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Evaluation on the Potential Application of Educational Animation Design Model for Virtual Reality-Based Learning

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Abstract

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This study aimed to improve the virtual reality (VR)-based educational animation design model for VR-based learning. The literature review shows that there is still limited information on (1) learners' subjective preferences for design elements of 360° virtual environment and (2) how to better utilise the design elements. Besides, a VR-based educational animation design model that comprises 41 design elements has been identified. However, such design model has yet to be evaluated in actual context and more information is needed for further refinement. The design model was evaluated in a focus group context, through proof-of-concept of educational animation, involving 19 university students, where users' or learners' experience (understanding and satisfaction) was examined. The focus group study consists of (1) pre-test and post-test, and (2) focus group interview. There was a significant average difference between the pre-test score and the post-test score ($t(18) = 4.572, p < .001$). From interview response, four new design elements that are not originally part of the design model were identified and were added to the design model. The four new design elements are: (1) ambiance sound, (2) clear resolution quality, (3) audio narration quality (appropriate sounding voice), and (4) audio narration quality (enunciation quality).

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Introduction

According to Stadlinger et al. (2021), video animation provides greater imagination for how educational materials are presented, where this has been enriched by augmented reality (AR) and virtual reality (VR) technologies in the past decade. Mixed media, VR, AR and video animation are emerging technologies that are playing an increasingly significant role in education (Stadlinger et al., 2021). VR animation or 360° animated media can help convey information and stories better, as well as improve the effectiveness of content learning process (Sutrisno et al., 2023). Educators have the responsibility to respond the call to prepare students in alignment with Industrial Revolution (IR) 4.0 and The United Nations Educational, Scientific and Cultural Organization (UNESCO)'s Sustainable Development Goals (SDGs) that encourage the utilization of digital technologies (Maaruf et al., 2022). 360° video, also referred to as desktop or mobile-based VR, offers the most popular, easiest, and inexpensive way to access VR applications (Le et al., 2022). With 360° videos, one can freely select his or her viewing perspective around a fixed camera point to explore the scene (Rosendahl & Wagner, 2024).

In time to come, VR may serve as an essential element in tertiary education, making learning more effective, immersive, and interactive (Zainudin et al., 2025). Immersive learning experiences may be the future of knowledge delivery and acquisition at higher education institutions in Malaysia (Adnan, 2020). As stated by Kalkofen et al. (2020), designing VR experiences for tertiary education in a proper manner is still an active research topic. The maturity of VR technology application in tertiary education remains questionable (Radianti et al., 2020). Content creation remains a major obstacle to widespread adoption of VR in education (Kavanagh et al., 2025). There is rising interest in (1) using VR tools to advance instructional design strategies in tertiary education contexts (de Jong et al., 2025), and (2) the potential of VR technologies to change tertiary education institutions radically or fundamentally (Dimitrov, 2024). Future studies should strive to fully exploit animation technology in VR to produce instructive, immersive, and unique user experiences (Hashim et al., 2024). As noted by Balalle (2025), to meet the needs of educators and learners, virtual learning environments should be frequently updated.

Some 360° videos design guidelines support the use of add-ons or design elements like virtual actor (Evens et al., 2023; Wuebben et al., 2023), however, information on the way to better utilise the add-ons or design the elements of animation is still limited (Evens et al., 2023; Mustafa, 2023). Learning experience design is a relatively new field (Schroeder et al., 2023), and the complexity of the 360° video should be adjusted according to the learner's level as mentioned by Evens et al. (2023). Huang, Zhou et al. (2024) noted that learners' subjective preferences for 360° video design elements require further research. While mainstream user experience concentrates on immersive VR (Alamäki et al., 2021), majority VR related research reviewed by Dogan and Sahin (2024) also adopt immersive VR. Since VR-based educational resources produced inconsistent effectiveness in learning (Huang, Chen, et al., 2024; Snelson & Hsu, 2020), indicate there is a need to explore the design of educational resources (Abdulrahman et al., 2020). To better assist educators with the creation of cost effective educational 360° videos, a VR-based educational animation design model was proposed. However, its potential applications in practical context have yet to be evaluated (Syarifuddin, 2024). So, the aim of this study is to improve the proposed educational animation design model for VR-based learning. This study is a continuation from the

research by Syarifuddin (2024), for which Syarifuddin's research focused on introducing a new design model, while this study aimed to continuously improve this novel concept via proof-of-concept of VR-based educational animation.

Research Questions

From the gaps mentioned above, this has led to the establishment of three research questions. The three research questions are:

1. How robust is the design model to meet the expected educational outcomes in practical context?
2. What are the subjective experiences, opinions, preferences, and expectations of user towards the design elements presented in VR-based educational animation?
3. What improvement can be made to the VR-based educational animation design model for VR-based learning?

Research Objectives

To address the research questions, three research objectives were developed. The three research objectives are:

1. To assess the design model for its potential effectiveness in practical context through focus group.
2. To investigate user feedback towards the design elements presented in VR-based educational animation.
3. To revise the VR-based educational animation design model based on the testing conducted with user feedback.

Based on these objectives, the following hypothesis was formulated to guide the quantitative aspect of the study:

- There is a significant difference between participants' pre-test scores and post-test scores after viewing the VR-based educational animation.

Literature Review

Educational Animation

Animation is referred to as a dynamic medium in which objects or images that are slightly different from each other are manipulated to create the illusion of movement and change (Atabhotor & Kofoworola, 2020; Hushain et al., 2023; Nagar & Yagnik, 2018; Singh, 2018). Educational animations are animations prepared with a goal to promote learning (Atabhotor & Kofoworola, 2020). Animation possesses five features that are helpful for learning, namely: (1) presenting information, (2) motivating students, (3) providing explanation, (4) making teaching appealing, and (5) attracting attention (Cevahir et al., 2022).

In recent years, animation has growingly become an important educational resource across wide range of subject areas (Alzahrani, 2025). In the digital era, educators can utilise social media or other mobile applications for animation video upload, so that learners can access the video easily regardless of their location. This also enables learners to have the flexibility to progress based on their own pace (Nagar & Yagnik, 2018; Suprpto et al., 2024). Animation is a reliable educational medium, from classic television to phones streaming curated playlists of

YouTube (Mustafa & Ibrahim, 2022). According to Nagar and Yagnik (2018), the two main benefits of educational animation are skill improvement and motivation.

In animation design, immersive technologies like VR have created new possibilities for audience interaction, design workflows and storytelling. In immersive storytelling, viewers are no longer passive observers but active participants, as they can involve with the content in a more participatory and interactive manner (Manchanda et al., 2025). 360° panorama animation is an immersive animation that uses a full 360° perspective to create an increased sense of realism and attraction (Fangling et al., 2023). 360° animation is an advanced method that makes the viewer feel as if they are physically present in the virtual space, and in educational contexts, understanding can be improved via approaches that make the instructional tools more vivid and easier to comprehend (Fangling et al., 2023). With the continuous advancement of technology, the popularity with regard to utilising animation and enriching animation via VR and AR technology for educational purposes is anticipated to grow further (Giri & Sharma, 2023; Stadlinger et al., 2021).

360° VR

VR refers to a technology that makes it possible for us to become completely involved in an artificial world, while this world can be a reproduction of the real environment or a completely fictional universe (Elmqaddem, 2019). 360° video is defined as a specific format of video having conventional video technology incorporated with characteristics of VR (Rosendahl & Wagner, 2024). As noted by Rosendahl and Wagner (2024), the viewing and controlling action of 360° videos can be done in a highly immersive manner using head-mounted-displays (HMD), or in a low immersive way utilising desktop. Natural Image (NI) and Computer-generated Graphics (CG) videos are examples of 360° content (Shafi et al., 2020). The process of creating a 360° video that includes three-dimensional (3D) content (such as animation) is slightly different from that of a video with real-world content only (such as live-action footage of real scenes) because the former involves certain steps, such as 3D modelling (Hussain, 2020).

The hurdles that prevent 360° video from extensive adoption and general implementation in education are: (1) a scarcity of video materials on the YouTube platform, and (2) a lack of specialised video materials on specific processes or for specific fields (such as, in the medical surgical field) (Ranieri et al., 2022). Huang, Chen, et al. (2024) noted that 360° videos do not always leave positive impact on learners. 360° videos cause learners to focus more on the immersive experience instead of the content, leading to distractions and higher cognitive load, impeding the processing of relevant information (Huang, Chen, et al., 2024). Sometimes novel instructional tools like 360° video, because of their engaging nature, can lead to enhanced perceived understanding, but in actual learning, there is no corresponding increase (Sun & Ch'ng, 2024). Hence, the challenge lies in designing this 360° technologies in a way that can facilitate deep cognitive processing, rather than simply attracting learner's initial attention.

