The Prototype of Assistive Courseware for Low Vision (AC4LV) Learners

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Abstract: Problem Statement: Current phenomenon faced by low vision (LV) learners is that their learning activities are problematic. With the restrictions in their vision, conventional teaching and learning techniques requires them to struggle more compared to their sighted peers. Even though Assistive Technology (AT) provides LV learners with various helpful features but most of them are in the form of hardware or software, which minimally assist the LV learners in accessing the knowledge. Meanwhile, the content applications that are specifically designed for the LV learners are highly scares. This could be seen when most of the existing content applications (i.e. courseware) that available in the market are designed for sighted students. Previous studies indicate that most of the existing courseware means too little or nothing to the LV learners especially for those who are severe. **Approach:** This study presents an ongoing project, with the main objective to develop an electronic learning material that focuses on content design application in an attempt to cater the needs of LV learners in their learning activities called Assistive Courseware for Low Vision Learners (AC4LV). Thus, to achieve the main objectives, this study comes out with two specific objectives which are: (i) to determine the design principles of AC4LV and (ii) to develop a prototype of AC4LV based on the gathered design principles. It is important for this study to gather information from the actual users and teachers as they are the experts in this field. Accordingly, other than document reviewed, User Centered Design (UCD) approach was utilized in gathering the inputs and comments to achieve both of the objectives. **Results:** The results highlight design principles which are categorized into eight elements of AC4LV. They are justified and labeled in the form of snapshots, presented sequentially in this paper. **Conclusion:** In a nutshell, this study has achieved both of the objectives. The AC4LV has been designed according to the needs of LV learners. It has to be emphasized that the main objective of this article is to highlight the development of AC4LV and it is also important to stress that the content design of AC4LV has to refer to the determined design principles. This could be as guidance for the developer or anyone who intent to develop AC4LV. The recommended future works is to investigate the user experience of using AC4LV among the LV learners. The target participant would be the LV learners from primary school level aged nine to twelve.

Keywords: Assistive Technology (AT), Assistive Courseware (AC), Low Vision Learners, Design Principles, User Centered Design (UCD) Approach

1. Introduction

Learning is for everybody [1] including the disabled. However, for the disabled, learning activities are quite challenging. With the restrictions that they have, learning activities always make them face various difficulties, which finally could demotivate them. Among many types of the disabilities, visual impairment (VI) is considered a serious one. [2] reports that 285 million people in the world are VI. Particularly 246 million of them have low vision and 39 million of them are blind. Approximately 90% of the VI people live in developing countries. Based on the facts reported by Social Welfare Department of Malaysia,between December 2007 and December 2011, the number of registered VI people in Malaysia increases year by year (Table 1) [3].

Table1. Statistics of registered VI people in Malaysia (2007 – 2011)

Types of Disability	Years				
	2007	2008	2009	2010	2011
VI	20,039	21,204	23,738	27,363	31,924

The facts reveal that the number of VI keeps on increasing drastically including LV learners. Therefore, exposing them to the world of education and technology is important because they should together be respected as part of the resources for the country. Unfortunately, [4] reveal that 80% of educational materials such as textbook and courseware are provided for fully-sighted students. This is because the main learning styles that prefer to use by normal students especially children is visual, followed by kinesthetic and further by auditory [5]

[6] [7]. Due to that, VI learners particularly LV have to adapt this situation into their learning activities even though they face problems in terms of information accessibility and navigation. As a result, they feel frustrated and have no pleasure in learning [1], which then affects their quality of education. Table 2 shows a summary of problems, method of teaching, and materials that are currently used in teaching and learning of LV learners. Meanwhile, Figure1 demonstrates the current learning activities that are utilized by LV learners. In the following, Figures 2 and 3 illustrate AT used to assist the LV learners during their learning activities.

Table 2. Problems and methods of teaching and learning LV learners

Details	Problems
LV learners	• The LV learners face difficulties in grasping the knowledge delivered through conventional teaching method. • Their difficulties are in terms of information accessibility and navigation. • Due to facing a lot of difficulties, these influence them not to have pleasure in learning activities.
Teaching method	Conventional teaching methods are similar with normal students which are conducted in class or computer lab.
Material	Typical text book, flash cards, book with pictures (e.g. big size), demo from the teachers, Close Circuit Television (CCTV), magnifying glass, online typical courseware (TC) (e.g. nursery rhymes).

Fig. 1. Online teaching courseware is played to the LV learners.

