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# Augmented Reality Fraction Apps for Low Vision Alpha Generation Based on Affective Design Principles

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***Abstract* – The advancement of affective computing and augmented reality (AR) have been growing rapidly in the Information and Communication Technology (ICT) domain. Even though the trend of both sub-research domains is increasing however most of the existing AR apps fail to stimulate affective interactions particularly in terms of feeling, thought, emotion, and action which is highly needed by the low vision alpha generation particularly to understand the fraction concept. Therefore, the objective of this study is to develop an Affective Augmented Reality Fraction Apps for Low Vision Alpha Generation (ARFA4LV).**

**The 3-Phases Development Model which consisted of (i) pre-production, (ii) production, and (iii) post-production has been utilized to develop the ARFA4LV. In addition, User-Centred Design (UCD) approach has been utilized throughout the development phase. The finding of this study is the ARFA4LV. The future work of this study is to provide the heuristic evaluation and user experience testing on ARFA4LV.**

***Keywords* – Mobile Human-Computer Interaction, Assistive Technology, Augmented Reality, Affective Design, User-centred Design Approach, Heuristic Evaluation, User's Experience.**

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## 1. Introduction

The trend of augmented reality (AR) is increasing rapidly in Information Communication Technology (ICT) domain. Unfortunately, most of the existing AR apps fail to stimulate affective interaction, particularly in terms of feeling, thought, emotion, and action which is highly needed by the low vision alpha generation particularly to ensure they master the fraction concept. Master in fraction concept is compulsory for all learners at the elementary level as it is related to other complex operations including decimals, percentages, and exponentiation. However, understanding the concept of the fraction is too complicated for low vision alpha generation due to their limitation in eyesight even though they have the similar cognitive ability as mainstream learners [1]. Also, as reported by the content experts the existing content related to the fraction concept is hard to be accessible with low vision as most of the available content was provided according to the needs of mainstream learners [2]. For learners with low vision, certain objects that were used to explain the fraction operation concepts were mental to grasp as their eyes only able to explore one object at a time [3]. Their comprehension or perception of spatial concepts and directional concepts that are used to express the fraction concept is more difficult to understand due to their limited eyesight. In other words, they have to struggle in adapting to the similar content provided for mainstream learners. Therefore, these difficulties have restricted their mind to aim for a career related to science, technology, engineering, and mathematics (STEM) that highly demands visual abilities which contrast with them. Before the crisis of pandemic COVID-19, the educators use various physical techniques including manipulating a lot of physical objects that require their energy, time, and cost to stimulate the affective interactions among the low vision learners, particularly in terms of feelings, thoughts, emotions, and actions to ensure they can grasp the fraction concept comprehensively [4]. The situation becomes more complex as currently, the mainstream education system was focusing more on the needs of general learners compared to low vision, particularly on the knowledge delivery approach (i.e. DidikTV Channel). In addition, initial investigation through elicitation of works of literature also reveals that the concept of affective interactions integrated with augmented reality, particularly in the delivery of the fraction concept to low vision alpha generation is insufficiently explored [4]. Even though the trend of affective computing and augmented reality is increasing however most of the existing apps fail to stimulate the affective interactions, particularly in terms of feelings, thoughts, emotions, and actions of low vision learners which are highly needed in ensuring they master the fraction concept.

Therefore, the main aim of this study is to develop the Augmented Reality Fraction App for Low Vision Alpha Generation based on Affective Design Principles which is named ARFA4LV. The next section discussed the related works of this study.

## 2. Related Works

This section discussed the related works that cover the scope of this study.

### *2.1. Affective Design Principles*

Affective design refers to a product's design that is capable of triggering specific emotional responses from users [5]. The affective design aims to identify the subjective emotional interactions that exist between users and products, as well as to think creatively that can provide users with pleasure [6]. In the context of this study, the developed app aims to stimulate feelings, thoughts, emotions, and actions in the low vision alpha generation through their learning activities.

### *2.2. Augmented Reality*

Augmented reality is a multisensory interactive experience in which real-world elements are supplemented with computer-generated perceptual information, generally across multiple sensory modalities including visual, auditory, haptic, somatosensory, and olfactory [7]. In this study, mobile augmented reality that emphasized the visual and auditory elements has been developed.

