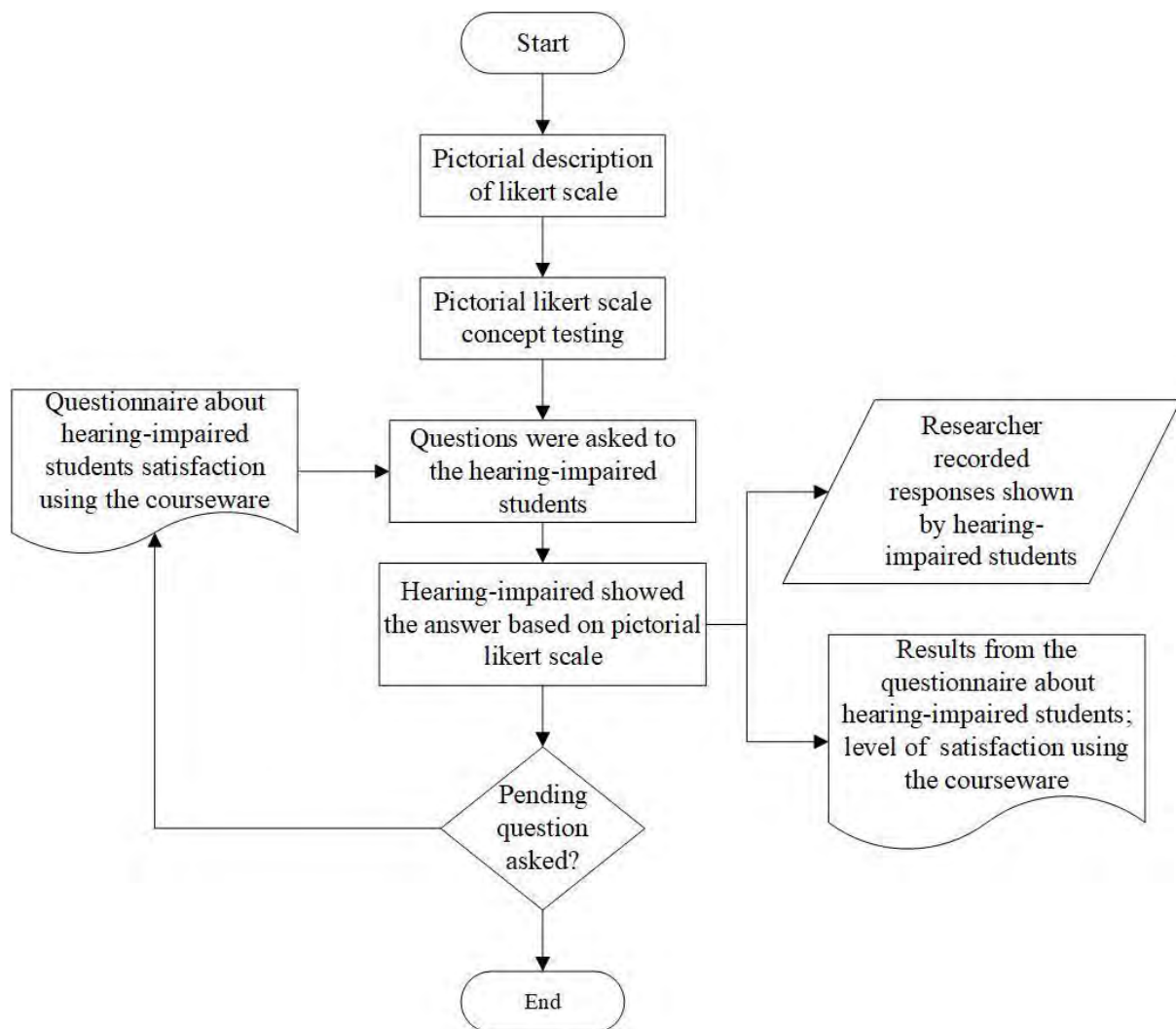

Fig. 5 The process of measuring satisfaction of PekAR-*Mikroorganisma* courseware

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 recommended 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; Vogelzang, M. et., 2021). 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). Educational equity is one of the advantages of using AR in the teaching and learning activities. The students able to understand certain topics easily from the satisfaction test result. The study suggested the used of AR gain acceptance among the hearing-impaired students. This could leverage the used of AR technology for teaching and learning for various level up to the tertiary education. The higher education need an immersive learning environment to understand and visualized the concept that hard to understand. AR suitable to the course in higher education that inaccessible due

to safety or hazard. The opportunities to venture the capability of AR in higher education could also be used in the area of research in aviation, space, healthcare, military and manufacturing industries.

