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RESEARCH ARTICLE

Dilemma Between Applying Coherent Principle and Signaling Principles In Interactive Learning Media

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Abstract:

Background:

Studies on developing multimedia content for eLearning have widely been conducted. In previous studies, multimedia learning contents were developed without applying any principles, making them less efficient in supporting user's mental effort. To this end, this study extends the current state by applying the coherence principle and signaling principle to make the multimedia learning content usable and interesting to use. Furthermore, the paper aims at describing the dilemma when applying both principles together.

Materials and Methods:

In this study, a four-phase methodology has been used. First, a prototype has been developed by applying the coherence principle and signaling principle. Following the development, five experts were consulted for identifying flaws in the developed prototype through a walkthrough session.

Results:

Finally, this paper showcases the flaws gathered by the experts for further improvement.

Keywords: Coherence principle, Signaling principle, Interactive learning media, Learning, Multimedia content, Dilemma.

1. INTRODUCTION

Teaching and learning activities have now gone beyond the classroom. In a digital environment, the learning ecosystem comprises a learning management system, a learning content management system, and a learning object. The technologies supporting the learning and teaching processes have become so advanced thus enabling anyone to have learning opportunities. As a response to such advantages, various works have been conducted for enriching learning experience. As an example, Aziz *et al.* [1] and Dalle *et al.* [2] made the multimedia learning content simpler through the simplicity principle for visually-impaired learners in schools. Meanwhile, Dolhalit *et al.* [3] applied the persuasive principle in their multimedia content that makes society aware of the danger of truancy among school students. While previously, Tosho *et al.* [4] and Elkabani and Zantout [5] coined a model for multimedia learning content for inclusive users. In fact, multimedia has been used also in teaching practical skills [2, 6], assisting people in learning practical tasks in extremely-crowded situation [7] and teaching culture [8]. While they evolve from different forms, the society forgets that such technologies actually prepare them for facing the learning paradigm in the fourth Industrial

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Revolution (IR4.0) [9, 10]. In general, the IR4.0 requires designers to be highly creative in providing solutions [11, 12].

In IR4.0, the learning and teaching processes have been largely improved by the multimedia technology [13]. Besides the fact that learning activities are diversified (as described in the studies in the previous paragraph), the learning contents are also made easily understandable and more attractive through the use of multimedia technology [14, 15]. As an instance, an extremely fast-moving object is presented in a slow representation. It has also been seen that abstract concepts (such as photosynthesis and respiration) can be represented in a concrete form. Furthermore, it can support educators in case of dangerous or rare phenomena that are difficult to be presented in class. In fact, Mayer [14] goes beyond that in which he expressed that multimedia technology supports various tasks for enabling learning takes place in a virtual environment.

Multimedia contents or interactive learning media must be tailored for intended users. Moreover, its context of use must be carefully considered. Without a proper design and development procedure, it will not successfully achieve its goals in its desired context. In this regard, Cooper *et al.* [16] expressed that designers have to focus on the learning experience. When there are too many difficulties in utilizing the learning materials, users tend to get frustrated [17] and such experience could disengage users with the learning content and learning activities.

In Indonesia, the government invests hugely in the education sector [18]. However, the teaching and learning technologies, including multimedia learning content, have to be wisely designed so that they do not go against human rights [19, 20]. Aspired to be at par with teachers in developed countries, the government also concerns with teachers' ability. Hence, it has been underlined in the main thrusts of the national agenda, which implies that each education level must possess a high quality of teaching and learning practice. This requires the co-operation of all teachers, especially regarding their teaching duties [20, 21] because learners have different types of intelligence [22, 23]. Considering Multiple Intelligence, one of the intelligences is, for example, visual intelligence, which argues that there are people who learn best through visual representations. In response to that, this study believes that multimedia learning will benefit students in their learning process [24]. It is especially applicable to topics that contain processes and step-by-step procedures, including learning mathematics.

Works on making learning mathematics interesting through multimedia contents have been widely conducted. In their recent study, Parera *et al.* [25] and attracted learners through digital creative games, as opposed to earlier approaches as of Chorianopoulos *et al.* [26], that used serious games. Even though both studies use games, their connotation is different. Nevertheless, both have shown a positive impact towards learning mathematics. Meanwhile, Chao-Fernández *et al.* [27] utilized music in making learning mathematics interesting.

The multimedia learning content has been used in supporting not only the needs of normal learners but also learners with special needs. This is shown in recent works of Ávila-Soto *et al.* [28] and Maćkowski *et al.* [29]. Meanwhile, Ahmad and Mutalib [30] designed a courseware for low-achieving learners. However, in the above-mentioned studies, authors have not reported the application of certain multimedia design principles. As it is shown in this study, without applying multimedia principles, the learning users do not experience the learning contents as they desire. Furthermore, they become cognitively tired and exhausted because they are dealing with audio and visual elements. When their cognitive is inappropriately loaded, their attention is disrupted, which negatively affects their learning process. The present study presumes that when multimedia design principles are applied, the courseware would better assist the learners.

