Chapter in Book

The Augmented Reality Educational Tool for Learning 2D and 3D Space Content in Primary School

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Abstract: *Space is a Mathematics topic that is difficult for primary school pupils to understand because it requires them to visualize the 3-dimensional shapes and 2-dimensional polygons. Augmented Reality (AR) allows pupils to see the visualization of 3-dimensional and 2-dimensional shapes practically. The objective of this research is to develop an effective AR educational tool based on UX and the identified needs for primary school pupils learning Space topic covering visualization of 2-dimensional and 3-dimensional shapes. ASSURE instructional design model and quantitative approach been used in this research. Quantitative research focused on analysed user needs for the AR educational tool that been developed. It involved the use of quantitative data, such as survey with questionnaires to understand the needs of the AR. This AR educational tool developed following waterfall method. All data were analysed to find the mean and were used to determine the user needs for the development of the AR educational tool. The findings of the research include a list of user needs and successfully developed AR educational tool based on the UX. This research is very important as an effort to increase pupil's understanding of space topic and assist primary school teachers implement teaching sessions more effectively.*

Keywords: Augmented Reality, Space Topic, 2D and 3D, User Needs, User Experiences.

1. INTRODUCTION

One of the topics that are difficult for primary school pupils is *space*. This topic requires the skills of visualizing 3-dimensional shapes and 2-dimensional polygons. Most pupils do not have good visualization skills. Some pupils are unable to imagine the 3-dimensional shapes and do not know how to answer questions related to surface area and 3-dimensional shapes (Flores-Bascuñana et al., 2019). Therefore, AR comes into the picture as it allows pupils to see the visualization of 3-dimensional shapes and 2-dimensional polygons practically. AR acceptance as a teaching and learning platform is bolstered by the benefit of 3D models. AR can display various 3D models and describe them in various ways and from distinct observing angles to pupils. This makes learning more understandable and effective (Cerqueira & Kirner, 2012). According to Bhausaheb et al. (2016) and Aldalalah et al. (2019) in their studies, AR can enhance the visual skills of pupils in education especially Mathematics, and AR is the best tool to help pupils improve their visual skills.

AR technology can help pupils who have difficulty visualizing complex learning concepts and can assist pupils to understand and learn new concepts in a new environment that cannot be viewed in the real world (Campos et al., 2010). AR helps pupils gain awareness by allowing them to have real-life experiences as a result of interacting with the virtual and real worlds (Arslan et al., 2020). AR also can enhance spatial skills as it provides better visualization hence giving them a new user experience (UX).

This research was conducted to develop an AR educational tool based on the UX and identified user needs. UX design principles are one of the constructs included in the user needs analysis questionnaire. The process of developing the AR educational tool started from analyzing the user needs data until the successful installation of the AR educational tool in an Android smartphone, which is reported in the following sections.

2. METHOD & MATERIAL

ASSURE instructional design model is used as research method when researcher want to develop learning/education courseware with specific material and involving pupils. Figure 1 shows ASSURE design model used for this research.

