Usability design strategies for children: Developing children's learning and knowledge in decreasing their dental anxiety

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Abstract: This paper presents an example of how usability design strategies for children can be designed into educational material using CD-ROM based multimedia application for assisting parents and teachers to develop children's learning and knowledge in decreasing as well as motivate children aged 7-9 years old to reduce their anxious feelings towards dental treatment. In this paper, the authors provide usability design strategies for children in designing the information interfaces and presentation of a PMLE (persuasive multimedia learning environment). PMLE is designed based on the six design categories of guidelines for children which have been applied to this study: general interaction, text, multimedia, navigation and search, graphical user interface and content. The results on presenting this PMLE to 240 primary school children selected at random show how the authors were able to decrease children's dental anxiety and motivate the children to get ready for dental visit.

Key words: design guidelines for children; usability for children users; PMLE; children dental anxiety

1. Children learning, knowledge, reasoning and cognitive development

Goswami and Brayant (2007) had done a report based on selective survey of the enormous quantity of empirical research on children's cognitive development since 1967, focusing on the early years (0-10). They found that in children's learning, children possess and demonstrate all the main types of learning, such as statistical learning, learning by imitation, learning by analogy and causal learning even as babies. This includes learning the relationship between the sounds that underpin language acquisition, or the visual features that specify natural categories or concepts, such as bird, tree and car.

In children knowledge, Goswami and Brayant (2007) reported that children think and reason largely in the same way as adults, but they lack experiences, and still develop the ability to think about their own thinking and learning (meta-cognition) and regulate their own behaviors and interactions. They need diverse experiences to help them develop self-reflective and self-regulatory skills. Knowledge learning can be enhanced by developing meta-cognitive strategies, self-reflection and inhibitory control in children. These skills can be taught.

In knowledge gaining, children construct causal frameworks to make sense of their experiences in the biological, physical and psychological realms, in order to explain, for example why other people behave as they

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are observed to do, or why objects or events follow observed patterns. Children gain their knowledge through active experiences, language, pretend play and teaching which are all important for the development of children's causal explanatory systems.

In children's cognitive development, incremental experience is crucial for learning and knowledge construction. The brains learn from every experienced event, but because cognitive representation is distributed across networks of neurons, cumulative learning is crucial. There is stronger representation of what is common across learning experiences, and there is multiple representation of experiences, for example, motor and visual representations. It supports the value of multi-sensory approaches to learning. Other important factors for cognitive development in children are pretending to play and the imagination. It helps children to reflect upon and regulate their own cognitive behaviors, and gain a deeper understanding of the mind. Pretending is more effective when carried out with other children and when scaffold by adults.

School Sanitation (2005) specified that children's learning can be more effective with the following considerations that are taken into account:

(1) Children want to learn and they have previous experiences and insights in mind;

(2) Children learn best when using a range of senses;

(3) Children like to copy and easily pick up both bad and good habits, so good role models are needed at their schools, homes or even everywhere;

(4) Children need to learn information that is relevant and the learning needs to be related to an individual child's environment;

(5) Children need praise and positive reinforcement, which help children to experiment successfully;

(6) Children love to play and playing is an active form of learning.

2. Design guidelines for children

This study considers the design guidelines for children as the target user in this study is children. Therefore, this subsection describes usability for children users and 6 categories of design guidelines for children. The detail of each is elaborated in further subsections.

2.1 Usability for children users

Gilut and Nielsen (2007) discovered usability findings for children users. Table 1 describes 4 usability findings for children as users.

Table 1 Usability findings for children users

Findings	Usability findings for children user
1	Animation and sound effects were positive design elements for children, often helping create a good first impression that encouraged users to stay with a site.
2	Children were willing to indulge in mine-sweeping behaviors, where they had to scrub the screen with the mouse in order to find clickable areas or enjoy the sound effects played by various screen elements.
3	Geographic navigation metaphors worked, in terms of presenting the children with pictures of rooms, villages, 3-D maps, or other simulated environments that served as an overview and entry point to the various features of a site or sub-site.
4	Children rarely scrolled pages and mainly interacted with the information that was visible above the fold.