Regarding multimedia learning content for learning mathematics, Sweller *et al.* [31] considered that reduced cognitive and minimized load is potentials for promoting user's engagement in using multimedia content. One of the famous ways to ensure this fact is to apply certain principles in the multimedia learning system design [32]. In response to that, this study applies in the design process two of the multimedia learning principles [33], which are recommended by Mayer and Fiorella [34] and Mayer *et al.* [35], namely the signaling principle and the coherent principle. In general, the coherent principle recommends that multimedia learning content should rather be simple, not complex. In contrast, the signaling principle recommends that important parts of the multimedia learning contents should be highlighted or supported with certain instructional technique [36]. This study involves a scientific and systematic process [37, 38] for designing and developing the multimedia learning content while considering an expert review upon the developed multimedia learning in accordance.

All the above-mentioned discussions highlight the importance of multimedia use in supporting the learning process. However, ensuring users' satisfaction when using the multimedia learning system is another issue. Accordingly, this study attempts to design a multimedia learning system related to mathematics content to be used in secondary schools in

Indonesia. For the purpose of this study, the content has been decided by the school teachers. Based on their experience in teaching mathematics for more than 8 years, the fraction topic is appropriate because it is not too difficult and has the potential to be understood by all learners.

This section states the aim of this study and discusses the background, including the problem that this study solves. A detailed explanation of the research procedure is enclosed in the next section, which is followed by the results and findings. Finally, this paper ends with a conclusive discussion regarding the way this study impacts the context of the study.

2. METHODOLOGY

To achieve the proposed aim, this study involves a set of activities, which cover three stages, as shown in Fig. (**1**) (Interactive Triangulation Methodology), namely requirement analysis, development, and evaluation. Every stage requires iterations of processes, which demand triangulations for the data source and methods.

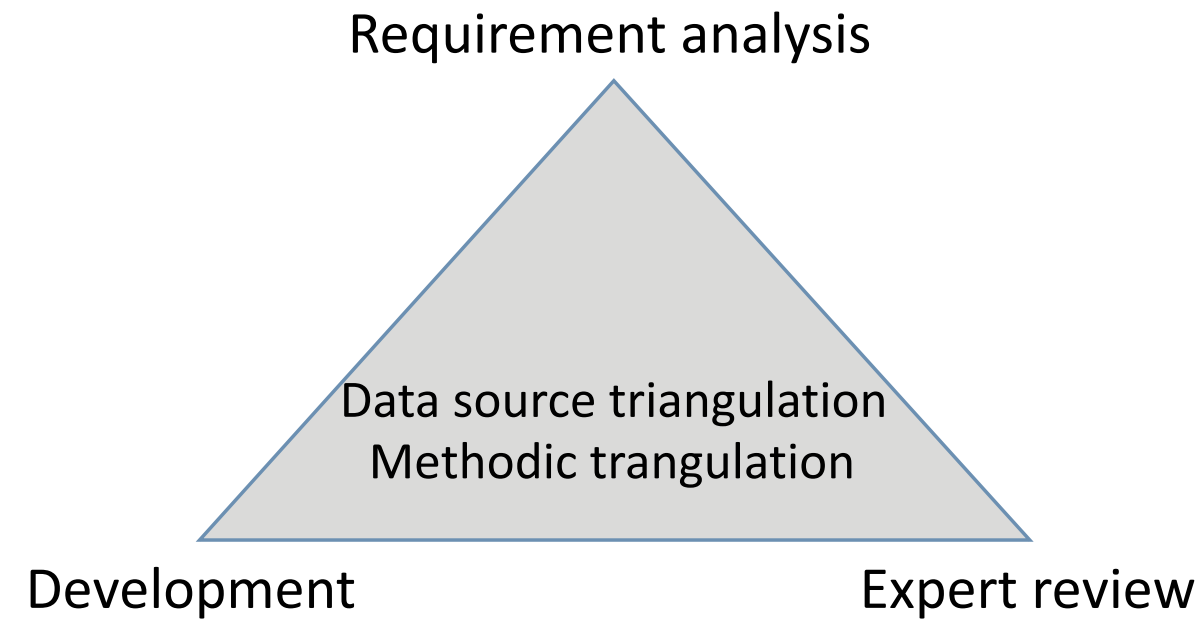

Fig. (1). Iterative triangulation methodology.

- Data source triangulation: This study gathers data from different timings, locations, and people. This increases the possibility of revealing typical data or the potential of identifying similar patterns, thus increasing confidence of the findings.
- Methodology triangulation: This could also be called mix method or multi-method and can be considered in both data collection methods and research methods. The use of different methods provides richer information to the study.

Furthermore, Fig. (**2**) visualizes the steps conducted throughout the research work mapped with the study deliverables.

Referring to Fig. (**2**), it is observed that the requirements were gathered through interviews and observations. Basically, based on the problem, this study observed the teaching and the learning process within class hours for five different schools. It was found that teachers use conventional means and the pupils (learners) do not engage in the process. The mediums relate only to chalk-and-board and books, for which learners show no excitement. After a few observation sessions, the teachers were interviewed as for the purpose of the study. The interviews were held in the corresponding five schools and two to three teachers were involved in each school. The purpose of interviewing the teachers was to gather their opinion on the use of visual representation (multimedia learning application) for their teaching and learning process, as a complementary medium to books. Additionally, it was aimed to gather inputs if they agree with the idea of utilizing multimedia learning application for learning mathematics.