A research basis on 360° video in education is still in its early stages (Evens et al., 2023). Whilst learner experience design is a relatively new field, Schroeder et al. (2023) encouraged researchers to contemplate every feature of

360° video and implementation design to ensure their system is easy to use. As noted by Evens et al. (2023), future research should focus more on the instructional design of 360° video. There is a need for further research into the specific design elements that contribute significantly to the development of different areas of learning (Dogan & Sahin, 2024). Instructional designs that go beyond novelty are needed to foster meaningful and continuous engagement while ensuring that perceived understanding is more consistent with actual academic achievement (Sun & Ch'ng, 2024). Some studies suggest that 360° video can aid learning. However, these cannot be applied to or generalised to other contexts (Rosendahl & Wagner, 2024).

VR-Based Educational Animation Design Optimisation

Research on educational 360° video is relatively new (Kavanagh et al., 2025). Regarding educational 360° VR animation design optimization, the literature reservoir consists of insights and research efforts related to (1) proposing strategies for collaboration with animators, (2) exploring and understanding design choices, and (3) developing design guidelines.

For efforts and insights related to “proposing strategies for collaboration with animator”, some people do not have much time to self-learn and produce educational animation on their own (Kayler et al., 2020); in such cases, collaboration with animators is necessary (Ala et al., 2022; Kayler et al., 2020). To promote the creation of educational animation, Kayler et al. (2020) reported three main challenges faced and corresponding strategies during the process of collaborating with a professional animator. Moreover, through having a well-defined framework, such as design elements with uniform definition, can help achieving a common understanding (Radianti et al., 2020), thus may facilitate the communication on design decisions or choices.

Regarding “exploring and understanding design choices”, existing research has focused on investigating the impact of caption presentation method, narration style, as well as cues acting on the two sensory channels (i.e., auditory and visual) and has made corresponding recommendations (Allman et al., 2022; Beege et al., 2024; Huang, Chen, et al., 2024; Huang, Zhou, et al., 2024; Liu et al., 2022). It has been pointed out that future research should explore learners’ subjective preferences on design elements of 360° video, the impacts of other elements in 360° virtual environments like colour and animation, as well as different types of cues and instructional strategies to guide learners to fully explore the virtual environment (Huang, Zhou, et al., 2024; Zhou & Bahng, 2025).

Mentioning “developing design guidelines”, for the design element framework by Radianti et al. (2020), the derivation of design elements only based on immersive VR. Kalkofen et al. (2020) derived their initial design of VR framework from the work by Radianti et al. (2020) and extended it in accordance with the feedback obtained from educators and learners, and the new tools or components added required the use of VR headset and smart pen. Hence, the VR framework by Radianti et al. (2020) and Kalkofen et al. (2020) might be less suitable for low-cost application. The design guideline by Evens et al. (2023) is made up of general features that created impact only. Another two design guidelines, one by Wuebben et al. (2023) and another one by de Jong et al. (2025) are meant to help with the creation of specific content i.e., (1) research communication (Wuebben et al., 2023), and

(2) healthcare programme (de Jong et al., 2025). Both design guidelines did not record and present design features from effective instructional 360° video (de Jong et al., 2025; Wuebben et al., 2023). Although the design model by Syarifuddin (2024) consists of design elements extracted from high quality 360° video artefacts, but such design model has yet to be evaluated in practical contexts.

VR-based Educational Animation Design Model

The VR-based educational animation design model by Syarifuddin (2024) consists of 13 categories with 41 core concepts (see Figure 1). Core concepts can be divided into singular essential core concepts and multiple supportive core concepts. The singular essential core concepts are those that under these seven categories i.e. Lesson Design Guidance, Visual Appearance, Virtual Environment, Sequence of Scene, Guided Viewing Route, Presenter Presence, and Presenter Appearance. Multiple supportive core concepts are those that under these six categories i.e. Attention and Redirecting, Visual Representation, Main Idea Supporting Elements, Unobtrusive and Complementary Sound, Animated Sequence Transition, and Engagement. During the design and development of the instructional materials, the singular essential core concepts play an essential role, for which from each category, one core concept must be selected and applied into the material design, however the selection of core concept should only be limited to only one core concept, as having more than one core concept shall lead to difficulty and confusion during the creation process. Multiple supportive core concepts assumed a supportive role that help to further enhance the fundamental composition of instructional material that made up of essential core concept. They enhance the learning process by offering additional depth, clarity or context to the essential concepts. During the design and development of the instructional materials, creators can make use one or more than one core concepts from the same category.



Figure 1. VR-based Educational Animation Design Model (from Syarifuddin, 2024)

Conceptual Framework

To address the research questions and objectives, this research study sought to evaluate and improve the proposed design model from user aspects, with user provided user understanding data (test performance i.e. test score to reflect whether the design choices used can help in achieving the desired outcomes) and user satisfaction data (user subjective experiences, opinions, preferences and expectations on the design elements).

As noted by Abdulrahman et al. (2020), evaluation involves evaluating whether a multimedia tool accomplish the goals set which includes being helpful or practical for its intended audience. A proof-of-concept study is a feasibility demonstration that a particular theory or concept possesses the potential in terms of greater application. Such study is not a pilot study; it is designed to find out the possibility of a concept's feasibility prior to a pilot study is carried out and it has a very small size of sample in general. The proof-of-concept study is regarded as an opportunity for capabilities demonstration in a controlled and small-scale manner, as well as for informing future development investments (Krauskopf et al., 2018). As stated by Amrullah et al. (2022), the feasibility of an educational animation video can be examined from three criteria, i.e., valid (having valid content), practical (positive learning experience e.g., easily to find clues in video), and effective (improvement of skills).

As stated by Hossain (2023), the evaluation techniques for educational interactive multimedia resource like VR and AR entail: (1) technique that assesses pedagogical alignment, (2) technique that measures learning outcome and efficacy, (3) technique that obtains feedback on user experience, as well as (4) technique that explores motivation and engagement. This research focused on the use of two evaluation techniques i.e. (1) technique that measures learning outcome and efficacy that involves examining learners' ability to put what they learn from the educational multimedia resource into practice, and (2) technique that obtains feedback on user experience that involves obtaining user's view with regard to the general satisfaction and usability of the educational multimedia resource.

Effectiveness refers to the achievement of goals. The achievement of educational goals is therefore central to the concept of educational effectiveness (Creemers & Scheerens, 1994). According to Reynolds et al. (2014), learner achievement remains as the primary criterion of effectiveness in educational effectiveness research. Among the 26 empirical educational studies on 360° video reviewed by Evens et al. (2023), learning content mastery is the most utilised dependent variable in assessing the effectivity of 360° videos. One group pre-test and post-test is often used in evaluation studies, such as examining the change in the student, examining the changes in the understanding of a subject, or testing the effectiveness of a programme (Shek & Sun, 2012).

User satisfaction has a four-decade history in information technology (IT) evaluations with the purpose to provide an illustration on what is needed (or expected) by the user versus what is delivered by the IT artefact (Ulrich et al., 2019). As stated by van Velson et al. (2008), group discussions and focus groups are appropriate for obtaining qualitative data in huge amount within a short period of time. Groups discussions and focus groups may aid in obtaining or achieving a more in-depth comprehension of the user behaviour, intention of use and appreciation (van Velson et al., 2008). Since researcher would like to opt for more in-depth data on user satisfaction, thus focus

group would be a better option for this research.

Moreover, the valid criteria in this study were within the control of the researcher (researcher ensured the video content is accurate and valid prior to YouTube upload), while both the practical and effective criteria of the model were examined using focus group study. There were two data collection activities or sessions inside one focus group study, i.e. (1) pre-test and post-test, and (2) focus group interview. The data for effective criteria (user understanding) was gathered using test instrument (pre-test and post-test) while the data related to practical criteria (user satisfaction) was elicited with the help of interview instrument (focus group interview).

Through collect data for effective criteria using pre-test and post-test approaches, this helped to address research question (RQ) 1, while the data related to practical criteria elicited using focus group interview aided in addressing RQ2. The revision of proposed model based on the testing conducted with user feedback aided in answering RQ3. At the end of this study, a VR-based educational animation design model that made up of perspectives from researchers (previous study) and users i.e. learners (current study) was established (see Figure 2), so as to provide a more holistic view to any content creator or educators regarding the unique design elements when adopting this design model for the production of VR-based educational animation. While creating VR-based educational animation, the content creator can refer to and involve the perspectives coming from both researchers and learners.