Source: Gilut & Nielsen, 2007.

Table 2 Design guidelines for children

Design categories	Design guidelines description
General interaction	(1) Design for no scrolling: Fit information on a page viewed at 800×600 resolutions.
	(2) Create immediate success: Make it easy for children to find what they want on their first attempt.
	(3) Make sure every feature works well: It is better to have fewer features that all work perfectly, rather than include some that are difficult to understand.
	(4) Provide explicit directions: Tell the users what to do, right on the screen.
	(5) Use icons and symbol in familiar ways: Match icons' design to their meaning in the physical world.
Text	(6) Use simple, relatively large fonts: Text fonts on screen should be comparable in size to at least 12-point print type. Provide good contrast between the text and the background. Contrast is especially important for beginning readers.
	(7) Do not use animated text: Using animation or other special effects on text causes and problems when it is too slow or too fast, or when objects and text are superimposed.
	(8) Use easily understandable and succinct text only: Minimize the amount of text on screens.
	(9) Provide instructions that are always accessible: Place easy-to-find links to brief text explanations wherever the users might need or want instructions.
Multimedia	(10) Use motion and sound to attract children's attention and engage them: Children find animation and sound extremely engaging. Use animation as a way to focus users' attention on important elements on the screen.
	(11) Show users the status of multimedia downloads and playtimes: Present progress to completion, how much time or file size remains for downloads, and how long it takes to play the actual multimedia clip.
	(12) Allow the users to control the multimedia clip: Provide an explicit skip feature (such as a "skip" button) for all flash movies.
	(13) Make intro animations short and interesting: Animations that are short (10-20 seconds) and meaningful (funny, surprising, intriguing and enjoying) work best.
	(14) Consider using rollovers for narration: Add rollovers for audio narration and instructions if your target users are unable to read or are in the initial stages of reading.
Navigation and search	(15) Use standard navigation and search schemes: Many children are familiar with these conventions and use them easily.
	(16) Create meaningful category names: Use informative titles for category names, rather than vague and trendy words.
	(17) Present noticeable "you are here" feedback to users: Show users where they are in the website structure, and where they can go.
Graphical user interface	(18) Make clickable item looks clickable: Add visual affordance of clickability to interactive images and links. Make the distinction between clickable and non-clickable items clear.
	(19) Add simple visual rollovers to images that can be clicked: Graphic rollovers serve as cues to users that an item is clickable.
Content	(20) Design characters that kids can identify with: Kids love character. Users will be excited about almost any object that appeared to be an animated being.
	(21) Allow users to control or interact with characters: Children enjoy the ability to influence various characters, and will seek out all the ways they can interact with them. The more users interacted with characters, the more engaged they became. Even when the interaction was minimal, controlling characters' actions was a great enhancement to the users' experiences.

Source: Gilut & Nielsen, 2007.

2.2 Six categories of design guidelines for children

Gilut and Nielsen (2007) also outlined 6 categories of the design guidelines for children derived from their study. This study adopts the guidelines as the strategies to develop the prototype. The 6 categories are general interaction, text, multimedia, navigation and search, graphical user interface and content. This study adopted some of the design guidelines for children as described in detail in Table 2.

3. How the design guidelines for children support PMLE

There are 6 design categories of guidelines for children applied to this study: general interaction, text, multimedia, navigation and search, graphical user interface and content, which are described in detail as following subsections.

3.1 General interaction

This persuasive multimedia learning environment is designed as recommended in general interaction category that ensures design for no scrolling which fits information on a page viewed at 800×600 resolutions. Children as users in this learning environment can easily find what they want on their first attempt based on the fun and interesting main screen of the prototype so that they can create immediate success. Also, every feature of the prototype is easy to understand and works well. The instructions in this learning environment provide explicit direction that tells children what to do right on the screen and use icons that match each icon's design to its meaning in the physical world. For example, a toothbrush icon is designed about telling the children that icon is used to explore about tooth brushing (see Figure 1).