5.   Acknowledgements

6.   References

Abran, A., Khelifi, A., Suryn, W., & Seffah, A. (2003, April). Consolidating the ISO usability models. In *Proceedings of the 11th international software quality management conference* (Vol. 2003, pp. 23-25).

Alsumait, A., & Al-Osaimi, A. (2009, December). Usability heuristics evaluation for child e-learning applications. In *Proceedings of the 11th international conference on information integration and web-based applications & services* (pp. 425-430).

Anam, H., Sadiq, M., & Jamil, H. (2020). Development of System Usability Scale (SUS) for the Urdu Language. *International Journal of Computer Science and Information Security (IJCSIS)*, *18*(6), 73-78.

Avgerinou, M., & Ericson, J. (1997). A review of the concept of visual literacy. *British Journal of Educational Technology*, *28*(4), 280-291.

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators & Virtual Environments*, *6*(4), 355-385.

Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of usability studies*, *4*(3), 114-123.

Brooke, J. (1996). SUS: a "quick and dirty usability. *Usability evaluation in industry*, 189.

Brooke, J. (2013). SUS: a retrospective. *Journal of usability studies*, *8*(2), 29-40.

Bueno, F. J., Fernández del Castillo, J. R., Garcia, S., & Borrego, R. (2007, June). E-learning content adaptation for deaf students. In *Proceedings of the 12th annual SIGCSE conference on Innovation and technology in computer science education* (pp. 271-275).

Calancea, C. G., Miluţ, C. M., Alboaie, L., & Iftene, A. (2019). iAssistMe-Adaptable Assistant for Persons with Eye Disabilities. *Procedia Computer Science*, *159*, 145-154.

Cawthon, S. W. (2010). Science and evidence of success: Two emerging issues in assessment accommodations for students who are deaf or hard of hearing. *Journal of deaf studies and deaf education*, *15*(2), 185-203.

Dhillon, B. S. (2004). *Engineering usability: Fundamentals, applications, human factors, and human error*. American Scientific Publishers.

Dünser, A., Grasset, R., Seichter, H., & Billinghurst, M. (2007). Applying HCI Principles to AR Systems Design. *Proceedings of the 2nd International Workshop on Mixed Reality User Interfaces: Specification, Authoring, Adaptation (MRUI '07)*, (March 11), 37–42.

Faulkner, L. (2003). Beyond the five-user assumption: Benefits of increased sample sizes in usability testing. *Behavior Research Methods, Instruments, & Computers*, *35*(3), 379–383

Folmer, E., Van Gurp, J., & Bosch, J. (2003). A framework for capturing the relationship between usability and software architecture. *Software Process: Improvement and Practice*, *8*(2), 67-87.

Gabbard, J., Swan II, J. E., Hix, D., Lanzagorta, M. O., Livingston, M., Brown, D. B., & Julier, S. J. (2002, May). Usability engineering: domain analysis activities for augmented-reality systems. In *Stereoscopic displays and virtual reality systems IX* (Vol. 4660, pp. 445-457). International Society for Optics and Photonics.

Hahn, D., Beutler, F., & Hanebeck, U. D. (2005, September). Visual scene augmentation for enhanced human perception. In *ICINCO* (pp. 146-153).

Heinich, R. (1996). *Instructional media and technologies for learning*. Simon & Schuster Books For Young Readers.

Holzinger, A. (2005). Usability engineering methods for software developers. *Communications of the ACM*, *48*(1), 71-74.

Hwang, W., & Salvendy, G. (2010). Number of people required for usability evaluation: the 10±2 rule. *Communications of the ACM*, *53*(5), 130-133.

Ibrahim, Z., Alias, N., & Nordin, A. B. (2016). Needs analysis for graphic design learning module based on technology & learning styles of deaf students. *Cogent Education*, *3*(1), 1178364.

Ivory, M. Y., & Hearst, M. A. (2001). The state of the art in automating usability evaluation of user interfaces. *ACM Computing Surveys (CSUR)*, *33*(4), 470-516.

Kato, T. (1986). What "question-asking protocols" can say about the user interface. *International Journal of Man-Machine Studies*, *25*(6), 659-673.

Kirakowski, J. (2005). Summative usability testing: measurement and sample size. In *Cost-Justifying Usability* (pp. 519-553). Morgan Kaufmann.

Krasavina, Y., Ponomarenko, E., Zhuykova, O., & Serebryakova, Y. (2022). Designing E-Courses for Hearing Impaired Students: Practices and Challenges. *ARPHA Proceedings*, *5*, 951-964.