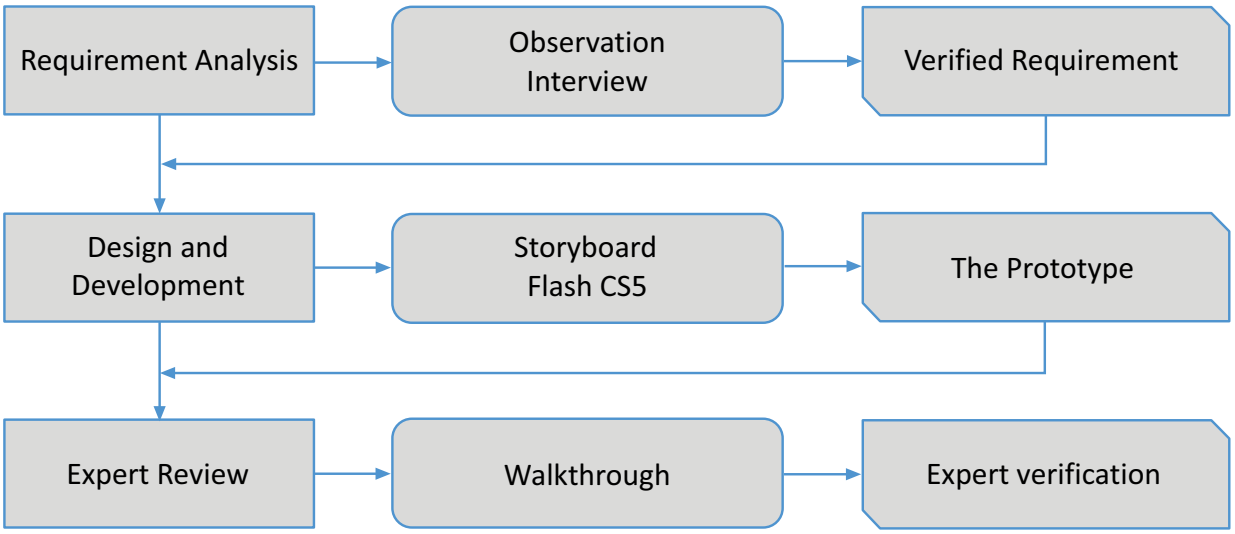

Fig. (2). Research procedure.

The teachers uncontestably accepted the idea of utilizing multimedia learning content for their teaching and learning purpose. In further discussions, the teachers agreed to select the fraction topic as a starting point. The topic was selected as it is not very difficult, it is famous and provides the potential for all learners to understand the concept. Given this fact, it is likewise a good strategy to familiarize them with the multimedia learning content considering other topics later on. Starting with a favorite topic could ensure learners' interest towards the multimedia learning content and further support their knowledge.

After the teachers were interviewed, this study interviewed a group of learners within each school to gather their requests related to the way they expect the multimedia learning content to support them in their learning. The interviews were also held in the schools where they study and between 13 and 17 learners from each school took part in this study. Although some learners were not sure about the format of the learning content, the majority expressed their preference for a courseware, no matter if it is online or offline. They had no idea on how the multimedia learning system should look or act, but only that it must be user-friendly. This implies that the learning content has to be in Bahasa Indonesia.