Figure 1 Snap-shot screen of a toothbrush character in PMLE

3.2 Text

Text font type used is Arial and the size is 12. It also provides a good contrast between text and background. This learning environment used static text and it is used for giving instruction in a brief text explanation. These are all in line with the suggested guidelines for designing text for children.

3.3 Multimedia

This learning environment is emphasized on the multimedia elements. Motion and sound are utilized to attract children's attention and engage them to the prototype because they find animation and sound extremely engaging. This study uses animation as a way to focus children's attention on important elements on the screen. The status of multimedia downloads and playtimes have also been shown to the children. Children are also allowed to control the video clip which provides a control panel feature for children to rewind, forward, stop and play the video-clip (see Figure 2). Other recommendations that have been applied in this learning environment are making intro of animations short and interesting which is spent only for 18 seconds.

Figure 2 Snap-shot screen of a video clip and the control panel

3.4 Navigation and search

This learning environment used icon based on a navigation convention, because many children are familiar with this convention and use them easily. For creating meaningful category names, this learning environment used informative titles for category names, rather than vague and trendy words. In this learning environment, children are shown where they are in the application structure, and where they can go.

3.5 Graphical and user interface

In this learning environment, there are many clickable items that look like clickable. For example, the PMLE highlights the line of images that can be clicked by the children. All clickable items are highlighted in a "blink" mode as a visual affordance of click ability to interactive images and links. These will help children easily identify and make the distinction clear in which item can be clickable or not.

3.6 Content

This category of guidelines selected for this study focus on the characters design, because children love characters. Users will be excited about almost any object that appeared to be an animated being. This multimedia

learning environment allows users to control or interact with characters. Most of the clickable images in this learning environment are designed as animated characters that represent things which can speak such as a toothbrush, represent role play such as a dentist, and represent the main narrator of this learning environment which is a healthy tooth called as "Gg" that is illustrated in Figure 3. It is believed that this is in line with the content category guidelines that children enjoy the ability to influence various characters, and will seek out all the ways that they can interact with them. The more children interacted with characters, the more engaged they became. Therefore, it will motivate the children to reduce their dental anxiety once they have engaged with the persuasive multimedia learning environment.

Figure 3 Snap-shot screen of a dental room in PMLE

4. Presentation modes of PMLE

Presentation modes in this study are based on the redundancy principle, which is one of the principles in multimedia design principles by Mayer (2001). Redundancy principle believes that a learner, particularly a child in this study, learns better from animation and narration without text than from animation and narration with text. Relating to this study, presentation mode 1 (PM1) is a learning mode, which comprises combination of narrated animation with on-screen text. Whereas, presentation mode 2 (PM2) comprises combination of narrated animation without on-screen text.

According to Mayer (2001), adding redundant onscreen text to a multimedia presentation could overload the visual channel. The case against adding onscreen text is based on the capacity-limitation hypothesis. The hypothesis mentioned that people have limited capacity to process visually presented material and limited capacity to process auditory presented material.

For this study, Figure 4 summarizes the cognitive activities that occur for a presentation in PM1 and PM2. The PM1 frame in Figure 4 shows that the animation enters the children's cognitive system through the eyes and is processed in the visual or pictorial channel, whereas the narration enters the children's cognitive system through the

ears and is processed in the auditory or verbal channel. However, the onscreen text also enters through the eyes and must be processed in the visual or pictorial channel. Thus, the limited cognitive resources in the visual channel must be used to process both the animation and the printed text in PM1. If children are unfamiliar with the material, they may experience cognitive overload in the visual or pictorial channel. The expected effect on PM1 is that some important aspects of the animation may not be selected and organized into a mental presentation.