Fig. 2. Example of CCTV

Fig. 3. Example of magnifying glass

In terms of definition,VI is categorized into four types which are totally blind, legally blind, color blindness, and low vision (LV). As has been discussed in the preliminary study carried out by [3] this study only focuses on LV, in which a person has a profound visual disability, but still retains some useful eyesight which resulted from two possible sources: (i) reduced visual acuity and (ii) restricted field of view [8]. From the two types of LV this study decides to focus on reduced visual acuity, which means having a limited ability to discriminate visual detail [8]. Further, Figures 4 through 8 demonstrates the different views of normal vision, and the four types of LV.

Fig. 4. Normal vision

Fig. 5. Reduced visual acuity

Fig. 6. Central field loss

Fig. 7. Certain field loss

Fig. 8. Reduction of vision field

The rationales of focusing on reduced visual acuity are as listed in the following points:

i) LV often occurs to children rather than reduction of vision field, certain field loss, or central field loss. They normally happen to old people. This explains that LV is appropriate because learning process starts in the childhood.
ii) As discussed in previous studies [3] [9] [10] [11] [12] the use of magnifying glass and CCTV or other AT devices is problematic for them either because of their incapability to buy that equipment, missing of the equipment, or psychologically they do not like to use AT as well as do not like to look different between their sighted peers [13] [14].
iii) Preliminary studies [3] results that transformation of learning content to multimedia application in terms of graphics, texts, audio, and animations is more applicable to be utilized by LV learners compared to others (i.e. totally blind, visual field loss).
iv) As suggestion from the content expert (i.e. VI teachers, school coordinator of special need department) to make this study usable for them in future.

Adapting similar teaching and learning technique with normal students is quite challenging for LV learners to enjoy their learning activities or at least learn without pressure. Even though AT (i.e. CCTV magnifying glasses, screen reader (i.e. JAWS), and screen magnification) could help them, but it still requires them to have technical skill to operate the functions. Moreover, those technologies are provided in terms of hardware and software, in fact the problems facing by LV learners is in terms of contents.

The above elaboration explains that it is difficult for LV learners to face their learning routine by utilizing similar learning materials with normal learners. AT in terms of hardware and software would also not fully fulfill their needs in learning. As of the restriction with the sense of seeing, LV learners have to struggle more compared to their sighted peers by utilizing their other complementary senses [15]. This indicates that they need a type of learning materials that specifically could fulfill their needs in learning without facing anymore difficulties particularly in terms of information accessibility, navigation, and pleasure aspects. Currently, most of the content application such as courseware is developed for sighted students, which totally are not appropriate for LV learners. They are known as typical courseware (TC) either it provided in the form of CD-ROM or available online. LV learners are also exposed to TC. Usually, when using TC, they have to face problems such as blinking button, crowded pages, inappropriate font size, mouse-based interaction and inappropriate animations. Those problems restrict their ability to access the displayed information, navigate the application and finally getting frustrated in their learning activities. This has been proven through the study carried out by [3].

In response to that, this study attempts to develop a prototype of courseware which specifically caters to the needs of LV learners in learning, which is named Assistive Courseware for Low Vision learners (AC4LV). Prior to developing the AC4LV, a set of specific design principles have to be determined in making sure AC4LV could fulfill the needs of LV learners. Hence, with the supported critical analysis carried out by [16] this study comes out with two specific objectives as pointed below:

i) to determine the design principles of AC4LV
ii) to develop a prototype ofAC4LV based on the gathered design principles.

Thus, in achieving both objectives,two phases of activities were performed as discussed in the next section.

2. Materials and Methods

In this study a series of activities were carried out, as shown illustratively in Fig. 9. The figure explains that this study involves two phases of activities which are specification identification, and prototype development [12]. The activities involved in the first phase include document study and interview. This method is call User Centered Design (UCD) approach. From this phase, data regarding the design principles of AC4LV were gathered and the first objective of the study was achieved. They are discussed in detail in the next section together with the snapshots of the prototype. The second phase is prototype development, in which the development process as illustrated in Figure 10 are employed based on the data gathered in phase two. At this stage, this study has achieved its second objective. Having finished the second phase, the whole objective of this study is achieved.