### *2.3. Existing Affective and Augmented Reality Apps*

This subsection reviews and discusses ten existing affective and AR apps.

*i. Affective 4D Mathematical Application for Low Vision Learners*

This application is introduced by [1]. It covers the Mathematics content in general. The components to express Mathematics in an AR environment are still insufficiently explored. It has no integration of affective interaction and AR which is currently compulsory for low vision alpha generation.

*ii. Object Identification AR for*

Object Identification AR is introduced by [3]. It is used to detect the object. Some of the components of this app are appropriate to be applied in this study. However, there are no components of AR to express the fraction concept for low vision alpha generation.

*iii. AR Magnification*

The fraction concept is not under the scope of this app. However, some of the components of this app are appropriate to be extracted from this study. This app is introduced by [8].

*iv. Accessible Mobile AR for Visually Impaired*

The app introduced by [9] can create an accessible full AR immersive experience for the users. The fraction concept is not provided in this app. However, some of the components of this app are appropriate to be extracted from this study.

*v. Multi-sensual AR in Interactive Accessible Math Tutoring for Flipped Classroom*

This app provides a multi-sensual user interface (i.e. hearing, the touch of a braille display, touch screen, and touch gestures). It was created by [2]. The concept of this app has flipped classrooms.

However, the components of AR in this app are still insufficiently catered to the needs of low vision alpha generation, particularly in terms of graphics, text, audio, and animation. The synthetic speech provided in this app is less friendly to low vision alpha generation. The use of colors is meaningless to low vision alpha generation. It still fails to cater to the concept of minimalist content which is important for low vision alpha generation.

*vi. AR Game (Helping Nemo)*

This AR game applies the principles of Universal Design Learning (UDL). It introduced the concept of an inclusive approach to learning. However, there are no specific components that cater to the needs of low vision alpha generation. This game also does not focus on the Math operation concept.

*vii. ARtention*

This app introduces the concept of design space for gaze-input-based interfaces for AR environments [10]. It is a form of input that interacts with the world based on where the user is looking. The ARtention does not focus on the fraction concept and does not cater to the needs of low vision alpha generation. However, some of the basic components of this app can be extracted to be utilized in the ARFA4LV.

*viii. Affective Computing Game (Pet Simulation Game)*

This app implements the affective computing concept as part of game design [11]. The app could capture, process, and interpret the player's emotions to enhance the player's experience in the game. However, no specific components of visual, auditory, speech, and touch cater needs of low vision alpha generation. It is used to detect emotion.

*ix. Multimodal Affective Computing (emoCook)*

The purpose of this app is to enhance the user's experience of educational software applications. The researcher presents the emoCook that incorporates affective computing by detecting the users' emotional states to adapt their behaviors to the emotions sensed [12]. However, the components of visual and auditory do not cater to the low vision needs. Also, there are no components related to speech and touch. It is used to detect emotion.

Based on the reviews it was found that some of them are generic AR apps and they exclude the low vision as part of the users. However, there is also an AR app that focuses on Math Operation for low vision but with minimum focus on audio, visual, speech, and touch (i.e. synthesis speech; crowded objects; fancy font face; inappropriate font size). Moreover, most affective apps focus on detecting the users' emotions rather than providing the emotions, thoughts, feelings, and actions to the users which are needed to express the fraction concept to low vision alpha generation. Overall, the concept of affective interactions and AR are still insufficiently explored. Most of the existing affective and AR apps fail to stimulate the affective interactions, particularly in terms of feeling, thought, emotion, and action which is highly needed by the low vision alpha generation. Thus, it ought to be noted that this is the research gap that should be the focal point of the study.

The next section discusses the research methodology used to develop the prototype.

## 3. Research Methodology

### 3.1. The 3-Phases Development Model

This study applied the 3-Phases Development Model throughout the development of ARFA4LV. It consists of three main phases which are (i) pre-production, (ii) production and (iii) post-production. Figure 1 depicted the phases and steps involved in the development of ARFA4LV.