In contrast, PM2 frame in Figure 4 shows that the animations enter through the eyes and are processed in the visual or pictorial channel, whereas narrations enter through the ears and are processed in the auditory or verbal channel. The chances for overload are minimized, so the children are more able to engage in appropriate cognitive processing. The expected effect on PM2 is that children will learn more deeply from persuasive multimedia learning environment in which redundant onscreen text is excluded rather than included.

On the basis of this theory, the expected result can be predicted in which PM2 will result in better learning and can be a better cognitive aid than PM1 in reducing children dental anxiety.

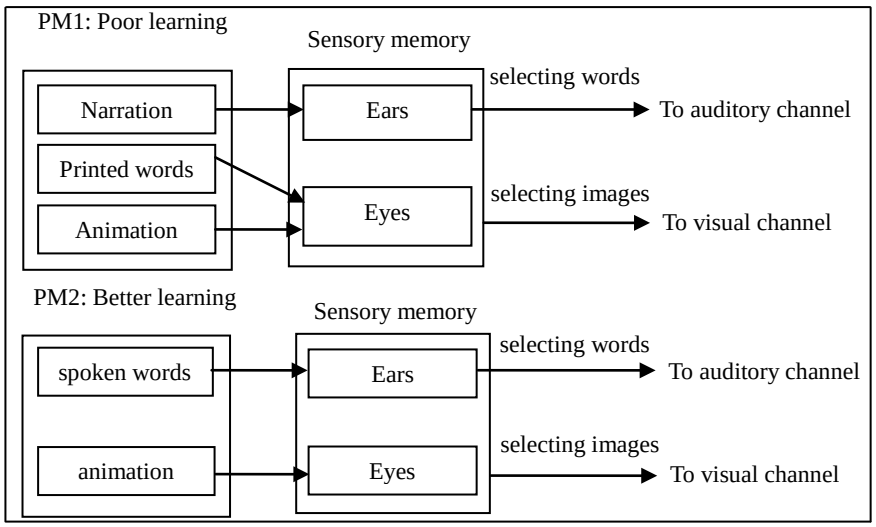

Figure 4 Intended results to be achieved in the study

5. User study

An experimental study has been used to evaluate the PMLE prototype, which assessed children's dental anxiety before and after the demonstration of a persuasive multimedia learning environment. This study excluded control groups, because there is no standard benchmark appointed by Ministry of Health in Malaysia.

This study involved random assignment of the intact groups to treatment with specific criteria, rather than assignment of individuals. The sample of this study must be a group of students that have a feeling on dental anxiety. Therefore, to make sure whether the group is equivalent, the baseline test in the phase 1 (see Table 3) has been used to measure the dental anxiety understanding among children. The measurement instrument will be Smiley Faces Program which will be given and analyzed in term of homogeneity of dental anxiety level.

The treatment group performed a different set of a persuasive multimedia learning environment which was intended to develop their understanding of dentistry, particularly dental treatment. This user's study involves three

phases. Phase 1 is the baseline test; phase 2 is exploration and the use of PMLE as a treatment; and phase 3 is the CDA (children's dental anxiety) test.

Table 3 User study phases

	Phase 1	Phase 2	Phase 3
Treatment group	O_1=Baseline test (using SFP instrument)	Y_1=PMLE (treatment)	O_2=CDA test (using SFP instrument)

5.1 Instrument: Smiley Faces Program (SFP)

The instrument that has been used in the experiment is a SFP instrument which is used in the baseline test and the children's dental anxiety test. SFP is used to measure both the baseline of children's dental anxiety level before the treatment is given and the children's dental anxiety level after the treatment is given.

According to Buchanan (2005), SFP is a dental anxiety measurement for children, which consists of 5 dimensions of children's dental anxiety. All 5 dimensions are the major causal factors of children's dental anxiety. Table 4 illustrates the dimensions in the SFP.