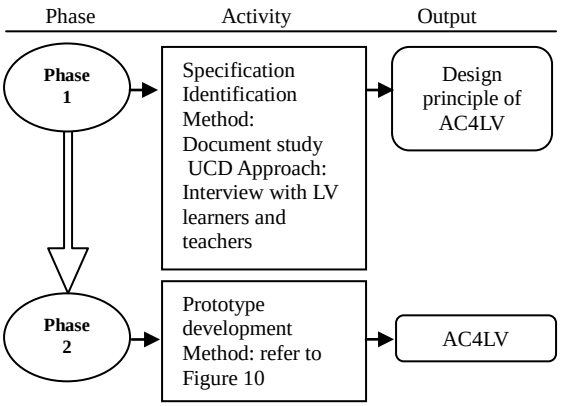


Fig. 9. Summary of activities

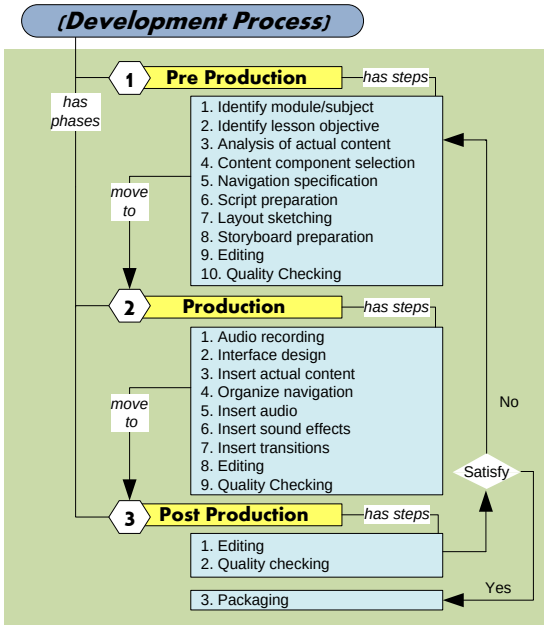


Fig. 10. Development process of AC4LV

Going in-depth into the development process of AC4LV, it involves three phases, which are pre-production, production, and post production. In the first phase, 10 steps were implemented. In developing AC4LV it is important to involve users and experts before the development of AC4LV begins. At this phase, user requirements were identified by interviewing the teachers regarding the needs of LV learners in terms of the actual content of AC4LV. Also, the LV learners were involved to gather the input and comments in terms of the design of AC4LV. All this input are important in preparing the script and storyboard of AC4LV. This is demonstrated in Fig. 11 and Fig. 12. Having finished the 10 steps in the pre-production phase, the development of AC4LV was started by utilizing Adobe Flash as the main development tool. Sound Forge was used to record and edit the sound, while Adobe Illustrator was utilized to design all the characters. In the post production phase, editing and quality checking were performed, which also involved real users and their teachers. It was done until they were satisfied and finally the AC4LV was packaged in the form of CD prior to test the user experience.

Fig. 11. UCD approach (having discussion with teacher)

Fig. 12. UCD approach (getting inputs and comments from the LV learners)

3. Results and Discussions

Having gone through the activities discussed in the previous section, this study has achieved both of the objectives as stated in the first section. They are the design principles of AC4LV and the prototype of AC4LV. Both of the results are discussed in the following subsections.

Design Principles

As discussed in the first section, AC4LV was designed catering the needs for information accessibility, navigationability, and pleasure. These three aspects are achieved through the design

principles that were gathered in the first phase. The design principles in AC4LV are constructed based on eight elements which are (i) audio, (ii) formatting styles and texts, (iii) graphics, (iv)animation, (v) interface layout, (vi) transitions, (vii) navigational button, and (viii) general interaction. These elements were gathered through comparative analysis as discussed in [16]. They are justified follow:

(a) Audio

There are six design principles of audio that the developer has to refer prior to develop AC4LV.

(i) Provide auditory explanation
VI learners including low vision depend 100% on audio to explain everything that appear on screen [17]. Without auditory explanation, the visual aspect means nothing to them. It is difficult for them to recognize information presented visually. However, it must be well-organized because not all information has to provide audio.

(ii) Provide clear pronunciation
The audio should be clear to the user. This means the desired information must be pronounced clearly word by word especially for the instruction part (i.e. activity or exercise).

(iii) Omit the background music
Even VI learners depend 100% on audio, but the use of background music blending with auditory explanation in actual fact make them confuse. They have to think deeply to distinguish between background music and the actual information. So, the best solution omits the background music.

(iv) Use friendly voice intonation
Children including low vision learners learn better when contents, instructions, or demonstrations are spoken by a friendly human voice or teachers' voice rather than a machine voice. This is inline with voice principle (Multimedia Learning Theory) and also agreed with [18]. This also avoids them from feeling bored and unmotivated in learning.

(v) Supply sound effects
Low vision learners have restriction in visualization, which means they are less sensitive on anything displayed on screen. So, it is important to enhance their alert by supplying sound effect especially for user interaction.

