Investigating cognitive task difficulties and expert skills in e-Learning storyboards using a cognitive task analysis technique

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Abstract

E-learning storyboards have been a useful approach in distance learning development to support interaction between instructional designers and subject-matter experts. Current works show that researchers are focusing on different approaches for use in storyboards, and there is less emphasis on the effect of design and process difficulties faced by instructional designers and subject-matter experts. This study explores problem aspects of the cognitive task and the skills required of subject-matter experts by applying a cognitive task analysis approach from the expert point of view. The result shows that subject-matter experts face difficulties in making decisions on three elements during e-learning course development. The three elements are storyboard templates, prescriptive interactive components, and review process. It is found that the representation skills and decision making of the three elements allows subject-matter experts to decide on alternatives of the task process. The result also indicates that it is important to leverage the design and process skills of subject-matter experts as it affects their interaction with instructional designers. Three recommendations are made: training development, prescriptive interactive components development, and interaction design document development. A new framework can be recommended to train subject-matter experts as e-learning storyboard users, and in turn provide for effective interaction between them and instructional designers.

1. Introduction

E-learning course development for distance learning is a complex process because it needs a high-calibre e-learning course of instruction to be created by many people. Therefore, quality e-learning production requires a highly organized and concerted effort in terms of the key players (Caplan & Graham, 2008) i.e. IDs and SMEs (Caplan & Graham, 2008; Hixon, 2008; Kam, 2008; Keppell, 1999, 2004). Instructional design is defined as the “systematic and reflective process of translating principles of learning and instruction into plans for instructional materials, activities, information resources, and evaluation” (Smith, & Ragan, 2005, p.4). Thus, the IDs are the people responsible for designing the basic principles of instruction and learning that follow the instructional design process. On the other hand, the SME is “the qualified person who provides information about content and resources relating to all aspects of the topics for which instruction is to be designed” (Smith, & Ragan, 2005, p.4). SMEs are responsible for checking the accuracy of the content treatment in activities, materials, and examination (Morrison, Ross, Kemp, & Kalman, 2011).

The process of e-learning course development involves a multi-disciplinary collaborative team of IDs and SMEs (Caplan & Graham, 2008; Hixon, 2008; Kam, 2008; Keppell, 1999, 2004). Research in instructional design has found that, owing to their different backgrounds and expertise, the interaction between IDs and SMEs faces many difficulties, such as conflicts in communication, challenges in media product development, and conceptualization in unfamiliar content (Castro-Figueroa, 2009; Gibby, Quiros, Densps, & Liu, 2002; Keppell, 1999). One possible way to solve the difficulties is to use a visual aid called the “e-Learning Storyboard” (Castro-Figueroa, 2009).
The e-learning storyboard comprises documentation for e-learning courses which includes prescriptive interaction components such as animation, sound, pictures, text, and graphics (Chapman, 2008). The storyboard signifies the blueprint of production (Tumminello, 2005). It also saves time, money, communication and helps in problem solving (Pardew, 2004). The amount and positions of these components should be designed and planned by the IDs and SMEs before they are passed to the multimedia team for the production process (Okur & Gümus, 2010). The design and the process of e-learning storyboards is difficult for SMEs, however, because they are not experts in the areas of instructional design (Gibby et al., 2002). Moreover, the increased complexity of e-learning content has also caused many problems for SMEs (Pardew, 2004). The challenge for IDs is to train SMEs in design and the process and at the same time communicate and collaborate with them effectively. On the other hand, the study by Dicks and Ives (2008) noted that the approaches to the study of instructional design in the design process are largely behaviorist, whereas none investigated the cognitive processes underlying design activities.

Using a cognitive task analysis approach, this study investigates the task difficulties in e-learning storyboards through the exploration of experts’ knowledge. The objective is to identify which types of cognitive tasks are required for the e-learning storyboard. The study also investigates SMEs’ challenges and errors in the design and the process of e-learning. The paper is organized as follows. It begins with a literature review and a description of the cognitive task analysis approach applied in the study. The next section provides the methodology, which includes the design and procedures of the cognitive task analysis technique, and the final section presents data findings, results and recommendations.