Table 4 Dental anxiety dimensions in SFP

The dimensions
(1) Going to the dentist tomorrow
(2) Sitting in the waiting room
(3) About to have a tooth drilled
(4) About to have tooth taken out
(5) About to have an injection

The measurement scale for SFP uses a set of 5 faces that represent the feelings of children's response towards the dimensions of dental anxiety. The 5 dimensions included in the SFP score ranges from 1 to 5. Hence, the minimum score possible is 1 and the maximum is 5, which higher scores indicate higher anxiety. While, the tolerance rate for this study is between 3 to 5 mean scores.

5.2 Characteristics of sample

Two to three intact classes were chosen from each of 5 different primary schools. A total of Year 1 to 3 school students participated in this experiment. The 240 learners (children) who had dental anxiety feeling were randomly divided into a group on their intact classes. The group was assigned to the PMLE as a treatment in reducing the children dental anxiety.

6. Results

Paired samples T-test is used to test the effects of PMLE. This paired samples T-test analysis indicates that there is a mean difference in scores of each child's dental anxiety dimension between the 2 presentation modes as depicted from Figure 5. In non-text version, the mean scores on the CDA test for each dental anxiety dimension was lower than the mean score on the baseline test for each dental anxiety dimension. For example, the mean scores on PM1 and PM2 in CDA test were lower than the mean scores for both PM1 and PM2 in the baseline test. In relation to text version, the mean scores on the CDA test for each dental anxiety dimension were also lower

than the mean scores on the baseline test for each dental anxiety dimension. This means that there is a reduction in the children's dental anxiety level after having both treatment of the non-text version and text version presentation modes. The reduction scores based on the mean scores have difference in scores of each child's dental anxiety dimension between the 2 presentation modes using PMLE as a treatment that are illustrated in Figure 5.

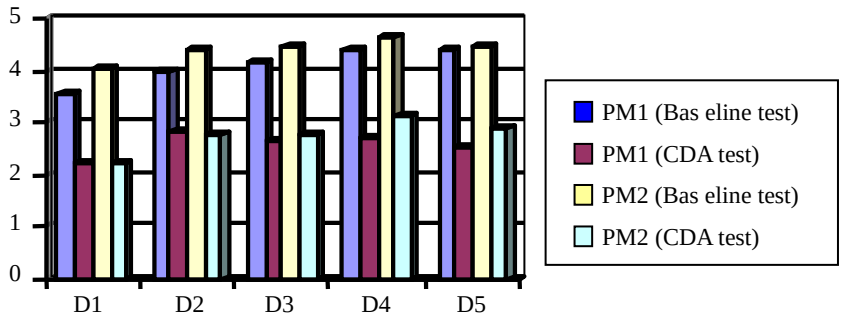

Figure 5 Children dental anxiety scores between the two presentations modes
Note: D1 to D5 refers to the dimension of children's dental anxiety.

Overall, both text version and non-text version presentation modes had significant positive effects on reducing children's dental anxiety. This was proved by the statistical results that both text version and non-text version presentation modes obtained significantly higher mean scores for the baseline test, which means that the children used to have the dental anxiety feelings. In relation to the CDA scores, both text version and non-text version presentation modes obtained significantly lower mean scores for the CDA test, which means that the children are successful in reducing their dental anxiety. This result proves that the PMLE is perhaps should be an alternative solution in reducing children's dental anxiety, particularly in Malaysia context.

This experiment had used both presentation modes as the treatment and the results proved that both presentation modes had reduced the children's dental anxiety. Interestingly, the statistical results have shown that text version presentation mode (PM1) is slightly higher than non-text version presentation mode (PM2) in reducing children dental anxiety.

This results are against the assumption of Mayer's (2001) redundancy principle. Figure 6 illustrates the actual result that reverses the redundancy principle. According to Mayer (2001), adding redundant onscreen text to a multimedia presentation could overload the visual channel. The case against adding on-screen text is based on the capacity-limitation hypothesis. The hypothesis mentioned that people have limited capacity to process visually presented material and limited capacity to process auditory presented material.