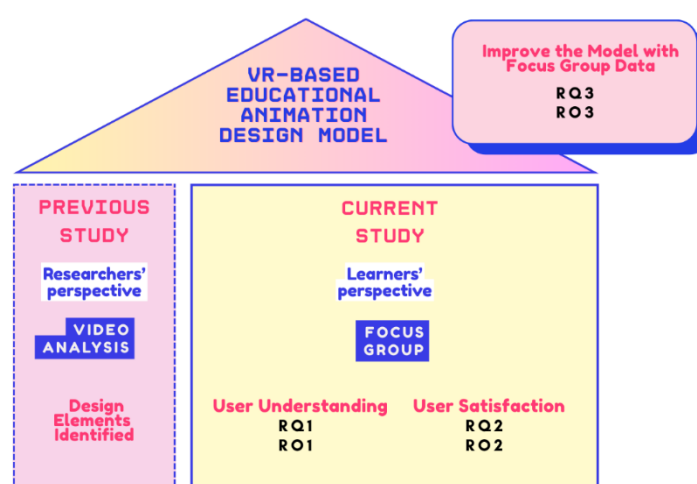


Figure 2. Design Model Constructed Based on Two Perspectives

Method

Research Design

In this study, mixed methods approach was used for data collection and analysis (Beatty et al., 2009; Dawadi et al., 2021; Kaushik & Walsh, 2019; Patel, 2015; Pretorius, 2024), and the study was conducted in a focus group context. The focus group study consisted of two data collection activities namely, one group pre-test and post-test (Capili & Anastasi, 2024) and focus group interview (Gill & Baillie, 2018; Muijeen et al., 2020). This study adopted a convergent design, where quantitative and qualitative data were combined and used to improve the design model (Creswell & Creswell, 2018; Creswell & Plano Clark, 2018). As for the research process flow, in current study, 23 out of 41 design elements of the design model were used to develop the VR-based educational

animation, then followed by focus group study, then lastly improved the design model.

Focus Group

The focus group study was to evaluate the proposed model through proof-of-concept of educational 360° animation video. Universiti Malaysia Sarawak (UNIMAS) was the study site, overall, there were five focus group studies. The focus group was conducted by one moderator (project supervisor (SV)) and one assistant (researcher) (Nyumba et al., 2018). The target population was the students from UNIMAS, and the participants were selected through purposive sampling (Nyumba et al., 2018).

Inclusion Criteria:

- Must be a UNIMAS student who agreed to participate in this study regardless of age, gender, race, year of study, and programme, as well as not having prior knowledge about the content to be presented.

Exclusion Criteria:

- UNIMAS student who did not agree to participate in the focus group study.
- UNIMAS student that has prior knowledge about the content to be presented.

Focus group was conducted at Discussion Room 2 in Tun Abdul Rahman Ya'kub Library (PeTARY) UNIMAS, there were 19 participants in total. Participant recruitments were conducted physically at PeTARY. Figure 3 showcases the data collection procedures during focus group undertake, starting with pre-test, then viewing of video, then post-test and lastly focus group interview (Allcoat & von Mühlenen, 2018; Chua et al., 2022; Creswell & Creswell, 2018; Creswell & Plano Clark, 2018; Harris et al., 2006; Hayat, 2021; Shek & Sun, 2012; Sim & Waterfield, 2019; Ulrich et al., 2019).

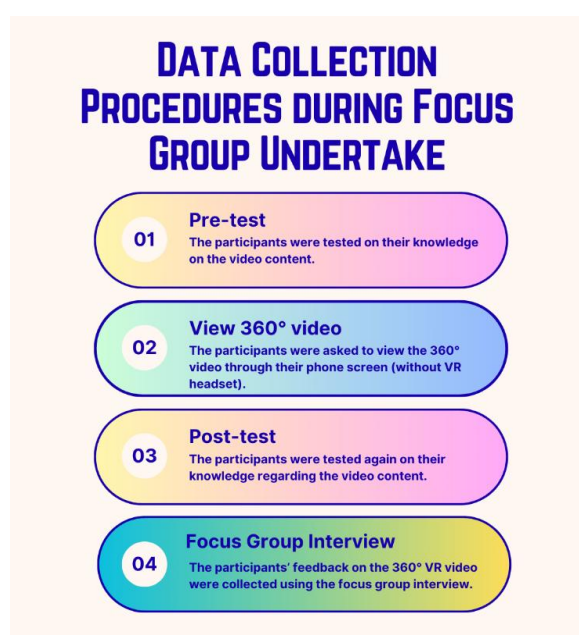


Figure 3. Data Collection Procedures during Focus Group Undertake

The five focus groups were conducted during the mid-semester break (from Monday to Friday), with one focus group study per day, each with varying number of participants (maximum five participants per group) (Gundumogula, 2020; Moser & Korstjens, 2018) and duration (see Table 1). The estimated duration was one and a half hours per study (Muijeen et al., 2020).

Table 1. Focus Group Studies Details

Focus Group (FG)	Number of Participants	Pseudonym	Duration
FG1	4	Hazim, Onail, Rosli, Eric	2 hours 1 minute
FG2	4	Jap, Matcha, Nunez, Chan	2 hours 4 minutes
FG3	3	Johan, Sree, Windy	1 hour 56 minutes
FG4	3	Nana, Dante, YJ	2 hours 5 minutes
FG5	5	Rin, Joan, Yen, Man, Rowil	1 hour 47 minutes

The 19 participants were from 9 out of the 10 faculties in UNIMAS. The participants' ages ($M = 22.21$; $SD = 4.74$) ranged from 19 years old to 41 years old. Among the 19 participants, there were 8 female participants (42%) and 11 male participants (58%). As for race, the participants were comprised of eight Chinese (42%), three Malay (16%), two Iban (11%), two Indian (11%), one Dusun (5%), one Banjar (5%), one Bidayuh (5%) and one Bajau (5%). In terms of the educational level currently being pursued, only one participant (5%) was currently pursuing a Doctor of Philosophy (PhD) while the rest ($n = 18$; 95%) were currently pursuing a degree. Regarding participants' experiences with VR-based animation video prior to participating in this research, only five participants (26%) ever watched VR-based animation video. All participants ($N = 19$; 100%) never encountered classes that use VR-based content. As for the type of device owned, all participants owned a mobile phone (100%), 15 participants owned a personal computer (PC) (79%), and 12 participants owned a tablet (63%).

During data collection, researcher and moderator properly informed the participants on matters like anonymity, compensation, and informed consent prior to the conduct of focus group. The moderator also explained the ground rules and ethical protocols of the focus group to the participants. Participants were asked to sign a consent form (only if they agreed to participate). The researcher also obtained participants' permission prior to recording. To create a conducive environment for the learning of video content, participants were requested to bring and use their own earphones during video viewing (to prevent a noisy and distracting environment due to the sound played on each participant's mobile phone in cases where earphones are not used). At the end of the session, each participant received 15-ringgit tokens.

360° Educational Animation

For video creation, there were three people involved in the creation of VR-based educational animation, namely researcher, animation programme master student and project SV. All three brainstormed on suitable video topic content together. Animation programme master student acted as the animator while the educational content and learning goals were developed by the researcher. Project SV and researcher pilot testing the video with learners.

When crafting the content, recognised sources like journals, websites and books were used to ensure the content developed is accurate. The content was given a title “Harmony with Nature”, the video content was about introducing the viewers to the production process of Sarawak local products, in which the local products are plaited item (i.e. Rattan Basket) and food products (i.e. Sago Pearl and Nipa Sugar) (see Figure 4 for screenshots of animation). The video duration was 11 minutes and 20 seconds. The voice of the virtual mascot was generated using artificial intelligence (A.I.) (site used: Clipchamp). Animation and recording were done using Unity 3D. In current study, 23 out of 41 design elements of the design model were used to develop the VR-based educational animation. Table 2 showcases the core concepts used or presented in 360° educational animation.