2. Literature review

The literature review describes different approaches relating to the design of storyboards. This section also presents an overview of the cognitive task analysis approach and the ACTA method in particular.

2.1. Approaches in storyboard design

Recent trends in storyboards show that researchers use different approaches to assist users. In this paper, the approaches are categorized as:

- early sketch design approach, instructional model approach, SCORM-compliance authoring approach, learning theory approach and multimedia collaborative approach. Each approach is tailored to assist users by using different strategies.

In the early sketch design approach, storyboards were developed to assist designers to sketch user interfaces and web pages. Silk is a storyboard that allows designers to sketch user interfaces easily by recognizing the designer’s ink strokes. It can be placed in simulation mode to allow the user to experience the envisioned interaction (Landay & Myers, 2001). Denim is a system to assist designers of web sites in the early stages of information, navigation, and interaction design. It is an informal pen-based system that allows designers quickly to sketch web pages, view them at different levels of detail, create links and interact among them in a run mode (Newman, Lin, Hong, & Landay, 2003).

Demais is a sketch-based and interactive multimedia storyboard tool that uses a designer’s ink strokes and textual annotations as an input design vocabulary. Early in the design process, it enables a designer to explore and communicate behavioral design ideas using working examples (Bailey, Konstan, & Carlis, 2001). Anecdote is an authoring storyboard system that supports the early design phase and the whole development process of multimedia applications and employs the concept of surrogate media. Sketches used in this system represent the content of the media data to be created. It also allows designers to edit different aspects of the scenario using multiple editing views, therefore helping to create the final application seamlessly from the prototype scenario (Harada, Tanaka, Ogawa, & Hari, 1996).

In the instructional model approach, storyboards are developed by adopting particular instructional models. Wan Adli Ridwan (2007) developed the Content Storyboard Application System Framework using Gagne’s Nine Learning Events (Gagne, 1985, p.272). Mustaro, Silveira, Omar and Stump (2007) developed a schematic storyboard for learning object development using the ADDIE Model developed by Dick and Carey (1978) and Gagne’s nine events (Gagne, 1985).

SCORM is a technical specification that governs e-learning content creation and delivery (Bohl, Scheuhase, Segler & Winand, 2002). In the SCORM-compliance development approach, storyboards are developed to create e-learning content that complies with SCORM specifications. Ting, Chong, Ooi, Tan, Chuah and Saw (2005) developed the eStoryBoard authoring tool which includes two intelligent components. They are capable of generating multiple SCORM lesson plans automatically from the keywords provided by content creators. The tool also provides functionality for content creators to make predictions about learners’ academic performances by manipulating the mastery level of the learning content. Yang, Chiung-Hui, Cun Yen and Tsung-Hsein (2004) developed a simple visualized sequencing authoring tool called VOSSAT, to provide an easy-to-use and web-based interface to help instructors edit existing SCORM-compliant content packages.

The application of learning theories in the storyboard informs the user of the flow of the modules in the e-learning course and ensures that all aspects of the intended course have been covered. In the learning theory approach, Hundhausen and Douglas (2000) developed Salsa based on social constructivist learning theory. The underlying theory is used in the prototype language system of Salsa as a teaching approach in which students use the simple art supplied to construct the algorithm visualization, and present the algorithm to their peers for feedback and discussion. Lee and Chong (2005) developed OntoD, an automated eclectic instructional design tool to facilitate the design phase through the exploitation of different techniques in the learning theory categories such as foundation (behaviorism), learning strategies (cognitivism) and learning transfer (constructivism). The instructor can select any technique from any method in these categories to fulfill different learning needs. Deacon, Morrison, and Stadler (2005) developed Director’s Cut using experiential learning theory for students to create their own video sequences from a set of clips in order to promote creativity. Igbrue and Pathak (2008) developed a framework for novice and experienced IDs based on multiple intelligence theory to inform the e-learning content.