(vi) Avoid using sudden loud sounds
Low vision learners are sensitive with sounds. Disturb them with sudden loud sound possibly make them shocked and confused on what happens on screen. As an example, automatic background sound is startling and unexpected. In some cases users' speakers were not set at appropriate volume. If possible, audio should start low and increasing gradually.

(b) Formatting Styles and Texts

The design principles that the developer has to refer when designing texts in AC4LV are:

(i) Use the preferenced font size
Low vision learners face difficulties to read small font size. They have to struggle and normally get eye strain after some reading. This will put them in frustrated condition. Therefore, the preferences font size is at least 18 point.

(ii) Create good contrast color between foreground and background
Low vision learners are different than normal people in color perception. It is very tough for them to differentiate combination of less contrasted colors. Therefore, font color and background color must be highly contrasted. As example, they are unable to distinguish between blue and red because the color is less contrast for them. Combination of black and white is an example of good pair of them.

(iii) Place text only on solid background
Avoid placing text on any background image either it is animate or static. The low vision learners are unable to grasp the information presented on it. This is also usually taking them into an unmotivated condition.

(c) Graphics

For the elements of graphic there are five design principles that have to be emphasized by the developer prior to develop AC4LV.

(i) Provide clear graphics
The graphics must be clear enough in terms of shapes and combination of colors. Use only two or maximum three colors for one attributes. It is recommended to outline the shapes of graphics with contrast colors.

(ii) Provide the preference size of graphics
The low vision learners are attend to the biggest element followed with smaller. So, the most important information should be made the biggest.

(iii) Provide good contrast color between graphics and background
Combination of attributes and background must be highly contrasted. Low vision learners are unable to compare the combination of colors that look almost similar such as red and orange or green and blue. Black is a good example for background while white and yellow is for the attributes.

(iv) Use meaningful graphics
Provides only meaningful graphics. Avoid adding extra unusable graphics as screen decorative element. It means nothing for low vision learners. Additionally, it also looks crowded for them.

(v) Minimize the use of graphics
Low vision learners are unable to absorb information like normal people. Too much graphics on one screen are crowded for them. Normally, they pay attention to information they are intended to. So, three attributes of graphics on one screen is the maximum for them.

(d) Animations

There are five principles that the developer has to follow when designing animations in AC4LV.

(i) Follow the same rules of graphics and texts
Use animations for graphics and texts when only necessary.

(ii) Provide animated character as attraction
Children like animated characters such as puppet and cartoon because the use of them can enhance their learning motivation. This also has been proven by previous studies. However, it must be well-organized as suggested in imaging principle (Multimedia Learning Theory).

(iii) Only animate the desired information
Do not animate every information at the same time. It is difficult for low vision learners to focus on the desired information.

(iv) Avoid too much animation
Only animate when it is necessary. Avoid animating the graphics for all the time.

(v) Avoid fast animation
Provide slow movement of animation. So, the low vision learners have time to capture the information.

(e) Transitions

Only one design principles for creating transition in AC4LV

(i) Create texts and graphics transition from one direction.
Avoid texts and graphics transition from multiple directions. It is important since the low vision learners are able to focus on a single direction at a time.

(f) Navigational button

In making sure the AC4LV caters to navigationability aspects, so designing navigational button also has their own design principles that have to be concerned by the developer. There are:

(i) Design button to look clickable
For low vision learners, buttons must be designed to look clickable so they are able to recognize the buttons. This includes in terms of shape and the usage of colors, even though the button function through the keyboard.

(ii) Minimize the number of button
Provide button only when it is required.

(iii) Avoid using blinking button
Blinking button will disturb the users' focus. It is not appropriate for low vision learners.

(iv) Avoid using image as button
Low vision learners have less ability to differentiate between images and button. So, avoid utilizing image-based button.

(v) Avoid using text only as button
It is complicated for low vision learners to differentiate between button and desired information if the text is also created as button. So, combination of shape and text is appropriate for them.

(g) Interface Layout

Interface in AC4LV is very important. This is to ensure the layout of interface is designed by catering to information accessibility aspects.

(i) Divide the screen area logically
Clear and consistent screen area is important for users navigate the application. Logically for AC4LV it should be divided into menu area and content area.

(ii) Minimize the number of screen area
The best number of screen area for low vision learners is two or maximum three main sections.

(iii) Place texts under the graphics
For low vision learners, placing text under the graphics is more effective compared to placing text within the graphics. This contrasts with spatial contiguity principle (Multimedia Learning Theory) because low vision learners incapable to discern text that are placed close with the graphics.