Figure 4. Screenshots of 360° Educational Animation

Table 2. Core Concepts Presented in 360° Educational Animation

Category	Design Element/Core Concept Used
Lesson Design Guidance	Tracking Lesson
Attention & Redirecting	Text Signalling, Object Signalling, Contrast Signalling, Verbal Signalling, Sound Signalling
Visual Representation	Non-numerical Data
Main Idea Supporting Elements	Visual Reference, Textual Reference
Unobtrusive & Complementary Sound	Non-disruptive Ambiance
Visual Appearance	Stylised Design
Virtual Environment	Virtual Reality
Sequence of Scene	Sequence of Multiple Scene
Guided Viewing Route	Travel
Animated Sequence Transition	Segment
Presenter Appearance	Virtual Presenter
Presenter Presence	Occasional Presence
Engagement	Ambiance Animation, Lesson Structure (Informative Main Title, Appealing Lesson Starter, Impactful Lesson Closure, Appropriate Lesson Pacing), Subject Focus (Object Focus)

Research Instruments

The research instruments prepared in this study were: (1) test instrument (Ghidinelli et al., 2021; Jovanovska, 2018; Liu et al., 2023) and (2) interview guide (Barriball & While, 1994; Bearman, 2019; Creswell & Guetterman,

2021; Creswell & Plano Clark, 2018; Jacob & Furgerson, 2012; McIntosh & Morse, 2015; Rabionet, 2011; Roberts, 2020; Turner III, 2010). As for the test instrument, both pre-test and post-test instruments are having the same question, number and structure, only question order is different. There were 10 multiple choice questions, each with 4 options. Questions were designed to examine participants' knowledge level or understanding of the production process of Sarawak local products (see Appendix A and B). As for the Interview Guide, there were 15 main interview questions (see Appendix C), each their own probes and follow up questions. The questions were used to explore participants' video viewing experiences. The research instruments preparation steps begin with the creation of first drafts, then expert review by Project SV, followed by pilot testing and lastly ethical review (Castillo-Montoya, 2016; Considine et al., 2005; Creswell & Guetterman, 2021; Creswell & Plano Clark, 2018; Desai & Patel, 2020; Kipli & Khairani, 2020; Lee, 2025; Majid et al., 2017; Sundram & Romli, 2023; Yeong et al., 2018; Yusoff, 2019).

Data Analysis

Since all participants were involved in every data collection procedure of the focus group study, hence all of them were included in the analysis. After data management (Lin, 2009; Sim & Waterfield, 2019), demographic info (Fisher & Marshall, 2009; Hayat, 2021; Kaliyadan & Kulkarni, 2019; Ranganathan & Gogtay, 2019) and the participants scores (Bettany-Saltikov & Whittaker, 2014; Byrne, 2007; Hasija, 2023; Hayat, 2021; Mishra et al., 2019; Parab & Bhalerao, 2010) were subjected to statistical analysis. The content analysis was used to analyse the interview transcripts (Bengtsson, 2016; Bingham, 2023; Cheung & Tai, 2023; Erlingsson & Brysiewicz, 2017; Vears & Gillam, 2022). The descriptive statistic which functions to describe the data set feature (Byre, 2007) was used to analyse the nominal, ordinal and discrete data while inferential statistic (Byre, 2007) was performed on discrete data i.e., students mark to identify whether is there any significant different between the pre-test and post-test result. From the result of normality test (Shapiro-Wilk Test) (Mishra et al., 2019), it was found the test statistic, W for pretest data and post test data were 0.954 and 0.916 respectively, while the p value for pre-test data and post-test data were 0.453 and 0.094 respectively. Since the student marks are normally distributed, thus, paired sample t test was performed.

Content analysis only involved single coder i.e. researcher; with two rounds of coding. Data were analysed manually using Microsoft Excel. The overall content analysis process started with first round coding, then peer debriefing and lastly second round coding. The first round of coding involved using the pre-defined categories and codes (13 categories with 41 codes) to identify those text segments with messages that fit the description, and for those remaining text segments that could not be coded with the pre-defined codes, researcher focused on identifying novel concepts (if any) that shall lead to new subcategories or codes, only then grouped the new subcategories or codes to relevant category. The first round coding consisted of three coding phases, phase 1 focused on reading and familiarising the data, then phase two focused on identifying big picture meaning units, phase 3 focused on performing literature coding and developing new subcategories for text segments not coded with literature code (Bengtsson, 2016; Bingham, 2023; Creswell & Guetterman, 2021; Erlingsson & Brysiewicz, 2017; Kleinheksel et al., 2020; Rabiee, 2004; Sutton & Austin, 2015; Vears & Gillam, 2022). There were three peer debriefing, one face-to-face and two via Microsoft Teams. Second round coding was performed after a 20-

day gap since researcher's last discussion with Project SV via Microsoft Teams, and in this phase, researcher went through the coding decision in phase three at once to see if researcher still agree with the coding decision made (Ahmed, 2024; Coleman, 2022; Kyngäs et al., 2020; Schreier, 2012).

Results

Statistical Analysis Results

With reference to Royal and Stockdale (2017) and Ghent University (2025), participants that answered 6 questions and above correctly were considered to have a good level of knowledge, while participants that having correct answers less than 6 questions i.e., 5 questions and below were considered to have bad level of knowledge. Before the intervention, only four participants (21%) had good level of knowledge while after the intervention, there were 11 participants (58%) having good level of knowledge, and the enhancement percentage is 37% (see Table 3).

Table 3. Description of Participants' Knowledge on Video Content

Knowledge	Before Intervention		After Intervention		Enhancement
	<i>n</i>	%	<i>n</i>	%	
Bad	15	79%	8	42%	37%
Good	4	21%	11	58%	

The result showed that the mean score of post-test was higher than the mean score of pre-test ($6.53 > 4.47$). There was a significant average difference between the pre-test score and the post-test score ($t(18) = 4.572, p < .001$). On average, the post-test scores were 2.05 marks higher than the pre-test scores [95% CI [1.11, 3.00]] (see Table 4).

Table 4. Paired Samples Test

	Paired Differences					<i>t</i>	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Post-test Score – Pre-test Score	2.05	1.96	0.45	1.11	3.00	4.572	18	<.001

Content Analysis Results

As for content analysis results, there were 13 categories and 40 subcategories (see Table 5). Among the 40 subcategories, it was revealed that the text segments contain messages that fit the description of the 36 pre-defined sub-categories or codes, while the other four (italicised) were inductively developed from those segments that did not fit the description of pre-defined codes. The reason why all the newly developed subcategories were grouped under Engagement Category is because they were considered as a component that might influence learner

engagement based on participants' feedback.

Table 5. Categories and Subcategories

Category	Subcategory
Lesson Design Guidance	Tracking Lesson
Attention & Redirecting	Presenter Signalling, Text Signalling, Object Signalling, Contrast Signalling, Verbal Signalling, Sound Signalling
Visual Representation	Numerical Data, Non-numerical Data
Main Idea Supporting Elements	Visual Reference, Textual Reference
Unobtrusive & Complementary Sound	Emotional Response, Non-disruptive Ambiance
Visual Appearance	Realistic Design, Stylised Design
Virtual Environment	Mixed Reality, Virtual Reality
Sequence of Scene	Sequence of Multiple Scene, Sequence of Singular Scene
Guided Viewing Route	Travel, Stationary
Animated Sequence Transition	Morphing, Segment
Presenter Appearance	Live Action Presenter, Voice-only Presenter, Virtual Presenter
Presenter Presence	Consistent Presence, Occasional Presence
Engagement	Ambiance Animation, Storytelling (Visual Storytelling, Verbal Storytelling), Lesson Structure (Informative Main Title, Appealing Lesson Starter, Impactful Lesson Closure, Appropriate Lesson Pacing), Subject Focus (Object Focus), <i>Ambiance Sound, Clear Resolution Quality, Audio Narration Quality (Enunciation Quality, Appropriate Sounding Voice)</i>

For the 23 design elements presented in VR-based educational animation, each design element did receive positive feedback, as reflected in the text segments coded into 23 pre-defined subcategories. Below showcases a few examples of the positive feedback received.

Category: Attention & Redirecting

- *Signalling (Text, Object, Contrast, Verbal, Sound)*. The signalling elements were “helpful” (Rosli) and managed to guide participants' attention towards the important content.

Category: Main Idea Supporting Elements

- *Reference (Visual, Textual)*. For Matcha and Jap, the components that support them to understand the main idea is the “labelled diagram” in the slide.

Category: Unobtrusive & Complementary Sound

- *Non-disruptive Ambiance*. Six participants (Hazim, Johan, Sree, Windy, Dante, Man) noticed the beach sound. The beach sound was “calming” (Hazim), not distracting, and contributed to immersive-ness of the video.

Category: Visual Representation

- *Non-numerical Data*. Onail found the abstract concept presentation was “very detailed” and “not too complicated” in a way that it is easy for him to understand.