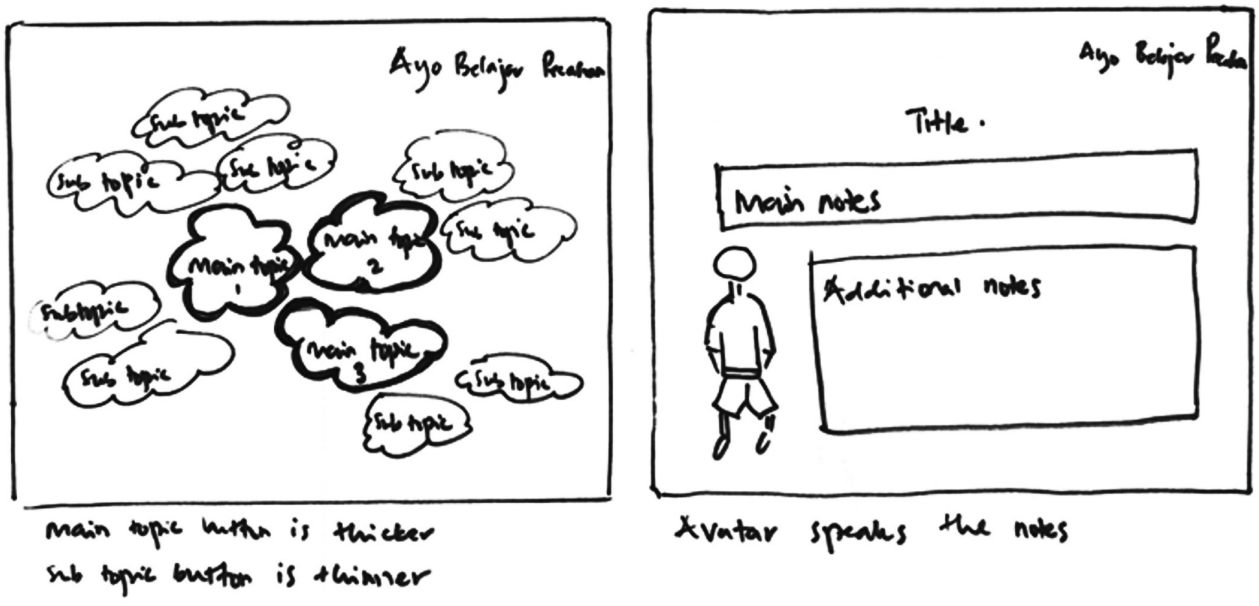

Fig. (3). Sample of the storyboard.

The results of the observations and interviews set the requirements for the multimedia learning content. It is clear

that users need an interactive multimedia for content learning that provides information on the fraction topic. They want to access the learning content from any location and at any given time. While the focus is to make the multimedia learning content usable for the users, the fraction content for this study was taken from the standard textbooks used in schools. Particularly, multimedia learning content should minimize users' cognitive load by minimizing assessments.

Based on the requirements gathered in Phase 1, this study designed the visual interface and the ambience of the multimedia learning content in Phase 2. Storyboard (the sample is available in Fig. (**3**) was used to locate ideas into concrete representations. It was necessary to ensure that quick responses could be gathered from users: teachers and students.

The alternative designs of storyboards were presented to users in a cyclical process, for them to give their comments and feedback on the designs. Providing alternative designs is necessary for the users to have opportunities to compare and express their responses as a reference to the designs, rather than having to think without any point of reference. The sample in Fig. (**3**) represents the finalized design.

When the design was selected, a working prototype was developed. Macromedia Flash 8 was used for developing the multimedia learning content. It is appropriate because the learning content contains hybrid interactivity and navigation style. Fig. (**4**) through Fig. (**8**) depict the snapshots of the multimedia learning content.

Fig. (**4**) shows the main menu of the multimedia learning content. A cloud representation is used for buttons. The cloud signals that they are clickable items. The title of the learning content is placed at the right-top corner of the interface.

Fig. (4). Main menu.

Similar cloud representation is used for selecting the topics, as shown in Fig. (**5**). The figure exhibits different line weights for the clouds contour, wherein a thicker contour represents a parent topic, while a thinner contour shows sub-topic.

Fig. (5). Selection of topics.

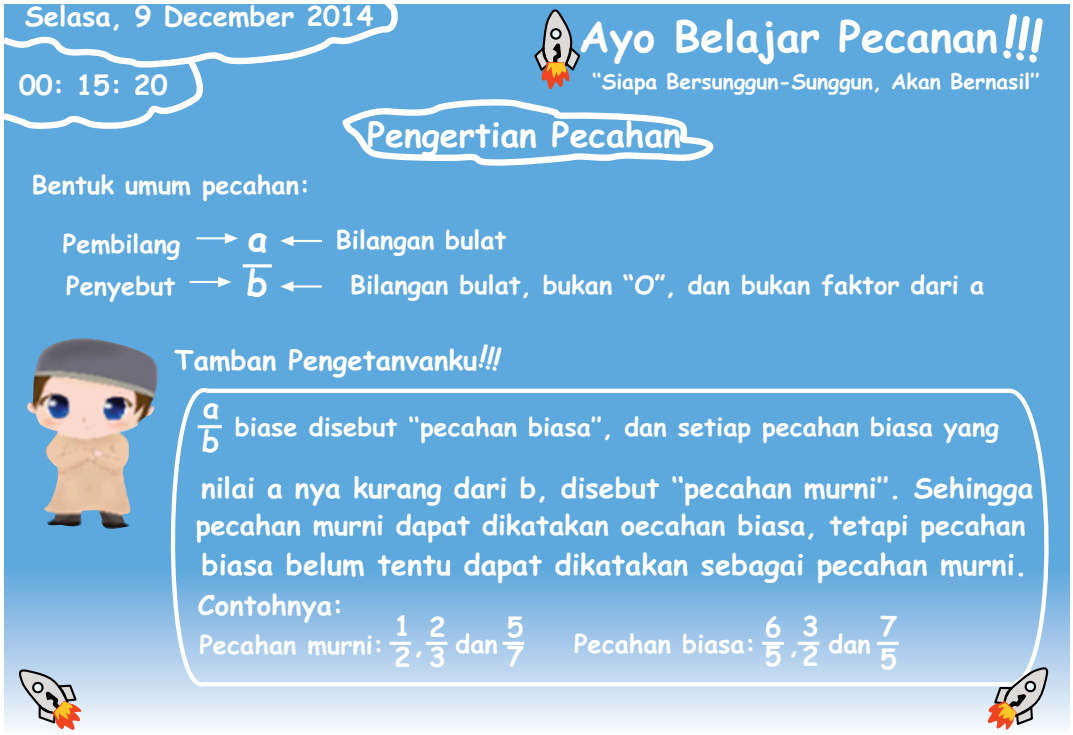

Fig. (6). Notes.