In the multimedia collaborative approach, storyboards are developed to assist designers in collaborating multimedia elements. Choo Wou (2007) developed an Intuitive Life Cycle Model for experts involved in the development of multimedia software and courseware. Jakkilinki, Sharda and Ahmad (2006) developed the MUDPY to streamline the process of creating a multimedia system by providing a clear pathway for planning, designing and developing. Baek (1988) developed a knowledge management system for multimedia design to create a new collaborative design environment in which multimedia designers could freely share their knowledge on the web. Kleinberger, Holzinger and Müller (2008) developed the Multimedia Module Repository or MEMORY system to handle continuous media with adaptive multimedia processes in order to achieve efficiency in search, selection, rating and usage. Bulterman (2007) developed a user-centred
control within multimedia presentation by providing ways of efficiently selecting content, assisting the location and recommending media objects.

In previous literature, researchers have focused on different approaches to be used in storyboard design, without any emphasis on the effect of design and process difficulties. No research has been carried out to understand the difficulties in design and the process for SMEs in improving the interaction between IDs and SMEs. Moreover, none of the researchers above have attempted to use a cognitive task analysis approach to elicit the cognitive task difficulties faced by SMEs and determine the expertise required for the e-learning storyboard.

### 2.2. Cognitive task analysis

Cognitive task analysis is “the extension of traditional task analysis techniques to yield information about the knowledge, thought processes, and goal structures that underlies observable task performance” (Schraagen, Chipman, & Shute, 2000, p.4). In contrast to the traditional task analysis techniques, such as Hierarchical Task Analysis, Goals Operators and Selection Rules, Verbal Protocol Analysis, which provide a physical description of the activity performed within complex systems, cognitive task analysis extends the traditional methods to describe the knowledge, thought processes and goal structures underlying observable task performance (Stanton, Salmon, & Walker, 2005). According to Wei and Salvendy (2004), cognitive task analysis is used to understand the cognitive elements of job performance, and for designing jobs that support and maximize cognitive skill performance. The cognitive task analysis approach is valuable for investigating tasks that depend on the cognitive aspects of expertise (Klein, Calderwood, & MacGregor, 1989).

The concerns in this study focus on the difficulties in cognitive structures such as knowledge-based and representational skills, and processes such as attention, problem solving and decision making (Stanton et al., 2005). The aspects of cognitive structures and processes in the cognitive task analysis can provide a description of the knowledge and thought processes that are required at the expertise level (Schraagen, Militello, & Ormerod, 2008; Seamster, Redding, & Kaempf, 1997). They can also lead to a process for designing, developing and evaluating a better human–computer interface intended to amplify and extend the human ability to make good decisions (Crandall, Klein, & Hoffman, 2006). Most studies in cognitive task analysis are concerned with expertise (Klein & Militello, 2001, p.180). Cognitive study is designed to elicit the knowledge and wisdom acquired (Crandall et al., 2006, p.134). For example, during cognitive task analysis interviews, interviewers will appreciate the nature of expertise when responses and feedback received are probed in detail. This study takes the expertise study approach in cognitive task analysis to discover the cognitive tasks and skills of expert designers that SMEs may acquire for e-learning storyboard development. Some related expertise studies that have been conducted using cognitive task analysis include experienced air warfare coordinators unpacking their expertise and coaching skills for the development of shipboard-based on-the-job training for the Navy (Pliske, Green, Crandall, & Zsambok, 2000), certified cytotechnologists detecting questionable cells and making sense of the clinical picture for the process documentation of tissue biopsies and cell samples for pathology (McDermott & Crandall, 2000) and army ranger squad or platoon leaders describing the required skills for clearing buildings in urban combat settings for the development of training software (Phillips, McDermott, Thordsen, McCloskey, & Klein, 1998).