Category: Engagement

- *Lesson Structure (Informative Main Title, Appealing Lesson Starter, Impactful Lesson Closure, Appropriate Lesson Pacing)*. Some participants found the title presented, introduction and closure were acceptable i.e. “okay” (Hazim) and there was no issue with that. As for some participants, the video was “nicely paced” (YJ).
- *Subject Focus (Object)*. Some liked the way the objects are being showcased to them e.g. floating items looked like a “loot” (Dante) which could be the centre of attention.

Besides, participants also offered their opinions e.g. suggestions based on their subjective experience with the design elements presented in the video.

Category: Lesson Design Guidance

- *Tracking Lesson*. Since description of each production process was done in the same way, two participants mentioned such repetitive format could lead to reduction of attention in learners and as a result, learners may not be able to retain the information delivered. YJ noted: “It’s like the same thing all over again. I wish there was like different media.”

Category: Attention & Redirecting

- *Verbal Signalling*. The narration was lacking “intonation” (Johan) that helps to emphasise important parts to the learners. Some noted that it is important to have intonation.

Category: Visual Representation

- *Non-numerical Data*. Since the abstract concept presentation was making use of both actual photos and animated icons to deliver the message, where Dante found it hard to focus on the presentation and suggested focus on animating and presenting a particular type of visual component, he noted: “It’s better to use, if picture, use all picture instead of different media.”, so that the abstract concept presentation looks consistent and better helps him in understanding the content.

Category: Visual Appearance

- *Stylised Design*. The colour scheme of the video was “not appealing” (Matcha), so some participants suggested to use more vibrant and “aesthetic” (Yen) colour to make the content delivery better.

Category: Virtual Environment

- *Virtual Reality*. Some participants mentioned the virtual space should be utilised more efficiently via (1) using more multimedia, and (2) having the components e.g. 3D products pop up around the hut. There were also participants who felt that if there are too many 3D models, the learners “might get a bit overwhelmed” (Hazim).

Category: Unobtrusive & Complementary Sound

- *Non-disruptive Ambiance*. For learners who are poor in language medium used (e.g., “English” (Joan)) to keep up with content (highly informative and unfamiliar), without background music is fine.

Category: Sequence of Scene

- *Sequence of Multiple Scene*. Participants preferred to have one special scene for each sub-topic, Sree noted: “I prefer like the three things in another three different worlds.”

Category: Guided Viewing Route

- *Travel*. Jap expressed that the content viewing pathway was “a bit off”. Jap faced issue in locating the

presenter when arriving at the screen of the next product, hence he suggested having the whole information delivery process is like having the presenter alters its form from 3D (guide the viewer to screen) then change to two-dimensional (2D) (appear inside the screen in 2D form during explanation) then becoming 3D again (guide the viewer to another screen).

Category: Animated Sequence Transition

- *Segment.* There was an “awkward quiet gap” (Nunez) between the transition of the products. To address the awkward quiet gap, there were three suggestions: (1) character still providing information verbally while bringing the viewer to the next product, (2) adding “background music” (Chan), or (3) using a faster transition, then with or without music is fine.

Category: Presenter Appearance

- *Virtual Presenter.* Some preferred to have the character to serve the role as a guide and instructor rather than just function as companion pet only, as Sree noted: “I prefer like this one... guide us...[...] Make sure you don’t lose...”. The presenter was “a bit static” (Nunez) and less expressive. There were suggestions on making the virtual presenter more expressive i.e. more facial expression (e.g. moving brows) and more body gesture to attract more attention.

Category: Presenter Presence

- *Occasional Presence.* Johan did not aware of presenter presence inside the hut, so he suggested making the size of the virtual presenter bigger as it was harder to spot the presenter inside the hut due to small size of the presenter.

Category: Main Idea Supporting Elements

- *Visual Reference.* Some participants mentioned the pictures were understandable, however, they suggested making the pictures, i.e. icons more colourful because those pictures were “mostly like black and white” (Sree). Dante mentioned the explanation of the process was “hard to understand” due to the lack of proper visuals. Participants suggested adding more visuals (e.g. 3D animated demonstration, real footage, or real image around the space as a supporting element) to help the learners to understand because in the video, only pictures and icons were presented, so they did not know how the things were processed and made.
- *Textual Reference.* Some found the textual elements were “enough” (Sree). Dante found the video was hard for him to understand because there were too many words, where he noted: “It just focuses on too much word setting.”

Category: Engagement

There were participants who found the video engaging, where they were still able followed to the end, and since the video was not too long, some found it bearable as well. Some regarded the video was less engaging because there was not enough animation, making the video components appeared static and bland. Participants suggested adding more animation to make the video more engaging. Some participants mentioned that the video was engaging only in the first three minutes. The video became less engaging as the content progressed because (1) the viewers were not moving during the explanation of production process, as well as (2) the repetitive pattern when it came to the explanation of production process.

- *Ambiance Animation.* Some participants suggested adding more (1) moving things (e.g. campfire) and (2) moving people at the background. Windy did not support the idea of having people moving at the

background, as surrounding people could distract her.

- *Lesson Structure (Informative Main Title)*. Some “did not notice the main title” (Joan), so it has been suggested to lengthen the time of title display so that the viewer can notice the title easily.
- *Lesson Structure (Appropriate Lesson Pacing)*. Some felt the overall learning journey was quite “fast” (Yen, Joan) paced and tight. Johan preferred having pause moments created by the creators instead of having one paused the video manually by oneself using the video player pause button.
- *Subject Focus (Object)*. The video was not very “user friendly” (YJ), which was due to the small screen size. YJ suggested having pop up user interface so that it is easier to see, thus making the information delivery more user friendly.

User feedback also contained information related to 13 other design elements of the design model (in addition to the 23 design elements presented in the video), as reflected in the text segments coded to 13 pre-defined subcategories.

Category: Attention & Redirecting

- *Presenter Signalling*: The “flying” action of the bird helped Joan to notice and keep track of the important content.

Category: Visual Representation

- *Numerical Data*. Jap suggested adding some statistical visuals for numerical data e.g. “how many percent of component” and “duration” because while he was listening to the narration on numerical data, there was no visuals that he could refer to.

Category: Unobtrusive & Complementary Sound

- *Emotional Response*. Rosli preferred the use of the “upbeat and motivational music like in documentaries”.

Category: Visual Appearance

- *Realistic Design*. Sree mentioned that maybe a more realistic art style could be adopted for “science related topics”.

Category: Virtual Environment

- *Mixed Reality*. Seven participants preferred mixed reality, where they were okay with adding real-life elements in the animation. Rin noted: “Yeah, I prefer mixed.”

Category: Sequence of Scene

- *Singular Scene*. When it comes to the idea of viewers staying in one scene with frequently changing environment, Hazim found such approach interesting. Hazim stated: “Personally, I do like it more when the scene changes around me because I think it is much more interesting.”

Category: Guided Viewing Route

- *Stationary*. According to the feedback, it is better to have the user “fix” (Yen) at a stationary spot during the explanation and are free to move to the next spot after the explanation, so that they would not lost track of information.

Category: Animated Sequence Transition

- *Morphing*. Eric did not prefer the scene to change totally in a sudden: “Like suddenly, no. [shake head]” while Hazim preferred morphing transition: “I prefer this.”

Category: Presenter Appearance

- *Live Action Presenter*. YJ was willing to try out the concept of having a real human as a presenter. From Man's perspective, unless the live action presenter is “famous person”, only then he would be okay with the use of real life human as presenter.
- *Voice-only Presenter*. Participants were okay with the use of voice-only presenter given (1) “the quality of the voice recording is just nice” (YJ), and (2) “the narration is as engaging as how David Attenborough does his narration” (Nana). According to Nana, some visual cues are needed to compensate for the lack of visual guidance in the video.

Category: Presenter Presence

- *Consistent Presence*. Windy preferred consistent presence as she would be startled by presenter’s sudden appearance.

Category: Engagement

- *Storytelling (Visual, Verbal)*. Nunez mentioned (1) visual storytelling elements and (2) verbal storytelling elements can attract his attention and keep him engaged.

From the text segments that could not be coded with the predetermined codes, four new subcategories (grouped under Engagement Category) emerged via inductive coding. User feedback related to the A.I. voice used had led to the emergence of two subcategories i.e. (1) Audio Narration Quality (Enunciation Quality), and (2) Audio Narration Quality (Appropriate Sounding Voice). Some mentioned that the audio was “too long” and “wordy” (YJ). Due to the long and wordy audio, Dante found the video was hard for him to understand, making it hard to pay attention to one point.