Krueger, L. J., Gaeddert, M., Koeppel, L., Bruemmer, L., Gottschalk, C., Miranda, I. B., ... & Denkinger, C. M. (2020). Evaluation of the accuracy, ease of use and limit of detection of novel, rapid, antigen-detecting point-of-care diagnostics for SARS-CoV-2. *medRxiv*.

Lewis, J. R. (2006). Sample sizes for usability tests: Mostly math, not magic. *Interactions*, *13*(6), 29–33.

Lewis, J. R., & Sauro, J. (2017). Can I Leave This One Out? The Effect of Dropping an Item From the SUS. *Journal of Usability Studies*, *13*(1), 38–46.

Liu, W., Cheok, A. D., Mei-Ling, C. L., & Theng, Y. L. (2007, September). Mixed reality classroom: learning from entertainment. In *Proceedings of the 2nd international conference on Digital interactive media in entertainment and arts* (pp. 65-72).

Lundy, J. E. (2002). Age and language skills of deaf children in relation to theory of mind development. *Journal of deaf studies and deaf education*, *7*(1), 41-56.

Mahrin, M. N. R., Strooper, P., & Carrington, D. (2009, December). Selecting usability evaluation methods for software process descriptions. In *2009 16th Asia-Pacific Software Engineering Conference* (pp. 523-529). IEEE.

Marschark, M., Paivio, A., Spencer, L. J., Durkin, A., Borgna, G., Convertino, C., & Machmer, E. (2017). Don't assume deaf students are visual learners. *Journal of developmental and physical disabilities*, *29*(1), 153-171.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational psychologist*, *38*(1), 43-52.

Medina, E., Chen, Y. C., & Weghorst, S. (2007, June). Understanding biochemistry with augmented reality. In *EdMedia+ Innovate Learning* (pp. 4235-4239). Association for the Advancement of Computing in Education (AACE).

Mekni, M., & Lemieux, A. (2014). Augmented reality: Applications, challenges and future trends. *Applied Computational Science*, 205-214.

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1995, December). Augmented reality: A class of displays on the reality-virtuality continuum. In *Telemanipulator and telepresence technologies* (Vol. 2351, pp. 282-292). International Society for Optics and Photonics.

Ministry of Education Malaysia. (2014). *Kurikulum Standard Sekolah Rendah Dokumen Standard Kurikulum dan Pentaksiran Sains Tahun Enam*. Bahagian Pembangunan Kurikulum.

Ministry of Education Malaysia. (2015). *Sains Tahun 6 Sekolah Kebangsaan*. Kuala Lumpur, Malaysia: Dewan Bahasa dan Pustaka. Retrieved from http://anyflip.com/tuezt/ikbh

Mohammadi, R., Sima-Shirazi, T., Nili-Pour, R., Rahgozar, M., & Pourshahbaz, A. (2010). Comparing of metaphoric expressions comprehension between hearing-impaired students and normal students of junior high school. *Archives of Rehabilitation*, *10*(4), 0-0.

Nguyen, L. (2021). *Communication challenges in User-Centered Agile Software Development and the role of UX designers towards them* (Master's thesis, Itä-Suomen yliopisto).

Nielsen, J. (1993). Chapter 6: Usability testing. *Usability Engineering, p165-205, Academic Press Les autres documents de travail du GRANEM accessibles sur le site Web du laboratoire à l'adresse suivante:(http://ead. univ-angers. fr/~ granem08/spip. php.*

Nielsen, J. (2000). Why you only need to test with 5 users. Retrieved July 15, 2020, from

https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/

Nielsen, J. (2001). Success Rate: The Simplest Usability Metric. Retrieved July 15, 2020, from https://www.nngroup.com/articles/success-rate-the-simplest-usability-metric/

Nielsen, J., & Landauer, T. K. (1993, May). A mathematical model of the finding of usability problems. *Proceedings of the INTERACT'93 and CHI'93 conference on Human factors in computing systems* (pp. 206-213).

Nischelwitzer, A., Lenz, F. J., Searle, G., & Holzinger, A. (2007, July). Some aspects of the development of low-cost augmented reality learning environments as examples for future interfaces in technology enhanced learning. In *International Conference on Universal Access in Human-Computer Interaction* (pp. 728-737). Springer, Berlin, Heidelberg.

Nishioka, T. (2002, July). The see-through head mount display as the information offering device for the hearing impaired students. In *International Conference on Computers for Handicapped Persons* (pp. 166-167). Springer, Berlin, Heidelberg.

Panselina, M. E., Sigalas, M. P., & Tzougraki, C. (2002). Design and development of a bilingual multimedia educational tool for teaching chemistry concepts to deaf students in Greek sign language. *Education and Information Technologies*, *7*(3), 225-235.