Cooke (1994) found more than 100 types of cognitive task analysis methods and techniques. Due to the growing number of cognitive task analysis methods, extensive cognitive task analysis reviews by Schraagen et al. (2000), Stanton et al. (2005) and Wei and Salvendy (2004) offer a broad exploration of the difference among these methods and techniques in a number of ways. Stanton et al. (2005) present five selected cognitive task analysis methods based upon their popularity and the application used, while Schraagen et al. (2000) described a comprehensive review of reviews and classifications to guide researchers interested in exploring and applying the cognitive task analysis techniques. On the other hand, Wei and Salvendy (2004) classify the cognitive task analysis methods into four broad families, namely: 1) observation and interview 2) process tracing 3) conceptual techniques and 4) formal models. This cognitive task analysis family classification is meant to guide researchers, who aim for particular outputs, to select appropriate techniques.

Due to the need to specify procedures involved in the e-learning storyboard which are not well-defined as an output, this study adopts the ACTA method by Militello and Hutton (1998) from Wei and Salvendy's first family classification. In this family classification, the technique, involving direct methods of watching and talking with the subjects (in this study, our subjects are IDs), is well suited to analyzing the experts' skills which need to be defined and circumscribed in the domain. Moreover, it is useful in our study to achieve subject rapport, because it seems natural. According to Stanton et al. (2005), the advantages of ACTA over other cognitive task analysis methods such as Cognitive Walkthrough (Polson, Lewis, Rieman, & Wharton, 1992), Cognitive Work Analysis (Vicente, 1999), Critical Decision Method (Klein et al., 1989), Critical Incident Technique (Flanagan, 1954), are its characteristics as a structured approach, the use of three different interviews to ensure the comprehensiveness of the method and probes, and the questions provided to the researchers to facilitate relevant data extraction. The usability of questionnaires in the ACTA method is also found to be clear in its output and useful in knowledge representation (Militello & Hutton, 1998). Schraagen et al. (2000) also denote that the knowledge elicitation approach in ACTA, such as knowledge audit interviews, schematics of equipment, scenarios that probe the key decisions and associated cues, provide the information in seeking the expert–novice differences in dealing with situations as seen by the experts. Hence, this comprehensive method which consists of probes from knowledge elicitation to data extraction which lead to clear output in knowledge representation, support the cognitive task investigation in the e-learning storyboard.

On the other hand, a successful cognitive study should include three primary aspects; knowledge elicitation, data analysis and knowledge representation (Crandall et al. 2006). Compared to other cognitive task analysis methods, the ACTA toolkit provided by Militello and Hutton (2000a), Militello and Hutton (2000b) covers these three aspects of cognitive study, emphasis on identifying the cognitive aspects of tasks, analysis of data in table forms and the value of structured methodology (Brandt & Uden, 2003). However, Klein and Militello (2001, p.187) concluded that some methods are better able to capture certain types of cognitive processes, hence, there is no method considered to be the best in cognitive task analysis.

#### 2.2.1. ACTA technique

The main objective of the ACTA technique is to elicit the critical cognitive elements of a particular task and in turn provide recommendations for a system design (Militello & Hutton, 2000a; Militello & Hutton, 2000b). An ACTA consists of a series of four techniques: 1) task diagram, 2) knowledge audit, 3) simulation and 4) cognitive demand table. The method of each technique is discussed in section 3.2.
The use of the ACTA technique is significant in designing interfaces that support the decision making strategies and information needs of the operator, and to uncover the skills and knowledge necessary to perform the cognitively challenging work of the system. It is also used to highlight differences between expert and novice performance, thus examining how novices can more quickly be brought to the performance level of experts (Mitre, 2010). The ACTA technique has been used in many studies which include determining whether tactical information should be displayed in 3D to improve battle space situation awareness (Eddy, Kribs, & Cowen, 1999), to analyze the decision strategies of submarine sonar and target motion analysts (Hardinge, 2000), to capture strategies and tactical concerns of air campaign planners for use in the development of a software decision support tool (Miller, Copeland, Phillips & McCloskey 1999) and to guide the development of a scenario-based training program on platoon leaders of MOUT (Military Operations in Urban Terrain) operations (Phillips et al., 1998).

3. Methodology

This section describes the participants involved in this research, the procedures, design, and instruments.

3.1. Participants

In this research, expertise is identified by using the expertise framework of Farrington-Darby and Wilson (2006). As suggested by the framework, the selected experts are the main operators of the e-learning storyboard. They are identified as designers who work at the Multimedia Production Unit (MPU) in Multimedia University Malaysia. Table 1 shows the profile of the participants.