- *Audio Narration Quality (Enunciation Quality)*. The pronunciation of certain localised words, e.g., Sarawak, were too westernised, making the video less immersive. Rin suggested using a voice over of “local people” who know the correct pronunciation. Hazim did not mind about the accent of human voice, as he believed accent could give the presenter more character. As long as the pronunciation is clear, Hazim would be fine with the use of human voice. As an international student, Joan preferred the use of A.I. voice due to standardised pronunciation. For Joan to keep up with the content, the use of A.I. voice is needed.
- *Audio Narration Quality (Appropriate Sounding Voice)*. The audio sounds very generic, robotic and monotone. According to Nunez, such voice tone is one of the reasons that not keeping him engaged to the video. Dante noted: “Yes, sounds robotic and unnatural which could bore the audience.” Some participants did not mind whether it is A.I. or human voice, as long as it sounds natural to the audience (e.g., advanced A.I. that can mimic Sarawakian accent). Dante and Nana supported the use of stylised voice (voice acting), and they thought the use of voice should match the appearance of the character. Jap was fine with the used of synthetic voice as he expected the VR video to be “fully artificial”, and in cases where human voice is included in virtual environment, this would make the virtual environment less immersive for him. Joan (the only international student) mentioned that if local people's voice is used, maybe she would lose track of the content as she is not familiar with local accent. For local student i.e. Rin, Yen, Man and Rowil, they preferred to have more localised sounds, as they are familiar with localised sound and localised voice can keep them more engaged due to the intonation.

User feedback related to the resolution quality and the absence of sound effect had led to the emergence of (1) Clear Resolution Quality and (2) Ambiance Sound respectively.

- *Clear Resolution Quality*. Some participants found the existing quality was okay and sufficient. Dante found the current resolution was “kind of blurry”, which might lead viewer to feel bored. According to Dante, higher resolution is better, maybe the creators can attract more users or audiences.
- *Ambiance Sound*. Participants mentioned the lack of footstep sounds, so it felt as if the viewer was following the presenter in a floating manner. Participants suggested adding sounds like “footstep sounds” (Man, Dante) and “the sound of the door open” (Yen) to make the virtual environment more realistic and more immersive, so that the viewing experience could be improved.

Discussion

Research Objective I

The improvement of participants’ knowledge on video content with VR-based educational animation was shown by the result of pre-test and post-test. Since there was a significant average difference between the pre-test score and the post-test score (failed to reject the hypothesis), indicating the design model has the potential in meeting (1) the expected educational outcomes in practical context, as well as (2) the original intention of Syarifuddin (2024) when creating this design model (i.e. establishing a design model that can assist the creators in the creation of high quality VR-based educational content that promotes learning and improves educational outcomes). This proof-of-concept of animation suggests that this concept idea (i.e. design model) possesses the potential to be applied as a reference or guide for creating VR-based educational materials that can help in achieving educational outcomes in a higher education context or setting.

Research Objective II

This study managed to collect feedback related to 36 core concepts (including the 23 core concepts presented in 360° educational animation) and recognise four new design elements that are not originally part of the design model. Positive feedback on the 23 design elements presented in video indicates that these 23 design elements hold the potential in helping learner with their learning. The feedback related to 13 other design elements in the design model (not shown in the video) reflects that these 13 design elements might have practical value for a specific audience or learning event. This section focuses on discussing the insights gained from user feedback.

Verbal cues involve emphasising key messages via techniques such as voice modulation (Ji & Zheng, 2025). In this study, it was mentioned that the narration was lacking intonation that helps to emphasise important parts to the learners. Hence, this shows that it is important to have intonation when adopting *verbal signalling*, so that the important messages can stand out to the learners. One participant mentioned that for learners who are poor in language medium used (e.g., English) to keep up with content (highly informative and unfamiliar), without background music is fine. Background music can affect cognitive performance, particularly in the time of complex tasks, where excessive arousal levels can distract attention and reduce performance (Lachance et al., 2025). Hence, when presenting the content to learners who are poor in the language medium used, might need to avoid the use

of background music (*non-disruptive ambiance* and *emotional response*). The feedback coded to *appropriate lesson pacing* revealed that participants preferred having pause moments created by the creators instead of having them paused the video manually by themselves using the video player pause button. The messages elicited are aligning with and to be further supported by what have been stated by Fiorella (2021) i.e. learners may be unwilling or unable to effectively manage the video lesson pacing themselves. System-determined pauses offer learners more time for information processing prior to moving into the next segment of the lesson (Fiorella, 2021).

Based on the comments, the *virtual presenter* was a bit static and less expressive, hence several suggested making the presenter more expressive i.e. more facial expression (e.g. moving brows and smile at participant) and more body gesture to attract more attention. As noted by Tao et al. (2022), the movement features of pedagogical agents predominantly comprise body movement (predominantly movement of hand) and head movement (eye guidance, nod, subtle changes in facial expression). It has been demonstrated that learning can be better facilitated by dynamic agents compared to static agents. The authors also pointed out that one should not ignore the impact of motion features of pedagogical agents on learners (Tao et al., 2022). The findings revealed that the placement of 3D models in the virtual environment (refer to *virtual reality* and *ambiance animation* subcategories) should be done in optimally, as the learners might get a bit overwhelmed if there are too many 3D models. In cases where there is a large amount of visual information display graphically at once, the act of filtering out the relevant learning content causes learners to become overwhelmed easily (Albus & Seufert, 2022). Incomplete information selection can lead to incomplete connections between information within the working memory (Albus & Seufert, 2022).

When it comes to the perception on wordiness, some found the text elements provided is just right, while some perceived as too wordy. Dante mentioned that the video was hard for him to understand because there were too many words. When designing content that is to be viewed on small screen i.e., smartphones, the creators should avoid the use of long texts because reading long texts on a small screen can be difficult (Beautemps & Bresges, 2021). One participant mentioned the video was not very user friendly, which was due to the small screen size (i.e. the virtual screen element presented inside the virtual hut environment). According to Kim and Kim (2012), learners could face more challenges in perceiving and comprehension of learning content in cases where a smaller screen is utilised for instruction; not to mention that in this study, participants had to view another "screen" element in the virtual environment through their phones. In addition, the user feedback revealed one participant did not realise presenter presence inside the hut, where he suggested making the size of the virtual presenter bigger as it was harder to spot the presenter inside the hut due to small size of the presenter. This reflects that creator should pay attention to the size of the information delivery components within the virtual environment for a better information delivery.

Although the creator did not consider the flying action of presenter as guiding cues, but some participants did consider it helpful in attracting their attention towards the main content. For the idea of using *live action presenter*, one was willing to try out the concept of having a real human as a presenter and one supported the idea with condition i.e., unless the presenter is a famous person. It has been suggested that learning performance may be enhanced when an agent with a self-selected favourite face such as a celebrity face is utilised compared to the

case where an agent with an actual instructor's face is adopted (Mizuho, 2023). The creators who intended to adopt *voice-only presenter* should pay more attention towards the *audio narration quality* and usage of signalling elements during video making. In situations that require careful observation and focus on a specific element, such as a visual or textual reference as the verbal information progresses, the *stationary* core concept may work well with the *object focus* core concept.

Generally, sound effects were associated with greater immersion and enjoyment. Character sounds are the sounds caused by the character's actions (e.g. attacks or footsteps). Character sounds may provide a more realistic virtual environment by serving as auditory action feedback, helping to establish an explicit association between actions and consequences (Haehn et al., 2024). Though there is no event of user having control over an avatar happened inside a VR-based video, but the sound effects suggested by the participants e.g. footsteps and door opening sound (refer to *ambiance sound* subcategory) are more leaning towards character sounds, the goal is to create the illusion that the viewer is performing actions, such as walking, throughout the predetermined viewing pathway within the virtual world as the content progresses.

Regarding the resolution quality of the video, although the video has reached 4k resolution, contradictory feedback was received, with some people believing that the existing quality was okay and sufficient, while others found the video blurry and from their point of view, the video did not reach 4K resolution. It was believed that low resolution quality it might lead the learners to feel bored. This is also aligned with participants feedback in the study by Allman et al. (2022), it was mentioned that the factor that negatively affect participant's enjoyment of VR experience is poor video quality (e.g., perceived low resolution), because poor video quality contributes to lower immersion, emphasising that content fidelity is a crucial element to the level of immersion when viewing VR-based material. Hence, this reflects that clear resolution quality plays a significance role in promoting learner's engagement, thus should be taken into consideration when designing VR-based educational content.