Papanastasiou, G., Drigas, A., Skianis, C., Lytras, M., & Papanastasiou, E. (2019). Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first-century skills. *Virtual Reality*, *23*(4), 425-436.

Parton, B. S. (2015). Leveraging augmented reality apps to create enhanced learning environments for deaf students. *International Journal of Instructional Technology and Distance Learning*, *12*, 21-28.

Passig, D., & Eden, S. (2000). Improving flexible thinking in deaf and hard of hearing children with virtual reality technology. *American Annals of the Deaf*, *145*(3), 286-291.

Pirozzo, S., Papinczak, T., & Glasziou, P. (2003). Whispered voice test for screening for hearing impairment in adults and children: systematic review. *Bmj*, *327*(7421), 967.

Plaza, I., Arcega, F., Castro, M., & Tovar, E. (2006, October). Work in Progress: Proposed Usability Model for the Analysis of Digital Electronic Educational web Pages. In *Proceedings. Frontiers in Education. 36th Annual Conference* (pp. 1-2). IEEE.

Quinn, C. N. (1996, December). Pragmatic evaluation: lessons from usability. In *13th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education* (pp. 15-22).

Quinsland, L. K., & Van Ginkel, A. (1990). Cognitive processing and the development of concepts by deaf students. *American annals of the deaf*, *135*(4), 280-284.

Ratwani, R. M., Zachary Hettinger, A., Kosydar, A., Fairbanks, R. J., & Hodgkins, M. L. (2017). A framework for evaluating electronic health record vendor user-centred design and usability testing processes. *Journal of the American Medical Informatics Association*, *24*(e1), e35-e39.

Roberts, V. L., & Fels, D. I. (2006). Methods for inclusion: Employing think-aloud protocols in software usability studies with individuals who are deaf. *International Journal of Human-Computer Studies*, *64*(6), 489-501.

Rosenblum, L. (2000). Virtual and augmented reality 2020. *IEEE Computer Graphics and Applications*, *20*(1), 38-39.

Saidin, N. F., Halim, N. D. A., & Yahaya, N. (2015). A review of research on augmented reality in education: Advantages and applications. *International education studies*, *8*(13), 1-8.

Samar, V. J. (1999). Identifying learning disabilities in the deaf population: The leap from Gibraltar. *NTID Research Bulletin*, *4*(1), 1-4.

Silver, R. A. (1977). The question of imagination, originality, and abstract thinking by deaf children. *American Annals of the deaf*, 349-354.

Sommerville, I. (2007). Software Engineering 8th Edition Pearson Publishing. *Essex, United Kingdom*.

Thorndike, E. L. (1913). *The psychology of learning* (Vol. 2). Teachers College, Columbia University.

Turner, C. W., Lewis, J. R., & Nielsen, J. (2006). Determining usability test sample size. *International encyclopedia of ergonomics and human factors*, *3*(2), 3084-3088.

Vogelzang, M., Thiel, C. M., Rosemann, S., Rieger, J. W., & Ruigendijk, E. (2021). Effects of age-related hearing loss and hearing aid experience on sentence processing. *Scientific reports*, *11*(1), 1-14.

Winter, S., Wagner, S., & Deissenboeck, F. (2007, March). A comprehensive model of usability. In *IFIP International Conference on Engineering for Human-Computer Interaction* (pp. 106-122). Springer, Berlin, Heidelberg.

Wong, A. V. Z. Y., & Geilani, J. (2004). Teddy Bear Hospital (TBH)–reducing children's fear of doctors and hospital environment. University of Sheffield, Dr. Andrew Charters–Barnsley Primary Care Trust. *Child and Adolescent Unit. Retrieved from http://www. ucl. ac. uk/teddy-hosp/tbh_barnsley_paper. pdf*.

Yahaya, W. A. J. W., & Salam, S. (2008). Smiley faces: Scales measurement for children assessment. In *Conf. 2nd International Malaysian Educational Technology Convention, Malaysia* (pp. 1-8).

Yu, D., Jin, J. S., Luo, S., Lai, W., & Huang, Q. (2009). A useful visualization technique: a literature review for augmented reality and its application, limitation & future direction. In *Visual information communication* (pp. 311-337). Springer, Boston, MA.

Zainuddin, N. M. M., Zaman, H. B., & Ahmad, A. (2009). Learning science using AR-Book by blended learning strategies: a case study on preferred visual needs of deaf students. *Journal of Educational Technology Development and Exchange*, *9*(2), 5-20.

Zainuddin, N. M. M., Zaman, H. B., & Ahmad, A. (2011, November). Heuristic evaluation on augmented reality courseware for the deaf. In *2011 International Conference on User Science and Engineering (i-USEr)* (pp. 183-188). IEEE.