The ACTA toolkit recommended three to five experts in conducting this method (Militello, Hutton, Pliske, Knight, & Klein, 1997). Interviewing a limited number of experts can lead to an increase in the knowledge of the interviewer, information can be verified among experts and a buffer can be provided for unsuccessful interviews (Militello et al., 1997, p.152). According to Ericsson and Smith (1991), the analysis of task performance approach undertaken to study expertise, tend to focus on a domain-specific training and practice that will lead to the construction of task-specific knowledge (Ericsson and Smith 1991). Ericsson and Smith further proposed that in the initial step of studying expertise, it is possible to elicit superior performance in a small number of representative tasks. Furthermore, in constructing a coherent knowledge base, there is a trade-off between group size and conflicting viewpoints. An example of a study by McGraw and Seale (1988)'s work with expertise in aviation systems, has recommended using groups of only two or three experts (Hoffman, Sharbolt, Burton & Klein 1995). Adopting small number of expertise has been shown in many studies. These includes employing three interventional radiologists in identifying cognitive thought processes involved in interventional radiology procedures (Johnson, Healey, Evans, Murphy, Crawshaw & Gould 2006), engaging four senior users of Fatigue Audit InterDyne (FAID™) in identifying usability areas of fatigue modeling software (Paradowski and Fletcher 2004), selecting four military intelligence analysts in identifying leverage points for the extremely challenging tasks of intelligence analysis (Hoffman, Neville & Fowlkes 2009) and using three expert players of Quake 2 computer gaming in capturing the underlying reasoning process for agent-based models of human behavior (Norling 2008).

Three expert designers agreed to participate in this study. One instructional designer who has two years’ experience is a project leader; the other two, who hold multimedia designer positions, have five and ten years’ experience respectively in the fields of e-learning and storyboard design. All of them have a degree in digital multimedia, multimedia, and computer science (in multimedia). One of them is pursuing a master’s degree in e-learning. Their selection was also recommended by the Head of Instructional Design at MPU. The request for interview was made by a formal e-mail. All of the participants agreed to attend the ACTA session. They were given a form of consent and assured the content of the session would be confidential. All participants signed the voluntary consent form and were given a token of appreciation for their involvement in the study.

3.2. Research procedures and design

The research uses four techniques in ACTA. Each technique is explained by Crandall et al. (2006).

3.2.1. The four techniques in ACTA

An ACTA, shown in Fig. 1, is a cognitive task analysis technique that consists of three series of structured interviews, conducted in focus group discussions.

The procedure of each technique is as follows (Stanton et al., 2005):

<table>
<thead>
<tr>
<th>Profile/participant #</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>33</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td><strong>Storyboarding experience</strong></td>
<td>10</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td><strong>No of project involvements</strong></td>
<td>7</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Position (s)/role (s)</strong></td>
<td>Instructional designer</td>
<td>Instructional designer</td>
<td>Instructional designer</td>
</tr>
<tr>
<td><strong>Software application in storyboard</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td>F, L, P, Cool, DW, SF, RE, M</td>
<td>PPT, Word</td>
<td>PPT, Word, Adol, MacrF, DW, Adol, SF, Cool</td>
</tr>
<tr>
<td><strong>Formal education</strong></td>
<td>Computer Science (Multimedia)</td>
<td>Webb, MMProg, Anima</td>
<td>PPT, Word, Rapv, Adol, MacrF, DW, Adol</td>
</tr>
<tr>
<td><strong>Certification</strong></td>
<td>ID certified</td>
<td>Degree in Digital Multimedia</td>
<td>Degree in Multimedia (pursuing MSc. in E-Learning)</td>
</tr>
<tr>
<td><strong>Soft skills</strong>&lt;sup&gt;a&lt;/sup&gt;</td>
<td>PPT, Word</td>
<td>Webb, MMProg, Anima</td>
<td>PPT, Word, Rapv, Adol, MacrF, DW, Adol</td>
</tr>
</tbody>
</table>