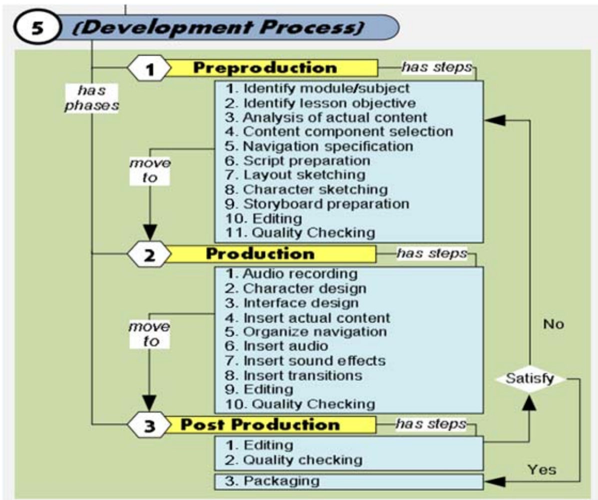


*Figure 1. The 3-phases development model*

### 3.2. User-centered Design Approach

A user-centered design approach (UCD) has been utilized at each step of the development phases. Content experts from the Special Education Primary School of Alma Penang Malaysia have been selected to be involved in the development of ARFA4LV. They have been chosen as they are Mathematics experts and have experience as teachers to low vision students for more than five years.

## 4. Findings

The findings of this study highlight the prototype of ARFA4LV. ARFA4LV is a type of mobile augmented reality application. It has been developed by utilizing Vuforia Engine with Unity.

### *4.1. The prototype of ARFA4LV*

Figure 2 shows the icon of the developed apps. The development of ARFA4LV considering the utilization of a large tablet screen size. It is crucial for the LV to enable them to explore the apps comfortably [13]. This study suggested the most suitable size for LV is any table device with a screen size greater than a 10-inch tablet.


*Figure 2. The icon of ARFA4LV*

The ARFA4LV was provided in the form of printed flashcards and printed markers. The main purpose of the flashcard and marker are to enable the content to be displayed on a mobile device such as a tablet. The scanning process would capture and recognize the marker on the flashcard, in which the learning content will be prompted for LV users to follow the lesson.

*A. The printed Flashcards of ARFA4LV*

Figure 3 depicts the sample of printed flashcards of the character of ARFA4LV. Followed by Figure 4 shows the flashcard for the main menu of ARFA4LV. Meanwhile, Figure 5 represents the sample of the border of ARFA4LV, and last but not least Figure 6 displays the samples of the content of ARFA4LV.