The A.I. voice used the video received varying comments from the participants, and it was revealed that voice dimension plays an important role in making the virtual environment more immersive, as well as in learner engagement. During sound and speech design, the creators should ensure audio narration quality. From the analysis, participants mentioned the A.I. voice used sounds very genetic, robotic and monotone, which is another reason that did not keep the participants engaged to the video. This feedback elicited is aligned with the students' negative comment on the agent voice in study by Wen et al. (2022), a significant number of students (21 out of 26) mentioned on the robotic and monotoned voice used in the study, it was suggested that the human-like and engaging aspects of the agent may be further enhanced with the use of real human voice, this indicates robotic voices are likely to distract learners. Moreover, from the feedback, the participants prefer *appropriate sounding voice*, where the voice used should (1) match with presenter appearance and environment setting, and (2) sound natural to the target audience (where audience is familiar with the accent used). *Enunciation quality* and recording quality are particularly important when human voice is used due to the accent of the narrator, it was mentioned that as long as the pronunciation is clear, the human accent would not be affecting the learning too much. As for some participants, they did not mind the use of synthetic voice if it sounds natural to them.

Research Objective III

The predetermined codes functioned as a filter to find out whether the interview responses contain messages that can lead one to identify or extract new design element(s) that is/are not originally part of the design model. From the user feedback, new design elements other than those in the design model were mentioned, in which they are: (1) *ambiance sound*, (2) *clear resolution quality*, (3) *audio narration quality (enunciation quality)* and (4) *audio narration quality (appropriate sounding voice)*. Based on the feedback and discussion, it seems that these design elements are crucial elements to the level of immersion and plays a significant role in promoting learner's engagement, hence they are grouped under the Engagement Category and functioned as supportive core concepts. Since some participants found the video less engaging, these newly identified design elements may serve as another design direction to engage learner. Through analysing user feedback and literature, despite the sound feature i.e. agent's voice is an important element in agent persona design (Tao et al., 2022), it was found out that the sound feature was not included in the design model and not being discussed in depth by Syarifuddin (2024). As noted by Klefodimos (2024), narrated animation helped learners to performed better compared to the other two forms of animation media i.e. (1) animation only and (2) on-screen text animation. Xu et al. (2024) also mentioned that learner's learning can be influenced by the voice in educational media. These messages reflect that it is worth having the core concepts i.e. *audio narration quality (enunciation quality)* and *audio narration quality (appropriate sounding voice)* to be included in the design model. The design model by Syarifuddin (2024) originally consists of 13 fundamental categories with 41 core concepts, while the outcome of this study consists of 13 fundamental categories with 45 core concepts (with additional four core concepts extracted from user feedback; and they are placed under Engagement Category) (see Figure 5). Table 6 showcases new design elements with their corresponding definition.

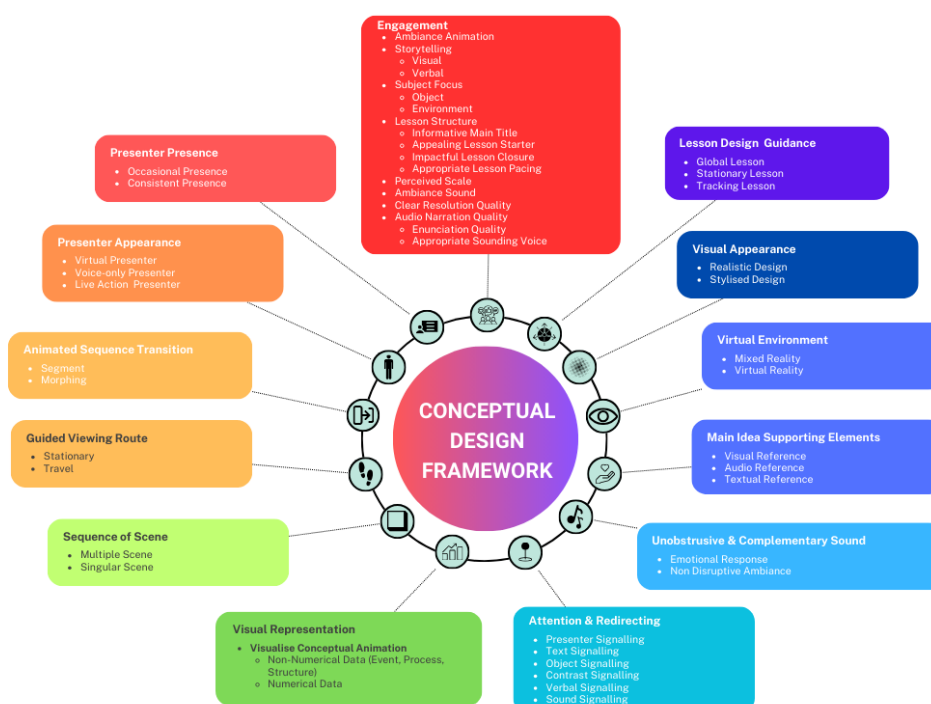


Figure 5. VR-based Educational Animation Design Model (Improved)

Table 6. New Design Elements with Their Corresponding Definition

New Core Concepts	Definition
Ambiance Sound	Sound effects such as footstep sound or door opening sound. These sound effects provide a sense of life and realism to the environment, making it feel more dynamic and immersive.
Clear Resolution Quality	Adequate level of detail and sharpness in visually displayed component that can promote a better viewing experience.
Audio Narration Quality	The spoken commentary that can make the virtual environment more immersive and help keeping learner's attention. It includes the characteristics like appropriate length, appropriate wording usage, as well as narrator's voice that fits the video theme including how it is generated (A.I. or human), its tone, language used (accent and pronunciation), and the recording quality of the vocals i.e. clarity.
i. Enunciation Quality	Speaking clearly and accurately, using the correct sounds and rhythms of a language, so that the learners would not find the pronunciation weird, thus making the virtual environment more immersive for them and allowing them to be able to keep up with the learning content. It includes the ability to follow the recognised phonetic patterns of words, as well as the ability to produce distinctive sound (articulation).
ii. Appropriate Sounding Voice	The use of voice that sounds natural and believable to the target audience and would not distract them from following the content or make them lose interest in the video content. Besides, the voice used matches or is consistent with the video topic and learning context, where the audience can understand why the voice is used because they are able to relate the use of voice with the video theme and learning context.

Conclusion

In summary, the improved design model consists of 13 fundamental categories with 45 core concepts. All four new core concepts were placed under Engagement Category. The testing conducted with user feedback adding up information about the potential effects of the design model in actual context. The findings indicate the design model has the potential in meeting the expected educational outcomes in practical context. This study managed to collect user feedback related to 40 design elements of the improved model; and also discussed the insights gained, the user feedback may serve as a useful reference to the creators in making their design decision. Within the improved design model, only Engagement Category has additional four new design elements while no new design element is added to any of the other 12 categories.

Limitations

Since the focus group study only involves students studying in local universities, for which the finding may vary

slightly in the data collection involving a broader range of participants. This study also did not manage to test and obtain feedback information for all the core concepts within the design model. The findings would be less helpful for creators and readers who seek to understand and explore (1) the effects of untested core concepts and (2) those core concepts that did not receive any feedback.

Focus group study were also subjected to the limitations posed by the data collection methods used, like self-selection bias due to the lack of randomization, the limitations of one group pre-test and post-test design like testing, maturation and regression to the mean, as well as the limitations of recorded focus group interview like Hawthorne effect and social desirability bias. Among those limitations, researcher put in effort to reduce those that can be mitigated by researcher like self-selection bias, Hawthorne effect, and social desirability bias. Researcher tried to minimise self-selection bias via incentive offering. Researcher utilised open-ended questions to minimise the concern about the Hawthorne effect.

Besides, during briefing session, the moderator created a welcoming space and communicated researcher's heartfelt desire and expectation i.e. to receive authentic and truthful comments about the animation video to the participants. Researcher tried to reduce social desirability bias via having the focus group conducted at a private location i.e. discussion room where the focus group conversation could not be easily heard by others, as well as involving a moderator who knows how to build rapport with participants, pay attention to their behaviour, and encourage them to share their opinions.

Significance of Study

This study is in line with the United Nations' SDGs on *Quality Education*, where learners can be given broader opportunities to use VR-based educational animations to enrich their learning experiences. Besides, this study also contributes to the ongoing development of 360° video in the education field.