(iv) Place menu area on the left side
It is high recommended to place the menu area on the left side of the screen area. For the reason that, if the AC4LV is play on the large monitor screen and the menu area is designed on top, it is very uncomfortable for the learners to access it. Also, if the menu area is place at the bottom this will disturb the content part. While, center and right side is suitable for content area.

(v) Design for full screen presentation
The overall design of AC4LV must covered full screen presentation. It is not recommended for the designers to design other than this as it will cause more difficulties for low vision learners to concentrate on learning.

(vi) Design for a single screen
It is high recommended for the designers to place the desired information for not more than one screen. This is easier for low vision learners to learn from the screen.

(vii) Having simplicity and consistency
The good interface layout for AC4LV should be simple and consistent from start to end. Having simplicity and consistency will keep users stay focus on the learning activities. This is the way the courseware become user friendly with the user.

(viii) Avoid unnecessary decorative elements
Decorative elements do not make sense to low vision learners. So, avoiding it is the best decision.

(ix) Avoid scrolling screen
Scrolling screen is inappropriate for AC. It requires more works from the disabled users to get the information.

(h) General Interaction

In AC4LV general interaction was designed to cater information accessibility. Without following the specified designed principles the courseware will be means nothing to low vision learners. The specified design principles are:

(i) Provide explicit instructions
Even instructions is provided in auditory form but it have to be simple and explicit not in a long sentences. In addition, the voice intonation to pronounce the instructions must be well-controlled to make it not too fast or not too slow. This is important for low vision learners to perform their task correctly after getting the instructions.

(ii) Provide repeatable function
Repeatable function must be provided which allowing the low vision learners to repeat the instruction or the lesson. This is to avoid them misunderstanding the instructions or the lesson.

(iii) Provide close function
Most of the low vision learners especially children have lack of knowledge on technical function, so providing suitable close function displayed on the screen make easy for them to exit the AC4LV.

(iv) Provide previous and next function
With the restrictions in visualization the low vision learners face difficulties in grasping the presented content, so providing previous and next function is important to help them revise the learning content when necessary.

(v) Keyboard-based interaction
Previous studies indicate that most of the VI learners required 100% of keyboard-based interaction. For the reason that, most of them are not able to utilize mouse to interact with the courseware. It is difficult for them to point the cursor to the desired information especially for the severe low vision. So, keyboard-based interaction is necessary.

(vi) Mouse-based interaction as optional
Creating mouse-based interaction is optional. It is designed for low vision learners that able to interact with courseware using mouse. Usually they are in moderate category. However, they still require biggest cursor to point and navigate the courseware.

The Prototype of AC4LV

Based on the gathered design principles the prototype was developed. For the purpose of this study, only one topic from the Science subjects was chosen to be prototyped. The content is learning about animals. Altogether the prototype consists of six learning modules and four types of activities. Each of the activities is attached to one demonstration. Fig. 13 illustrates the architecture of AC4LV.

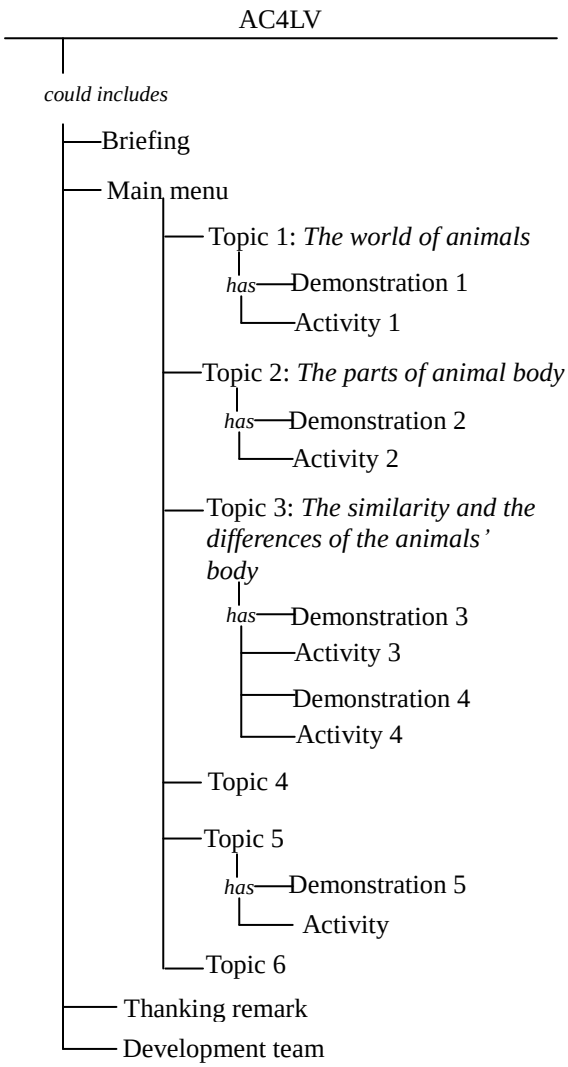


Fig. 13. Architecture of AC4LV

Fig. 14 through 20 depict ten samples of AC4LV snapshots developed in this study labeled with design principles found in phase 1.