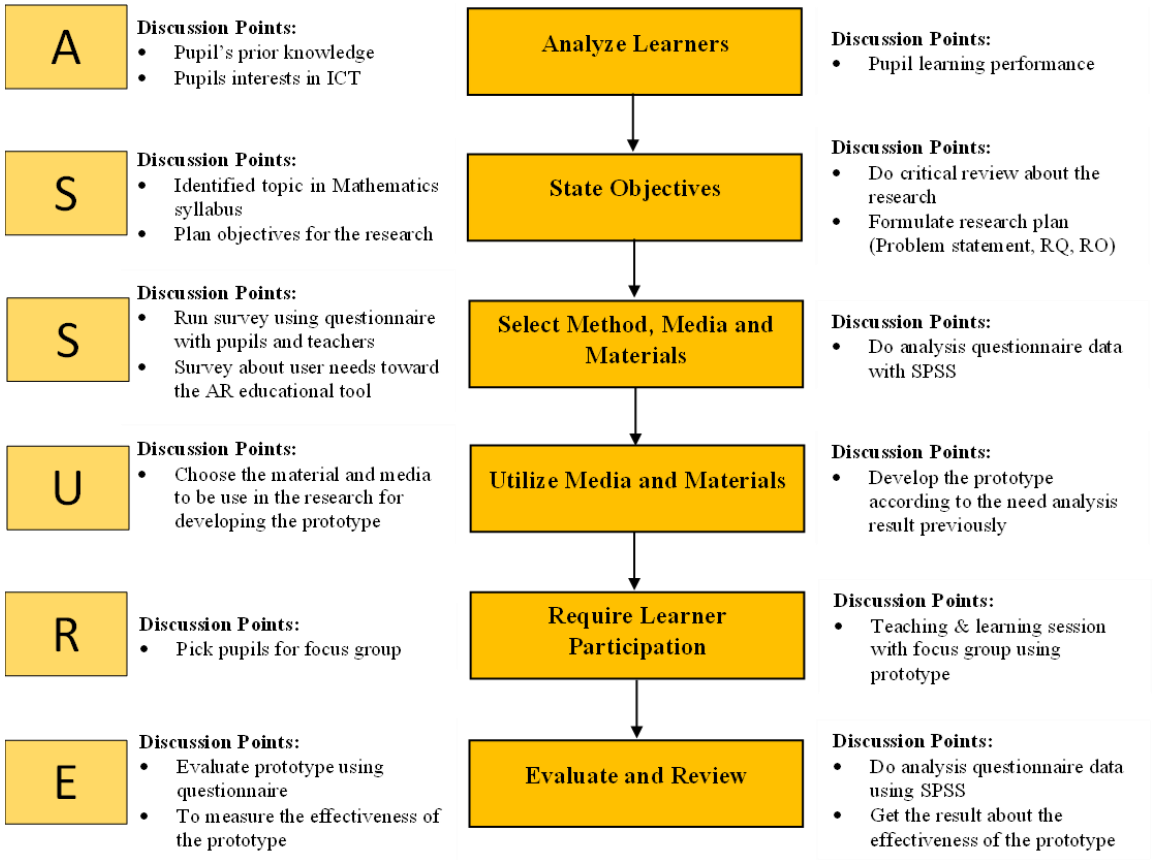

Figure 1. ASSURE design model. Source: Nor Salhana Mohd Arshad, 2022.

There were three stages of data collection implemented in this research to achieve the objectives of the research:

1. The first stage was the pilot test of the user needs questionnaire. Researcher had done the pilot test to see the reliability of the questions in user needs questionnaire (Nor Salhana Mohd Arshad, 2022).
2. The second stage was the distribution of user needs questionnaires to actual respondents.
3. The third stage was the distribution of questionnaire to measure the effectiveness of AR educational tool.

This paper discusses the second and third stages of data collection; the distribution of questionnaires to actual respondents of 166 pupils and 20 teachers and the distribution of questionnaire to measure the effectiveness of AR educational tool to 15 pupils. For second stage, the questionnaires were distributed to three primary schools in Kubang Pasu district, Kedah using Google Meet online platform due to Covid-19 pandemic. The session involving researcher, respondents, and respondent's Mathematics teacher. Researcher guided respondents with the help from their Mathematics teachers to answer user needs questionnaire. A safe time allocation of 30 minutes was required for a briefing session from researcher and a questionnaire answering session for the pupils. Responses from the questionnaires were immediately collected after the 30 minutes was completed. Meanwhile, data collection for Mathematics teachers used the Google Form platform.

Third stage data collection is the distribution of questionnaire to measure the effectiveness of AR educational tool to 15 pupils. The sessions were done following the ISO 25022 guideline. The sessions were done face to face and pupils used the AR educational tool prototype and completed 4 task using the prototype.

3. FINDINGS

Researcher identified the user needs that had been gathered from the user needs questionnaire. The result of the questionnaires was analyzed using IBM SPSS Statistic 20.0 using descriptive statistics method to determine the frequency and mean of user needs according to pupil's and teacher's views. The results helped researcher finalized the user needs for the AR educational tool. The analysis is performed using interpretation of mean score by Darusalam and Hussin (2016) as illustrated in Table 1.

Table 1. Mean Score Interpretation (Darusalam & Hussin, 2016).