When notes are included, they are separated into different representations. Main notes are presented without a frame, while additional notes are located within frames, as shown in Fig. (**6**). This strategy highlights to learners the parts to focus more and where to focus less. Additionally, an avatar explains the notes using audio, with various intonations to highlight important points for the learners.

Fig. (7). Instructions.

When instructions are provided, they are represented in numbered lists, as indicated in Fig. (**7**). The use of numbered lists enables learners to systematically organize their learning process in a step-by-step order of actions to be performed. Fig. (**7**) exhibits a page for learners to perform exercises. From this page, the learners are supposed to select an appropriate level of questions to answer. From the figure, it is seen that the buttons clearly state the level of taxonomy for the questions. If learners click the "Uji Kompetensi 1" button, they will be provided with questions of knowledge level only. Meanwhile, the "Uji Kompetensi 2" button provides learners with questions of comprehension level. A similar procedure is considered for the other buttons. This strategy informs the learners about the level of questions they are expected to answer.

Fig. (8). Exercises.

When users click any button, a page appears, as shown in Fig. (**8**). It is seen that the questions and answer options are presented in a scrollable window, with a panel of responses at the bottom. The panel is consistently visible. This strategy is significant to notify the learners on their attempts.

Then, the prototype was reviewed by experts by means of a walkthrough process. The expert walkthrough process aims at determining whether users could easily carry out their tasks. For this study, experts' comments regarding the walkthrough are important, as indicators whether the learning content could reach learners before being implemented in actual teaching and learning activities. For such purpose, Blackmon *et al.* [39] employed five experts, and they were able to gather saturated feedbacks. Hence, this study adopts their technique, because we believe employing less than three experts is doubtable in terms of maximum feedback, while employing more than five experts may lead to a waste of resources. All experts involved in this study have experienced consulting projects in the industry. At the same time, they have been researching in human-computer interaction and teaching their respective fields for at least seven years. The walkthrough session was conducted as the procedure visualized in (Fig. **9**).

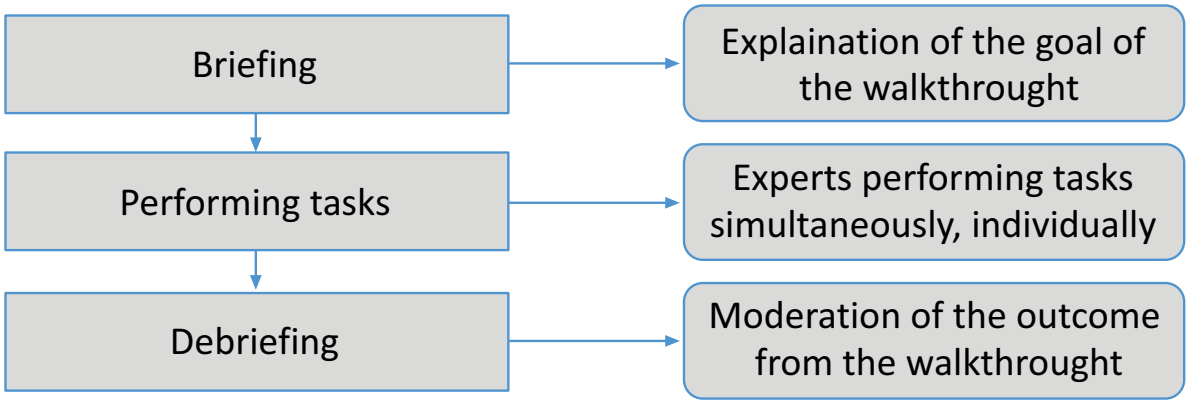

Fig. (9). The walkthrough procedure.

During the day of the walkthrough session, the experts were briefed about the aim of the walkthrough session. They were cleared that at the end of the walkthrough session, they should assemble usability flaws in the prototype, particularly on flaws regarding unnecessary activities that increase cognitive loads. Then, they conducted specific tasks to walk through the multimedia learning content. The tasks are (1) reading the notes about fraction, (2) understanding the instructions, (3) answering the exercise questions, and (4) analyzing their attempts. It was emphasized to the experts that they should note all findings while individually walking through the session. The expert provided their consent that they were not allowed to discuss during the walkthrough. The session was followed with a debriefing session, wherein the experts gathered together and discussed what they found. After brainstorming and moderating the outcomes, they finally provided the conclusions of this study.

3. RESULTS

The multimedia learning content was developed based on a storyboard designed in a cyclical process, which eventually has been approved by the users. The contents were adopted from the textbook used in schools. When experts walked through the learning content, their concern was focused on whether the prototype supports well the user tasks, through the way it interacts with the users. This refers to unnecessary activities that create cognitive loads, which may lead to negative impacts on user experience.