(a) Audio in AC4LV

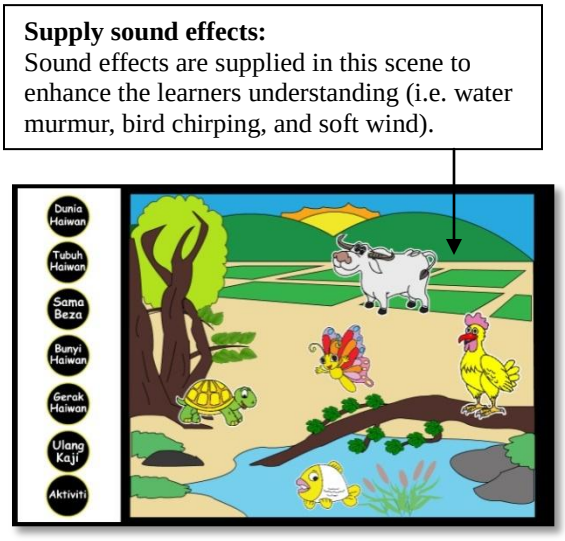


Fig. 14. The use of sound effects

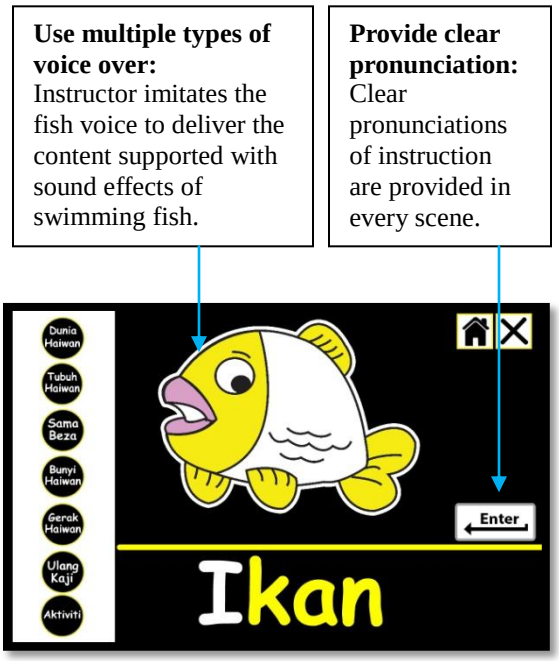


Fig. 15. The use of multiple types of voice over with clear pronunciation

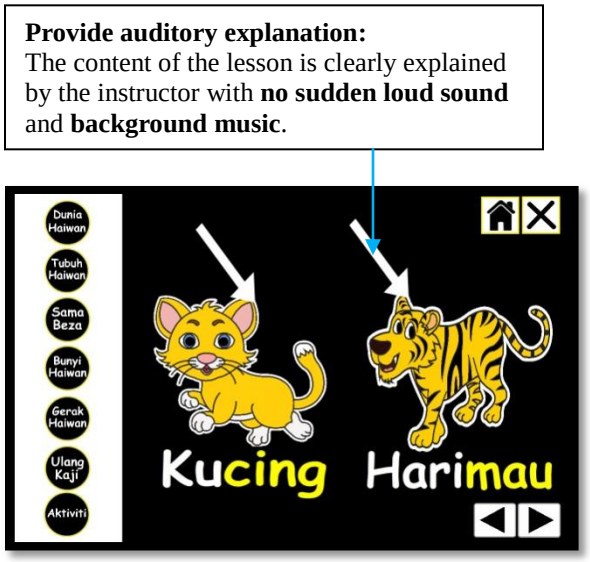
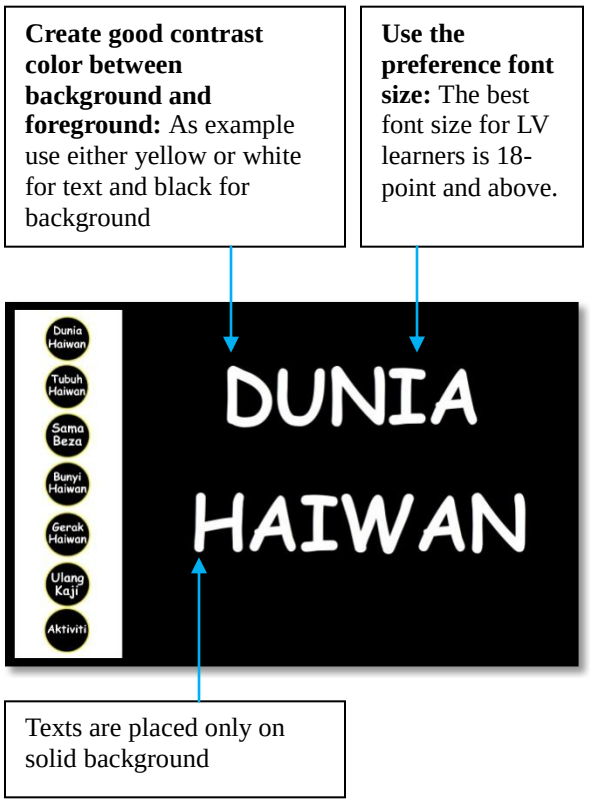