Mean Score	Interpretation
1.00 – 1.80	Very Low
1.81 – 2.60	Low
2.61 – 3.40	Moderate
3.41 – 4.20	High
4.21 – 5.00	Very High

According to Allen and Seaman (2007) in their study, Likert scales were developed in 1932 as the familiar five-point bipolar response that most people are familiar with today. These scales range from a group of categories (least to most) asking people to indicate how much they agree or disagree, approve or disapprove, or believe to be true or false. Some examples of category groups as stated at Table 2.

Table 2. Likert Scales Response Categories (Allen & Seaman, 2007).

Mean Score	Interpretation	
1.00 – 1.80	Very Low	Strongly disagree
1.81 – 2.60	Low	Do not agree
2.61 – 3.40	Moderate	True to some extent
3.41 – 4.20	High	Agree
4.21 – 5.00	Very High	Strongly agree

Researcher consider the moderate (True to some extent) until very high score be excepted in this research. This research also gathers the teacher perception to support the pupils' perceptions because teachers are more knowledgeable than pupils in content of the Mathematics curriculum in Malaysia, pedagogy trends now a day, and UX design principles.

Table 3 shows the summary of the analysis result on content construct according to pupil's and teacher's perception.

Table 3. Summary User Needs Questionnaire Result on Content Construct According to Pupil's and Teacher's Perception.

Construct	Item	Pupil's Perception		Teacher's Perception		Result
		Mean	Interpretation	Mean	Interpretation	
Content	*Saya suka belajar topik ruang dalam Matematik.*	3.58	High	4.10	High	Accept
	Saya tahu dan faham bentuk 2 dimensi.	3.52	High	4.30	Very High	Accept
	Saya tahu dan faham bentuk 3 dimensi.	3.36	Moderate	4.25	Very High	Accept
	Saya tahu dan faham bentangan bentuk.	3.29	Moderate	3.65	High	Accept
	Saya tahu dan faham jenis-jenis garisan.	3.52	High	3.85	High	Accept
	Saya tahu dan faham jenis-jenis sudut.	3.16	Moderate	3.90	High	Accept
	Saya tahu dan faham perimeter.	3.06	Moderate	4.10	High	Accept
	Saya tahu dan faham luas bentuk.	3.23	Moderate	3.80	High	Accept
	Saya tahu dan faham isipadu bongkah.	3.02	Moderate	3.70	High	Accept
	Saya tahu cara menyelesaikan soalan perimeter.	2.96	Moderate	3.90	High	Accept
	Saya tahu cara menyelesaikan soalan luas segi empat dan segi tiga.	3.19	Moderate	3.50	High	Accept
	Saya tahu cara menyelesaikan soalan isipadu kubus dan kuboid.	3.09	Moderate	3.60	High	Accept
	Saya tahu menjawab penyelesaian masalah topik ruang.	3.01	Moderate	3.20	Moderate	Accept

The statistic showed that mean scores for content construct were moderate for pupil's perception and high for teacher's perception. This finding showed that pupils were still agreed with the content proposed by the researcher. For the teacher's perception, they agreed with the proposed content provided by the researcher. Thus, the researcher accepted all user needs for content construct. Hence, AR educational tool will have the following content:

- 2 Dimensional polygons
- 3 Dimension shapes
- Shapes layout
- Types of lines

- Types of angles
- Perimeter
- Area
- Volume

Table 4 shows the summary of the analysis result on pedagogy construct according to pupil's and teacher's perception.

Table 4. Summary User Needs Questionnaire Result on Pedagogy Construct According to Pupil's and Teacher's Perception.

Construct	Item	Pupil's Perception		Teacher's Perception		Result
		Mean	Interpretation	Mean	Interpretation	
Pedagogy	*Saya seronok belajar matematik di rumah.*	3.35	Moderate	3.20	Moderate	Accept
	Saya suka belajar Matematik secara online.	3.13	Moderate	2.95	Moderate	Accept
	Saya suka belajar Matematik dengan melayari YouTube.	3.16	Moderate	3.85	High	Accept
	Saya suka belajar Matematik dengan menggunakan Wordwall *dan* Liveworksheets *yang selalu diberikan oleh guru semasa PdPr.*	3.64	High	3.75	High	Accept
	Saya suka belajar Matematik dengan menggunakan aplikasi belajar Matematik dari PlayStore.	3.19	Moderate	3.00	Moderate	Accept
	*Saya suka belajar Matematik menggunakan komputer/komputer riba (*laptop*).*	3.14	Moderate	3.15	Moderate	Accept
	Saya suka belajar Matematik menggunakan telefon bimbit.	3.43	High	3.95	High	Accept
	Saya suka belajar Matematik menggunakan teknologi berbanding buku.	3.06	Moderate	3.15	Moderate	Accept
	Saya suka belajar Matematik menggunakan Augmented Reality *iaitu boleh melihat objek dalam 3 dimensi.*	3.29	Moderate	4.05	High	Accept
	Saya suka belajar Matematik menggunakan Bahasa Melayu berbanding Bahasa Inggeris.	3.66	High	4.45	Very High	Accept