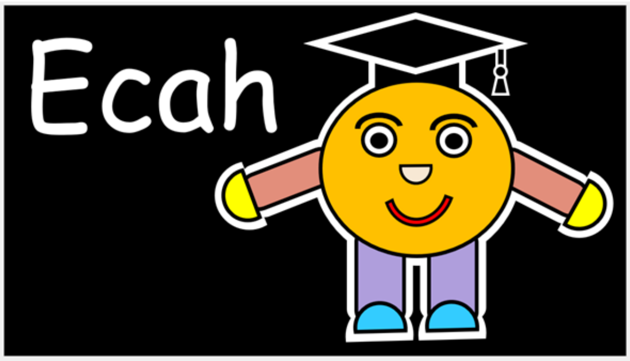


*Figure 3. The character of ARFA4LV*

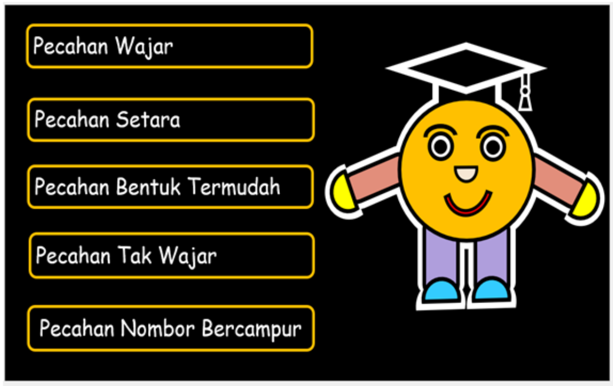


*Figure 4. The main menu of ARFA4LV*

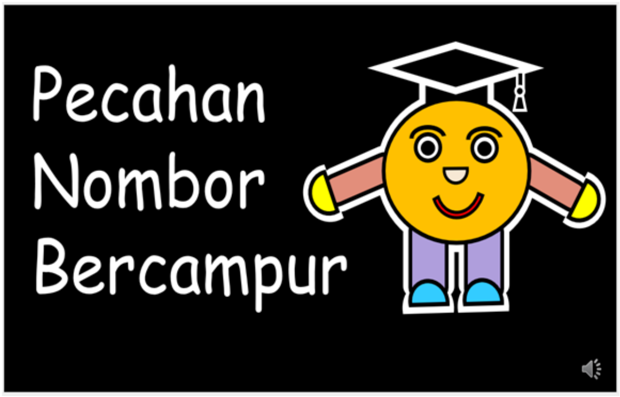


*Figure 5. The sample of the border*

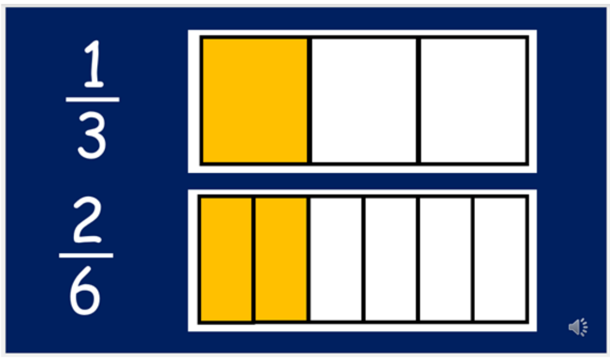


*Figure 6. The sample of the content*

Overall there are 19 printed flashcards of ARFA4LV have been provided. It is based on the content of the fraction topic provided by the Ministry of Education Malaysia which is also contained in the textbook for mainstream learners. The content has been taken out and revised according to the needs of low vision alpha generation as suggested by the expert in UCD. The flashcards of ARFA4LV have been printed on cards. It is portable and easy for users to access the content anywhere and anytime. The use of contrast color to the content also makes it accessible by low vision alpha generation. The expert also suggests that the cards should provide the sense of touch (a braille like version) where the users are able to recognize each of the content by touching the cards with their fingers. This ensures the content is delivered to the users even though they have severe low vision.

*B. The printed Markers of ARFA4LV*

The markers of ARFA4LV have been provided based on content, which contains a hidden symbol recognized by the apps. It is to make the content on the cards appears in the form of augmented reality. The users can enjoy the audio and animation provided as augmented reality. Figure 7 depicts the sample of the printed marker.


*Figure 7. The sample marker of ARFA4LV*

The markers also have been designed with contrast colors and suitable font size, style, and face, so that it is easy for the low vision alpha generation to match it with the flashcards. The size of the marker can be printed in various sizes to suit their preference and necessity. Having considered the cost of the marker printed materials, this study suggests a simple laminated card or digital photo paper printing material.

C. The Demo of ARFA4LV

Figures 8, Figure 9, and Figure 10 depicts the demo of ARFA4LV. Figure 8 shows the first steps that can be followed once the user activates the apps. Once the scanning process is successful, the lesson content will be displayed as shown in Figure 9. The demonstration for this prototype utilized a smaller device to show the success of the apps.


*Figure 8. The demo of ARFA4LV* (scene 2)


*Figure 9. The demo of ARFA4LV (scene 7)*


*Figure 10. The demo of ARFA4LV (scene 14)*

Figures 10 display the demo of another scene in ARFA4LV. It shows that the user simply scans on the printed marker then the learning content will be played in the form of augmented reality.