Fig. 16. The use of auditory explanation in AC4LV

(b) Formatting Styles and Texts in AC4LV



(c) Graphics and Animations in AC4LV

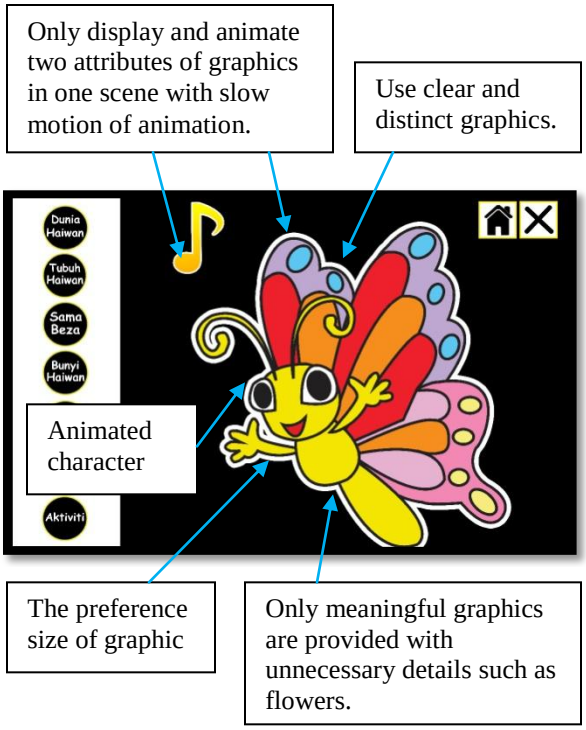
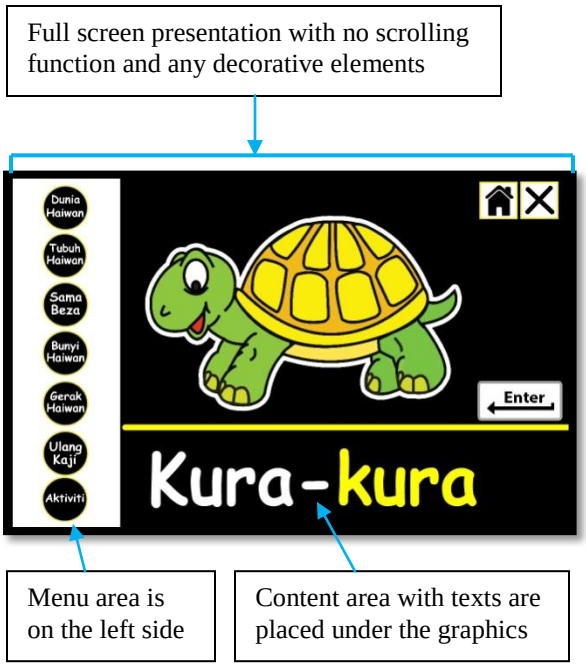