Having gone through the walkthrough process, the experts found that the multimedia learning content is able to properly deliver the learning contents. However, all experts agree there are some activities in certain parts that may lead to unnecessary user efforts either physically or cognitively. These additional activities are detailed in the following paragraphs.

In the main menu, the real-time date is stated in a cloud (Fig. (**10**), which could be understood as a button (*excise 1*). This is because all buttons are represented with a cloud formation, and therefore confuses the users. It is similar to the exit button that should be represented in a special representation to notify its impact (*excise 2*). Another fact is that the buttons are not organized (*excise 3*). Users have no order when searching for the desired button to be clicked; hence, they have to visually search the entire interface.

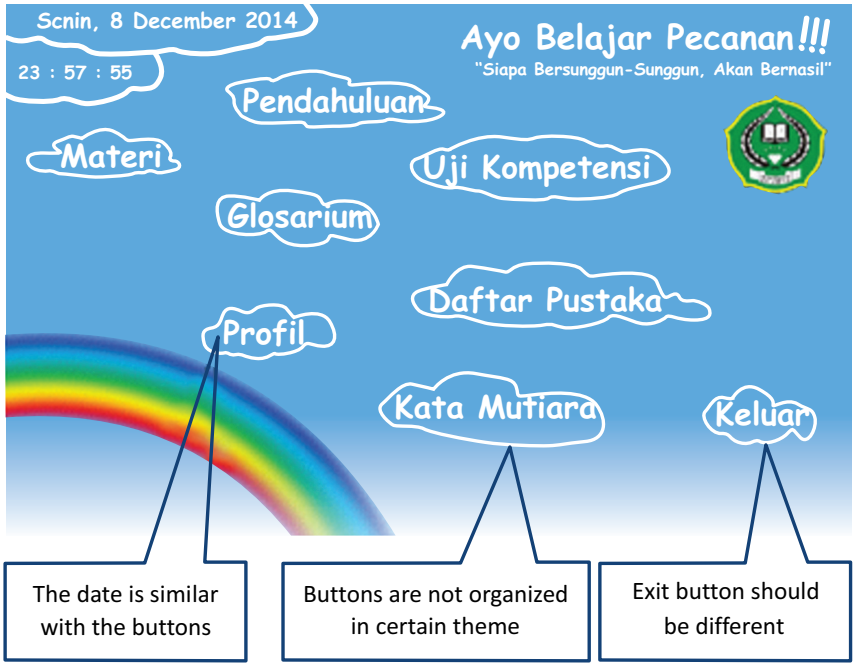

Fig. (10). Excise in main menu.

The buttons for selecting sub-topics are shown in Fig. (**11**). It is observed that the buttons for the parent topic and sub-topic are represented identically, except the outlines for the parent topic, which are thicker (*excise 4*). In such situations, some learners may not give attention to that or some may think that it is merely a mistake. Moreover, all buttons for sub-topics are not organized, similarly as found on the main page (*excise 5*). The buttons are also not associated with their parents. In this case, learners have to think additionally which sub-topics correspond to which parent. To avoid this additional load, topics have to be linked, for example using lines. Some good examples for that are using breadcrumb (in normal websites) or tab (in excel). Furthermore, the menu contains many topics, and therefore it (*excise 6*) should propose the order of topics to the learners so that it makes learners aware of the desired order and the corresponding topic family. This perhaps could be done using colors, shape, size, grouping, or other similar representations.

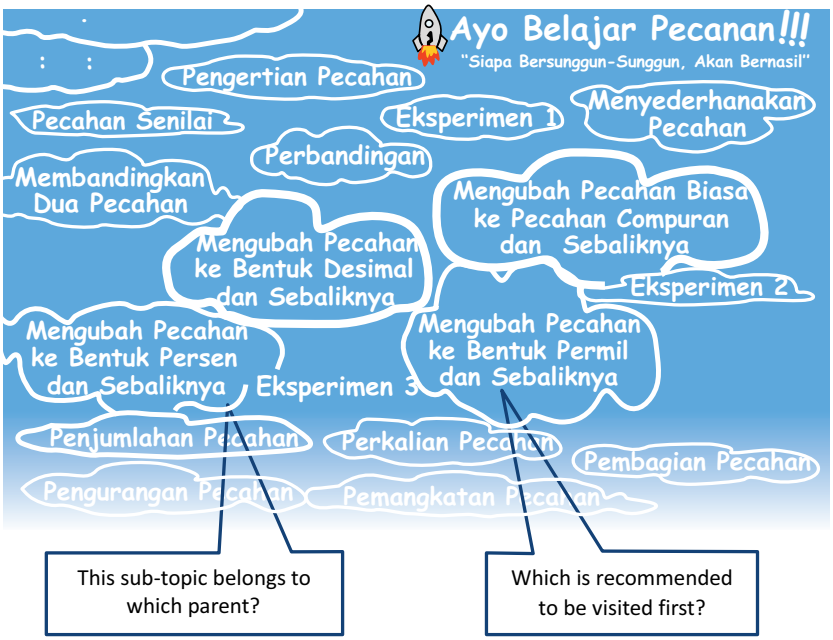

Fig. (11). Excise in sub-topic.