Statistic showed that mean scores for pedagogy construct were moderate for pupil's perception and high for teacher's perception. This finding showed that pupils were agreed with the pedagogy method proposed by the researcher. For the teacher's perception, they agreed with the proposed pedagogy method provided by the researcher. Thus, the researcher accepted all user needs for pedagogy construct. So, the AR educational tool will include the following pedagogy method:

- using technology
- using augmented reality (AR)
- using smartphone
- suitable for learning at home
- via online
- learn by watching video/animation
- exercise in interactive form
- using Malay Language

Table 5 shows the summary of the analysis result on UX design principles construct according to pupil's and teacher's perception.

Table 5. Summary User Needs Questionnaire Result on UX Design Principles Construct According to Pupil's and Teacher's Perception.

Construct	Item	Pupil's Perception		Teacher's Perception		Result
		Mean	Interpretation	Mean	Interpretation	
UX Design Principle	*Saya suka belajar bersendirian (seorang diri).*	2.27	Low	2.45	Low	Reject
	Saya suka belajar di ruang tertutup.	2.59	Low	2.80	Moderate	Reject
	Saya suka melihat objek dalam animasi/video yang nampak seperti objek sebenar di sekeliling saya.	3.54	High	3.85	High	Accept
	Saya suka melihat paparan di skrin komputer yang nampak ringkas (tidak serabut).	3.59	High	4.15	High	Accept
	Saya suka belajar Matematik menggunakan aplikasi yang mempunyai audio/suara.	3.66	High	4.20	High	Accept
	Saya suka menggunakan cara yang sama untuk pergi ke skrin yang lain (pautan seragam).	3.27	Moderate	4.15	High	Accept
	Saya suka belajar dengan menggunakan skrin komputer yang menunjukkan kedudukan benda di skrin yang hampir sama dengan aplikasi pembelajaran yang selalu saya gunakan di sekolah.	3.42	High	3.90	High	Accept
	Saya suka membaca tulisan pada skrin komputer yang menggunakan warna yang berlawanan dengan skrin computer (tulisan nampak lebih jelas).	3.67	High	3.85	High	Accept
	Saya suka melihat tulisan yang sedikit di skrin komputer.	3.15	Moderate	4.00	High	Accept
	*Saya tahu menggunakan komputer/tablet/telefon bimbit dengan menggunakan jari saya untuk tekan (*tap*), sapu (*swipe*) dan picit (*pinch*) pada skrin.*	3.67	High	3.80	High	Accept

Statistic showed that mean scores for UX design principles construct were high for pupil's and teacher's perception. However, item number one had low interpretation from pupils and teachers and item number two had low interpretation from pupils but moderate interpretation from teacher. So, this UX design principle be rejected. The rejected UX design principle was environment category which users did not want the AR educational tool been used in their intimate space within 45cm from users. Other finding showed that pupils and teacher were agreed with the UX design principle proposed by

the researcher. Thus, the researcher accepted item number three until item number ten for UX design principles construct. So, the AR educational tool will include the following UX design principles:

- Animation/video looks like a real object
- Not cluttering the screen
- Involves the use of audio
- Common links used in terms of shape and position
- Display screen looked familiar like MOE applications
- An easy-to-read / clear writing to see
- Restricted the use of text
- Use common gesture and prompts to interact with application

4. DESIGN AND DEVELOPMENT

Upon completion of listing all user needs and requirements, researcher planned tasks in Waterfall process to develop AR educational tool. Some diagrams have been provided by researcher for detail view of system architecture and related UX and user needs obtained. The diagrams were:

1. System Architecture: shows overall outline of the software system and the relationships, constraints, and boundaries between components.
2. System Flowchart: representation of the sequence of steps and decisions needed to perform a process.
3. Use Case Diagram: summarize the details of system's users and their interactions with the system (Refer Figure 2).
4. Storyboard: visualize the UX ideas in design (Refer Figure 3).