Contributions and Implications

This study introduces a refined VR-based educational design model for VR-based learning, contributes learner's viewing experiences (without using VR-headset) to the literature, and provides a cost effective and more feasible example to implement VR-based educational animations in higher educational settings. The findings offer insights for creators on creating effective and engaging VR-based content and for Higher Education Institution in terms of the adoption of VR-based educational animation.

Future Research

Future research could explore the untested core concepts for their potential effects and user feedback, as well as animator's design experience and making use of animator's feedback information to further improve the design model. Besides, future evaluation and improvement of design model could involve university students from other university or geographical area, as well as learners from other age range or educational level.

Statements and Declarations

Acknowledgments/Notes: The paper was derived from the first author's master's thesis. The authors sometimes used Google Gemini in conjunction with tools like Cambridge Dictionary and relevant reading materials like journal articles for the purpose to explore accurate use of terms or words during manual paraphrasing of sentences, so as to ensure the messages can be conveyed to the reader clearly and accurately. The authors took full responsibility for the content of this paper. The content represents authors' original idea and meets academic integrity and quality requirements.

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Data Availability: De-identified data may be provided upon reasonable request, provided that ethical requirements are met. Raw data that contain identifiable information cannot be made available due to ethical reason.

Ethics Approval: The research instruments were sent to Faculty Human Research Ethics Committee (HREC), Universiti Malaysia Sarawak for ethical review and ethical approval was received (No. Ethics Approval: FACA-HREC(NM)/2024(2)).

Informed Consent: Informed consent was obtained from all participants (i.e. university students) involved in the study.

Conflicts of Interest: The authors have no conflicts of interest to disclose.

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Appendix A. Pre-Test Instrument

Date:

Time:

Venue:

Name:

Pseudonym:

Pre-Test

Dear participant, thank you for taking your time to answer the following multiple-choice questions. This pre-test instrument consists of 10 multiple choice questions, and it has been estimated that it may take around 5 minutes to read through the questions and complete the pre-test instrument. Please circle the most appropriate answer. While answering the pre-test instrument, aside from filling in your name and pseudonym, please do not to leave any other identifying marks on this pre-test instrument for the purpose to ensure anonymity and to protect your identity.

1. Which part of the rattan plant is primarily used in weaving basket?
 - A. Roots
 - B. Stems
 - C. Fronds
 - D. Flowers
2. Which of the following parts of sago palm contain the starch used to make sago pearls?
 - A. Sago Palm Flower
 - B. Sago Palm Trunk
 - C. Sago Palm Frond
 - D. Sago Palm Fruit
3. Nipa sap is collected from which part of nipa palm?
 - A. Flower Buds
 - B. Fruit Stalks
 - C. Fruitlets
 - D. Seeds
4. Which of the following best describes the timing to remove rattan leaf sheaths?
 - A. Throughout the weaving process
 - B. During the harvesting process
 - C. During the dyeing process
 - D. After the drying process
5. What properties of rattan would a skilled harvester consider when selecting rattan to harvest?

- I. Age
 - II. Odor
 - III. Aesthetic
 - IV. Thickness
 - A. I and IV
 - B. I, II and III
 - C. II, III and IV
 - D. I, III and IV
6. Regarding the drying process in the production of rattan baskets, what specific benefits does it provide?
- I. Prevent mold formation
 - II. Increase durability
 - III. Increase weight
 - IV. Enhance colour
 - A. II, III and IV
 - B. I, III and IV
 - C. I, II and IV
 - D. I, II and III
7. During the sago pearl production process, what is the purpose of using the settling container?
- A. To mix the raw starch with rice bran, shredded coconut, and salt
 - B. To separate the raw starch from the starchy mixture
 - C. To remove impurities from the raw starch
 - D. To enhance the colour of raw starch
8. In the sago pearl production process, why the kneaded raw sago starch is left overnight in a tin can or stone jar?
- A. For reducing the overall moisture content
 - B. For enhancing the colour and texture
 - C. For accelerating the cooking process
 - D. For developing the flavour
9. How does the tapping of nipa sap differ from the coconut sap tapping process?
- A. Nipa sap tapping occurs at ground level
 - B. Coconut sap tapping occurs at ground level
 - C. Nipa sap tapping occurs in the afternoon only
 - D. Coconut sap tapping occurs in the afternoon only
10. If a local producer wants to adjust the richness of nipa palm sugar, what should they do?
- A. Change the boiling time
 - B. Change the stirring speed

- C. Change the cooling down time
- D. Change the amount of water added

Appendix B. Post-Test Instrument

Date:

Time:

Venue:

Name:

Pseudonym:

Post-Test

Dear participant, thank you for taking your time to answer the following multiple-choice questions. This post-test instrument consists of 10 multiple choice questions, and it has been estimated that it may take around 10 minutes to read through the questions and complete the post-test instrument. Please circle the most appropriate answer. While answering the post-test instrument, aside from filling in your name and pseudonym, please do not to leave any other identifying marks on this post-test instrument for the purpose to ensure anonymity and to protect your identity.

1. Which of the following best describes the timing to remove rattan leaf sheaths?
 - A. Throughout the weaving process
 - B. During the harvesting process
 - C. During the dyeing process
 - D. After the drying process
2. Nipa sap is collected from which part of nipa palm?
 - A. Flower Buds
 - B. Fruit Stalks
 - C. Fruitlets
 - D. Seeds
3. What properties of rattan would a skilled harvester consider when selecting rattan to harvest?
 - I. Age
 - II. Odor
 - III. Aesthetic
 - IV. Thickness
 - A. I and IV
 - B. I, II and III
 - C. II, III and IV
 - D. I, III and IV
4. Which of the following parts of sago palm contain the starch used to make sago pearls?
 - A. Sago Palm Flower
 - B. Sago Palm Trunk

- C. Sago Palm Frond
 - D. Sago Palm Fruit
5. Which part of the rattan plant is primarily used in weaving basket?
- A. Roots
 - B. Stems
 - C. Fronds
 - D. Flowers
6. How does the tapping of nipa sap differ from the coconut sap tapping process?
- A. Nipa sap tapping occurs at ground level
 - B. Coconut sap tapping occurs at ground level
 - C. Nipa sap tapping occurs in the afternoon only
 - D. Coconut sap tapping occurs in the afternoon only
7. During the sago pearl production process, what is the purpose of using the settling container?
- A. To mix the raw starch with rice bran, shredded coconut, and salt
 - B. To separate the raw starch from the starchy mixture
 - C. To remove impurities from the raw starch
 - D. To enhance the colour of raw starch
8. If a local producer wants to adjust the richness of nipa palm sugar, what should they do?
- A. Change the boiling time
 - B. Change the stirring speed
 - C. Change the cooling down time
 - D. Change the amount of water added
9. Regarding the drying process in the production of rattan baskets, what specific benefits does it provide?
- I. Prevent mold formation
 - II. Increase durability
 - III. Increase weight
 - IV. Enhance colour
- A. II, III and IV
 - B. I, III and IV
 - C. I, II and IV
 - D. I, II and III
10. In the sago pearl production process, why the kneaded raw sago starch is left overnight in a tin can or stone jar?

- A. For reducing the overall moisture content
- B. For enhancing the colour and texture
- C. For accelerating the cooking process
- D. For developing the flavour

Appendix C. Focus Group Main Interview Questions

1. I would like to start by learning more about each other. Can you briefly introduce yourself, starting with your name and then followed by year of study, and education level?
2. During the viewing of 360-degree educational animation, what do you think about the arrangement of information i.e. learning/video content in the scene?
3. Let's talk about the artistic presentation of the video. Tell me about your opinion on the art style of the video?
4. Let's discuss your experience with the virtual environment. How do you find the construction of virtual environment?
5. During the viewing process, is there any video component that you find can support you to understand the main idea?
6. Regarding the non-verbal sound elements like background sound, what do you think about it?
7. Are the important contents or clues can be easily found in the video? Tell me about it.
8. Let's talk about the presentation of abstract concept like the process of making sago pearls/rattan basket/nipa sugar. What do you think about the presentation of abstract concepts?
9. Moving on to the next question, can you share your thoughts on the design of scene sequence (i.e. number of locational scenes) that have been used to provide a complete explanation of the video content?
10. Tell me about your thoughts on the content viewing pathway (i.e. the way you are being guided to explore the video content).
11. Let's talk about the transition of the animation content. What do you think about the transition of the animation?
12. What do you think of the presenter appearance/looks in the video?
13. Tell me about your thoughts on the way presenter appear in the video.
14. Let's move on to next question. Do you find this video engaging?
15. Is this an adequate summary? Is there anything that you would like to add prior to concluding?