In the notes page (Fig. **12**), the title is represented in a cloud, identical with the buttons (*excise 7*). This really confuses learners, because they have associated the cloud with buttons in their mind. The title should be the dominant element in the page, with different colors and larger size, free of cloud. In the pages, the text is white (*excise 8*), which does not bring any emphasis from the learners' perspective. Hence, learners are not guided by repetition and emphasis. This could be avoided by using color, underline, punctuation, and others.

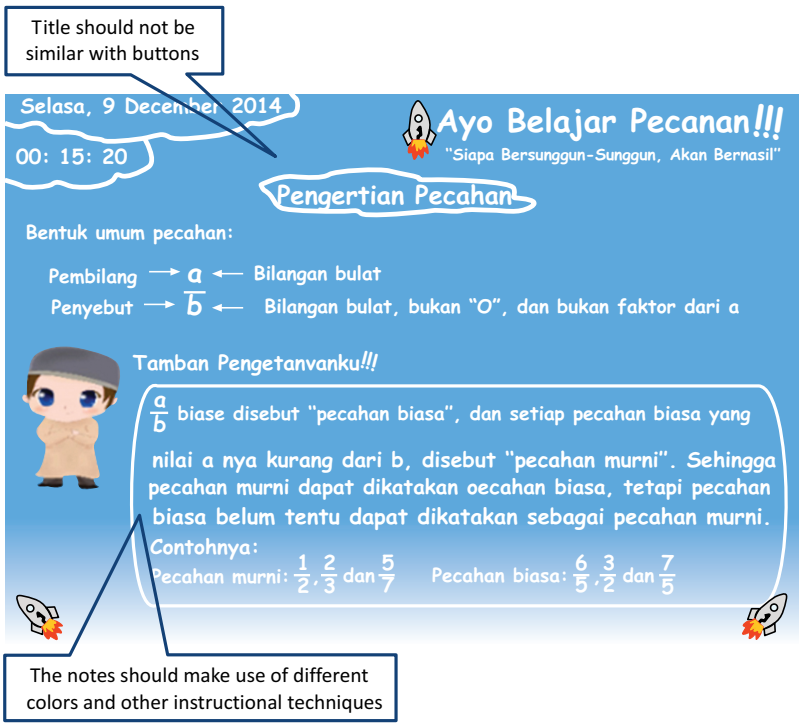

Fig. (12). Excise in notes.

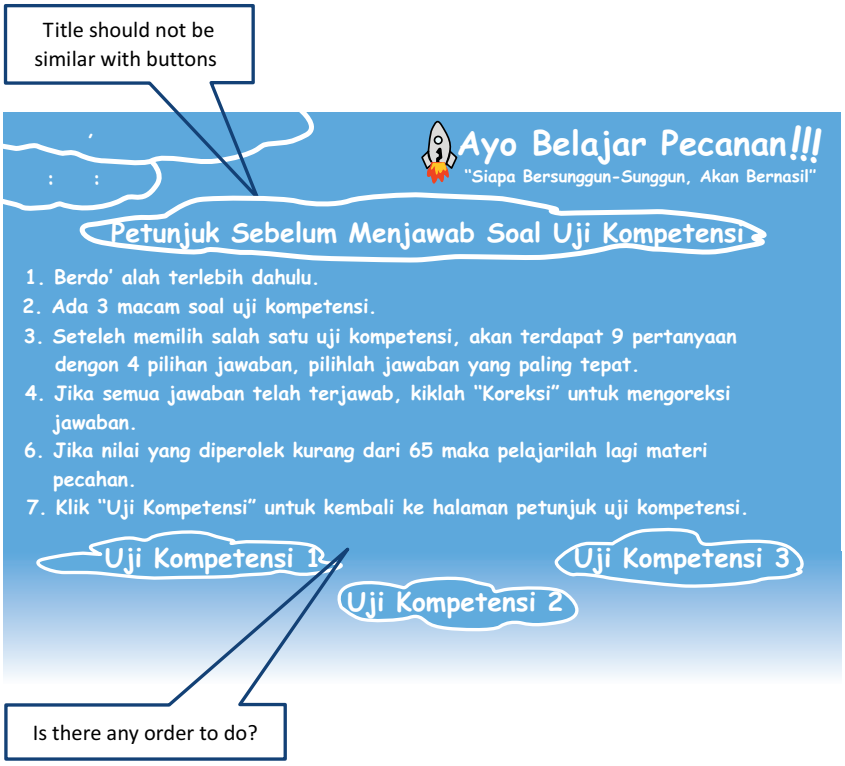

Fig. (13). Excise in instructions.

When instructions are available in the interface, they are represented in a numbered order, as shown in Fig. (**13**). In general, they are helpful, but the title is similar to buttons (*excise 9*) and can confuse some learners. At the bottom, there are three buttons intended to enable learners to test their knowledge and understanding about the topics. However, there is no indication related to the order (*excise 10*); therefore, learners do not know whether there is any order. This may force them to do the exercise in an inappropriate order. Moreover, the instruction lists are plainly white without any emphasis (*excise 11*). In this situation, learners are not motivated to go through the instructions, as it is desired. To avoid this situation, the use of different color for keywords may help.