Fig. 18. The use of graphics and animations

(c) Interface Layout in AC4LV



(d) Transition in AC4LV

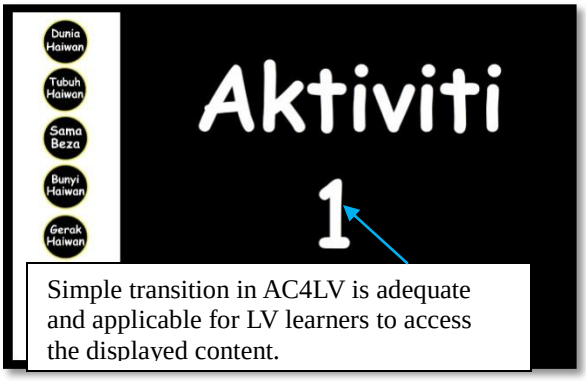


Fig. 21. Transition

(e) Navigational Button in AC4LV

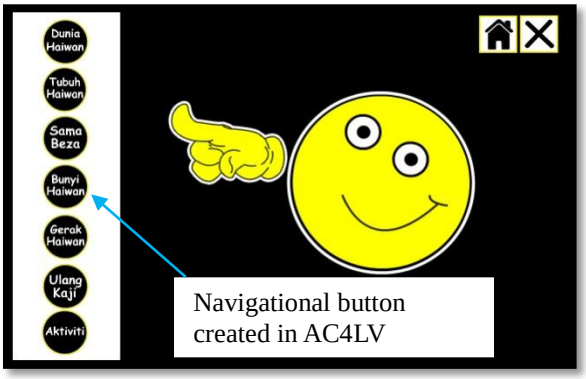
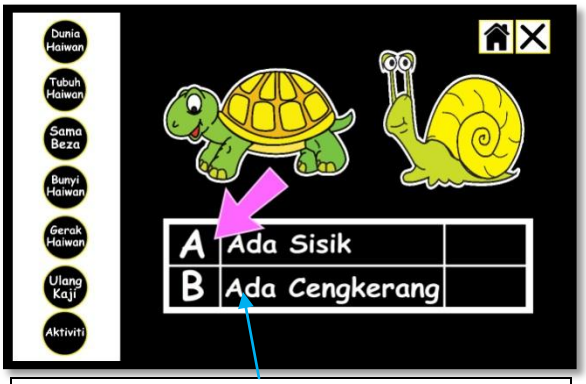
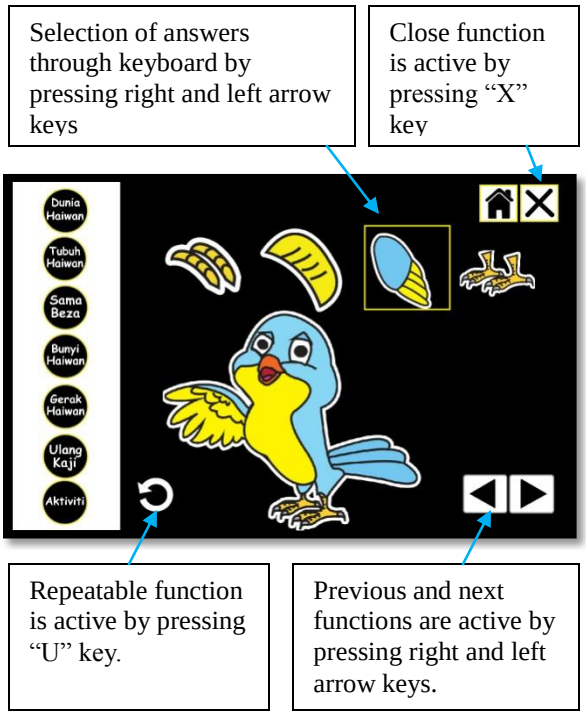


Fig. 22. Sample of navigational button in AC4LV

(f) General Interaction in AC4LV



a. Explicit instructions



b. Keyboard-based interaction

Fig. 23. Keyboard-based interaction applied in AC4LV

Conclusion and Future Works

Overall, this study reports an ongoing project regarding the development of AC4LV. Two objectives have been achieved which are the identified design principles of AC4LV and the prototype of AC4LV. AC4LV was developed based on the identified principles in attempt to fulfill the needs of LV learners in learning activities. Information accessibility, navigationability, and pleasure aspects are applied in AC4LV through the identified design principles. Future works of this study is to investigate the user experience of using AC4LV in terms of information accessibility, navigationability, and pleasure aspects.

Acknowledgement

The researchers wish to thank to the Primary School of Jabi (Visual Impairment Integration)and Special Primary School of Alma (Visual Impairment) for their cooperation participating in this study. This study also has been financed by Universiti Utara Malaysia (UUM), Malaysia and Ministry of Higher Education, Malaysia. The authors gratefully acknowledge both of the credibility organizations'.

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