### *4.2. The AR elements of ARFA4LV*

A. Visual

Up to 80% of human knowledge is gathered through visuals. AR enhances the visual sense with contextually relevant information. It allows users to see both the digital and physical worlds simultaneously. The character and graphic design on the flashcard also related to the content of the lessons. It is crucial to maintain consistency on the content and printed material graphic design to avoid confusion to them. In the context of this study, the content of ARFA4LV has been designed according to the needs of low vision alpha generation. This study found that the appropriate size of the font should be 18pt. The appropriate font face has to be sans-serif which means have no decorative strokes; for instance Arial and Comic Sans. The appropriate background color is a dark color (i.e. black, dark green, and dark blue). It has to be designed to contrast with the color of the content. Therefore the appropriate color for content has to be light color (i.e. yellow, white, and light pink). This means the ARFA4LV is able to make the low vision children grasp the delivered content through visual even though they face limited eyesight.

B. Auditory

Visually impaired including low vision depends on 100% on audio in order to understand the delivered content. Therefore providing the auditory elements in ARFA4LV is essential. However, not all of the appears elements must be transformed into audio. In ARFA4LV the characters of *Ecah* play an important role to deliver the content. The pronunciation and intonation have to be clear, friendly, fresh, and attractive.

C. Touch

The touch senses of ARFA4LV are provided in the printed flashcards. The users could recognize the content by touching the flashcards as it has been provided in the form of embossed printing. It is crucial to design the flashcard using this approach as it can be utilized by the user with severe vision.

### *4.3. The Affective Design Principles of ARFA4LV*

The affective design specifies a product design that is capable of provoking specific emotional responses from people. The affective design aims to identify the subjective emotional interactions that exist between users and products, as well as to create products that can provide users with pleasure. In this study, four dimensions of affective design principles have been integrated into ARFA4LV as suggested by the content expert. There are (i) feeling, (ii) thought, (iii) emotion, and (iv) action.

*A. Feeling*

The feeling is an emotional state or reaction. The element of feeling that has been adapted in ARFA4LV is pleasure, relaxation, excitement, enthusiasm, inspiration, and interest. The character of *Ecah* that acts as the peer instructor could reflect those feelings to low vision alpha generation when they use the ARFA4LV. In addition, the script expressed by the character plays an important role to evoke positive feelings to low vision alpha generation as they depend 100% on audio to understand the delivered content. The narration of the lesson content has been recorded using a female child's voice. The character voice represents and acts as a buddy or peer to the user to ensure that they feel comfortable while exploring the apps.

*B. Thought*

Thought is the action or process of thinking that occurs suddenly in the mind. In other words, thought is the conscious cognitive process that can occur without sensory stimulation. The elements of thought that have been integrated into ARFA4LV are judging, concept formation, and problem-solving. There are five basic concepts of the fraction that have been taught in ARFALV. All of the concepts have been explained by *Ecah* with examples. Through the explanation of the fraction concept, the low vision alpha generation will automatically judge the delivered content. Therefore, the explanation that comes with the problem-solving element could trigger the low vision alpha generation to think more deeply in the process of understanding the fraction concept. The accessible and appropriate animation, the shape of fraction, font face, font type, and combination of color provide in the content of ARFA4VL also could trigger the low vision alpha generation to judge the learning content.

*C. Emotion*

Emotions are mental states caused by neurophysiological changes and are associated with various thoughts, feelings (a degree of pleasure or displeasure), and behavioral responses (action). In ARFA4LV happiness and surprise are the positive elements of emotions that have been integrated. The animation provided in ARFA4LV contains the surprise element and the combination of colors, the character of *Ecah*, the cheerful voice intonation provides the happiness emotions to the low vision alpha generation while they play the ARFA4LV.

*D. Action*

Action is the movement or the activity of doing something. In the context of augmented reality, application action can be in terms of navigation and interaction. Currently, ARFA4LV provides minimal interaction for low vision alpha generation. The embossed printing flashcards required the low vision alpha generation to match it with the augmented reality content.

## 5. Conclusion

In conclusion, the main aim of this paper has been achieved which is to develop the ARFA4LV based on the affective design principles. There are four dimension affective design principles that have been suggested by the content expert which are feeling, thought, emotion and action. All these affective elements are important to be embedded in the ARFA4LV as low vision alpha generation required it in their learning activities, particularly in learning fraction. The pre-production, production, and post-production phases have been utilized to develop the ARFA4LV. The development of ARFA4LV will be upgraded in the future so that more affective design principles could be integrated.

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