In the exercises page (Fig. **14**), the use of the windowing approach is excellent, because it can ensure information about user attempts, which is always visible. However, the title looks like a button (*excise 12*). The questions and options for answers are in white (*excise 13*), which does not emphasize their meaning. If the options for answers would be in a different color, it may strongly convey its meaning. The level of information within and outside the window is also different. However, in Fig. (**14**), having similar color and size, they look alike (*excise 14*). This could be avoided using different size and color.

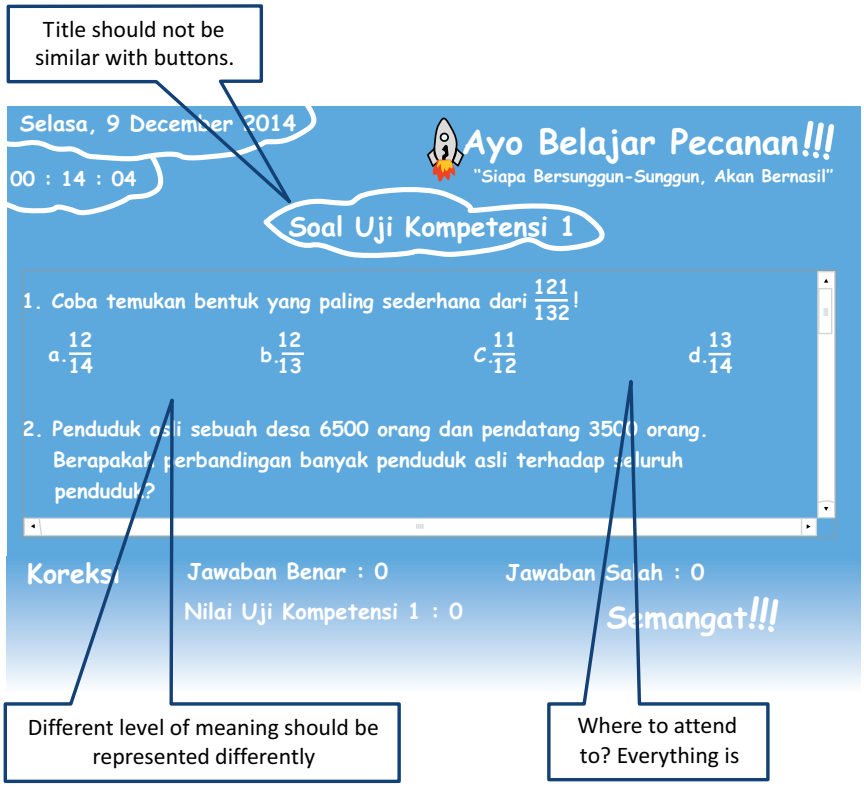

Fig. (14). Excise in exercises.

4. DISCUSSION

Involving experts in the design process is crucial for multimedia learning because they can discover flaws that may potentially disrupt the users. As an evidence, the experts in this study discovered 14 additional loading activities through the walkthrough sessions and they believe that there are severe excises regarding coherent and signaling principles that may disrupt learners' attention while learning using multimedia eLearning platform. Other studies have also involved experts in the development of interactive products such as Karajeh *et al.* [40], and Mohd and Shahbodin [41]. They also gathered similar results, wherein expert evaluations discover a number of a flaw in terms of excise in the interactive products.

Besides those 14 severe excises, they also discovered other excises that affect the learners but are not severe. Moreover, excises regarding aspects that are not related to coherent and signaling principles are also discovered (not discussed in this paper).

Although there are excises, the developed multimedia learning content has applied the principles at its best. Obviously, the coherent principle is applied throughout the learning content. By applying the principles, unnecessary

remedies are eliminated, which further help learners to focus on the learning content.

Similarly, the signaling principle is applied throughout the learning content. However, the designers are confused between strategies considering the coherent and signaling principles. It is observed that the designer is not confident to use elements for signaling the learners (by applying the signaling principle) to avoid making the display complex (the coherent principle).

Considering experts' feedback, this is a trade-off. However, in case it impacts more positively, let the use of signaling principle harmonizes the coherent principle. In case it is not necessary, follow the coherent principle [34, 35]. Such instructional approach is very important in the learning process because it can determine learners' knowledge [42].

CONCLUSION

Although the design is approved by the users (teachers and learners) through the storyboard, experts still recommend severe excise to be readdressed regarding the coherent and signaling principles. This study agrees to the experts' recommendations because they are experienced with numerous projects (as recommended by Preece *et al.* [17] and Mayhew [43]). Based on their experience in dealing with various users and various context, their recommendations are valid.

This study will take appropriate actions accordingly. All excises will be eliminated through appropriate instructional strategies. This will lead to a new design, which will need another expert evaluation, followed by user acceptance as it has previously been conducted within various works [44, 45]. In fact, this is likewise strongly emphasized by experts like Nielsen [46], Preece *et al.* [17], and Schneiderman *et al.* [47].

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No Animals/Humans were used for studies that are base of this research.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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