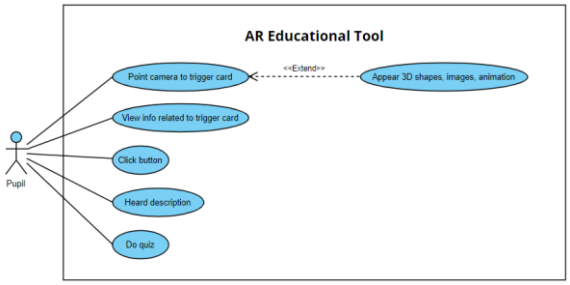

Figure 2. Use Case Diagram for AR Educational Tool.

Pupils will interact with the AR educational tool in five ways. Pupils will point the camera at the trigger cards and the AR multimedia contents will display on the camera screen. Pupils also can view all the information according to the specific trigger cards, click button on the screen, heard audio when button click and do quizzes included in the AR educational tool.

A storyboard communicate a story through images display in a sequence of panels that chronologically maps the story's main events (Krause, 2018). Figure 3 shows the storyboard for AR educational tool.

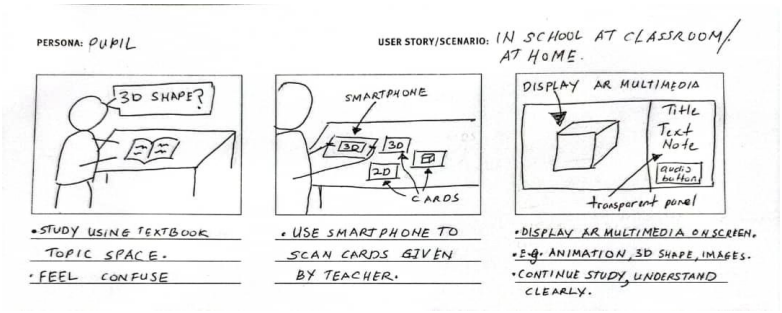

Figure 3. Storyboard for AR educational tool.

Through this storyboard, it can be seen how UX is present in this AR educational tool. How users connect and interact with the AR educational tool.

5. DEVELOPMENT OF ARANA

Researcher used Unity 3D software for the setting and design of the AR application and Vuforia SDK platform to made it to be AR application in android devices. The setting for AR in 31 trigger cards that represent all the user need contents construct were done in this phase. Researcher also included the UX design principles construct where the interface is not clutter with texts and buttons, less texts used, include sound note, and the display shows the same display as application in DELIMa Portal MOE.

6. THE DEPLOYMENT ON ANDROID SMARTPHONE

The AR educational tool been tested and converted to an android application package (APK) file. Researcher name the AR educational tool as ARANA. Figure 4 shows screen capture of 3-dimensional notes in ARANA and Figure 5 shows screen capture of 2-dimensional notes in ARANA.

Figure 4. UI of 3-Dimensional Shape Note.

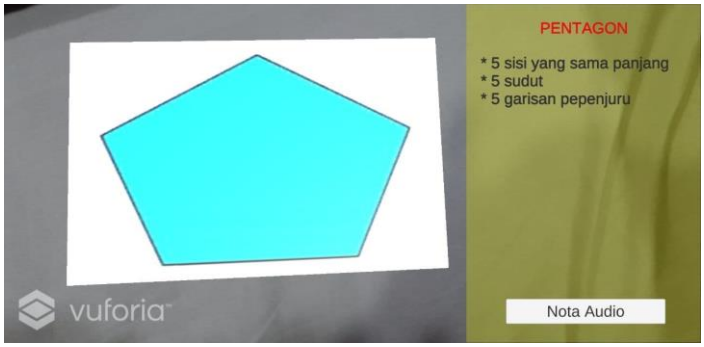

Figure 5. UI of 2-Dimensional Polygon Note.