For other reasons, Moreno and Mayer (2000) obtained a reverse redundancy effect with concurrent spoken and written text superior to spoken text alone. They attributed this failure to find redundancy to the virtual reality environment. They found that written text in the spoken/written combination was not redundant compared to spoken text alone.

On the basis of this theory, the intended result can be predicted in which PM2 will result in better learning and can be a better cognitive aid than PM1 in reducing children's dental anxiety. However, the statistical result shows that PM1 had better learning result as compared to PM2. The actual result is illustrated in Figure 6. This result can be explained by the findings from Kalyuga, Chandler and Sweller (2000) and Morena and Mayer (2000).

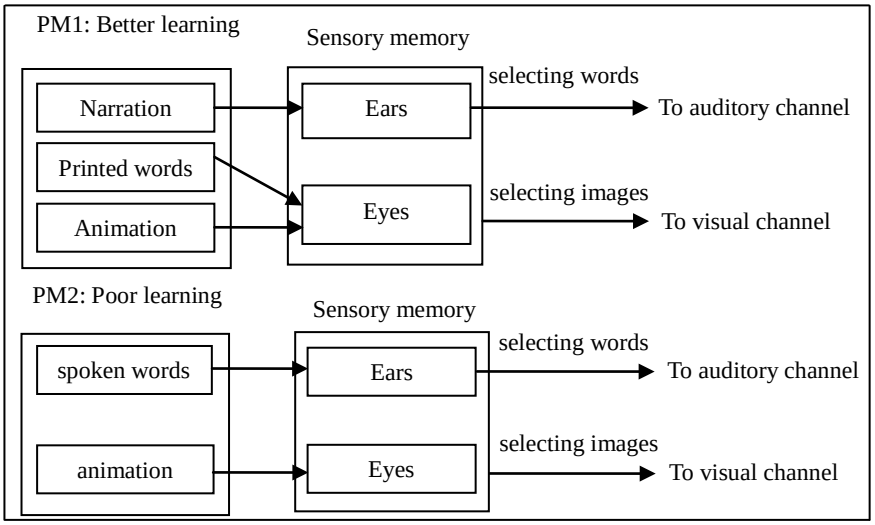

Figure 6 Actual result which reversed the assumption of redundancy principle

Kalyuga, Chandler and Sweller (2000) demonstrated that the replacement of written text associated with a diagram by auditory text resulted in superior learning but the addition of auditory text eliminated any advantages. This finding was only obtained with novices (Mayer, 2005). For novices, construction of new schemas represents the prevailing activity that needs to be appropriately supported by instructional material. Providing detailed textual (visual or auditory) explanations together with animated pictures in proper formats might be optional for these learners (Sweller, 2003). At this stage, the learners who do not have many relevant, pre-acquired instruction would not constitute appropriate instructional formats.

6. Conclusion

This study has proved that design guidelines for children have been successfully applied to the design and development of the PMLE in decreasing children's dental anxiety problem.

Furthermore, the finding of the study has shown that the text version presentation mode has highly reduced children's dental anxiety compared to non-text version presentation mode. This study also had reversed the redundancy principle effect. The redundancy effect is a precursor of and so essential to the understanding of the reasons behind. This finding is supported by Kalyuga, Chandler and Sweller (2000) and Morena and Mayer (2000).

Therefore, both reasons of reverse redundancy effects are caused of novice learners and virtual reality environment, which are significantly related to the PMLE nature. This is due to that the PMLE learners are novice learners at younger age and had not experienced any knowledge on how to reduce their dental anxiety. In addition, the nature of PMLE itself is a virtual reality environment. Hence, the result of this study is obtained from the occasions as mentioned above.

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(Edited by Nicole and Lily)