We can see, researcher had included text and button. The text is simple and compact without cluttering the interface. The button style used also common in various application. The audio can be heard clearly when user click the button and the 3D shapes are very clear and just like real objects that merge with the real world without any difference. All the user needs and UX design asked by users were included successfully into ARANA.

7. EFECTIVENESS EVALUATION FOR ARANA

The effectiveness evaluation of ARANA used ISO/IEC 25022 manual guideline. According to ISO/IEC 25022, the effectiveness of a system can be measured when the user can complete all the tasks correctly without any assistance from the test administrator. A satisfaction questionnaire was given to the user to answer while using and exploring the AR educational tool prototype.

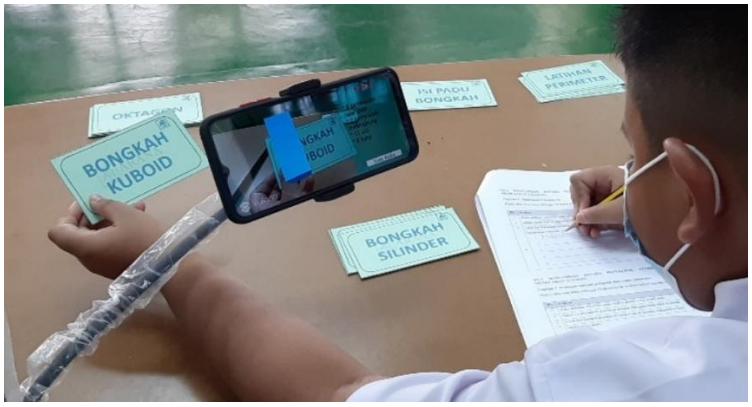

Figure 6. Pupil Completing the Tasks using AR Educational Tool Prototype.

Figure 6 shows pupils sitting on the set prepared by researcher. The smartphone in the figure was installed with ARANA application and pupils can scan the trigger cards as in Figure 6 shows. Pupils explore ARANA and try to complete all four tasks given by researcher in the time period provided.

Figure 7 shows the result of the satisfaction test of ARANA. Satisfaction gives an overall feeling of satisfaction from user while using ARANA. Usefulness indicates how effective ARANA been use for user learning session, ease of use is the user's perception of ease to use (process), clarity indicates the clearly used of teams in ARANA, and attractiveness is the user's perception of user interface in ARANA.

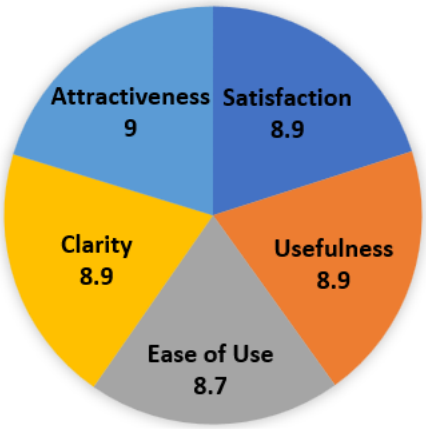

Figure 7. The Summary of Satisfaction Result with Five Dimensions.

8. CONCLUSION

This paper discusses two important phases that have been successfully performed to develop AR educational tool named ARANA. Researcher extracted data from the questionnaire and analyzed the results and later transformed all the data into a list of user needs that are used as a guideline to develop the AR educational tool. The UX design principles are one of the guidelines used to develop the AR educational tool. Each step has been considered to involve the UX design principles required by the users. The results show that all the UX design principles requested by the users and all user needs are successfully incorporated into the ARANA. The effectiveness of ARANA also had been done using ISO 25022 manual guideline. The result showed mean of 5 dimensions were above 8.5 and respondents managed to complete all 4 tasks 100% and achieve intended outcome 93% in 20.4 minutes. So, it showed ARANA meet the expectations of user's needs. This research involves the use of AR as a learning tool for space topic in primary school Mathematics syllabus and using offline contents. In future, the research can be extended to other topics in primary school Mathematics as the application of AR in teaching and learning Mathematics in Malaysia is quite limited, especially that takes into consideration the user needs amongst pupils with special needs or pre-school children. This can also be an effort towards examining the needs of special needs pupils and pre-school children for inclusivity and accessibility to learning and technology. This research also can be extended to online type of content where user share the virtual content in a network and the data can constantly update by other users that use the same AR educational tool.

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