<sup>a</sup> Note: **Soft skills**: F (Flash) – I (Illustrator) – P (Photoshop) – Cool (Cool Edit) – DW (Dreamweaver) – SF (Sound Forge) – RE (Reload Editor) – M (Moodle) – WebD (Web Design) – MMProg (Multimedia Programming – Anima (Animation)) – SB (Storyboarding). **Software application in storyboard**: PPT (Microsoft PowerPoint) – Word (Microsoft Word) – AdolF (Adobe Photoshop) – MacrF (Macromedia Flash) – Adol (Adobe Illustrator) – Rapv (Rapvity) – DW (Dreamweaver).
3.2.1.1. **Task diagram technique.** The purpose of the task diagram interview is to elicit a broad overview of the task under analysis. Once the task diagram interview is completed, a diagram is developed representing the component task steps involved and those task steps that require the most cognitive skill.

This technique is used to identify the cognitive skills required in the e-learning storyboard process. The steps of the technique start when the IDs are presented with the e-learning storyboard process as shown in Fig. 3. They are asked to decompose the task into relevant task steps. The sample question as presented by Militello et al. (1997) is used. To assist the procedure in this session, “Task of Interest” is written at the top of a whiteboard, and used to elicit the required steps in the e-learning storyboard. The tasks are recorded across the board from left to right in chronological order. Arrows are used to indicate the order in which the steps occur. The outcome of the result is projected in the form of a task diagram.

3.2.1.2. **Knowledge audit technique.** This technique employs a set of probes designed to describe types of domain knowledge or skills and elicit appropriate examples. The goal is to ascertain the nature of these skills, specific events and strategies that have been used.

This technique is used to explore the cognitive task difficulties identified in the task diagram technique. IDs are asked about cues and strategies they rely on when they face e-learning design and process difficulties. In this technique, “Task of Interest” is again written at the top of the whiteboard, and the space below divided into three columns. The columns are titled “Examples”, “Cues and Strategies” and “Why Difficult”. Using the previous task diagram, the cognitive skills identified by the IDs are further explored using the lists of probes using the questions as shown in Table 2 (Militello et al., 1997). The data findings are presented in a knowledge audit table.

3.2.1.3. **Simulation technique.** In simulation technique, the data finding is independent of the findings of the knowledge audit. The IDs are presented with a scenario that addresses difficult and challenging elements of the e-learning storyboard. The simulation can be either high fidelity or low fidelity. In this study, low-fidelity simulation is used by presenting the IDs with an e-learning storyboard design template (shown in Fig. 3) with a simulation of the step-by-step process. In this technique, five columns are drawn on the whiteboard, titled “Events”, “Actions”, “Situation Assessments”, “Critical Cues” and “Potential Errors”. The IDs are then allowed to interact with and experience the simulation. They are asked their views about e-learning storyboard design simulation using the questions shown in Table 3. Each answer is recorded.

The data findings are presented in a simulation table, which provides specific detailed information on IDs' cognitive processes. It also provides a view of the IDs' problem-solving processes in design and process using the e-learning storyboard design template.

3.2.1.4. **Cognitive demand technique.** The final technique is to integrate the data obtained from the data findings from the previous techniques: task diagram, knowledge audit and simulation. The data are presented in a cognitive demand table, which contains difficult cognitive elements, with “Why Difficult”, “Common Errors” and “Cues and Strategies” used as the headings. It provides a format to analyze the types of information needed to design a new system.

3.3. **Instruments**

In this study, the following instruments were applied during the ACTA process.

3.3.1. **Storyboarding design process**

In this study, a particular storyboard design process is used to identify the cognitive skills of the IDs during the task diagram and knowledge audit techniques. A generalized form of design cycle storyboard consists of five stages: analysis, synthesis, simulation, evaluation and decision. This design cycle involves design activities, purposes, and visualization styles and is produced in a particular form (Lelie, 2006). The storyboard design process for e-learning content development shown in Fig. 2 is described within this form of design cycle storyboard.

![Fig. 2. Design process in e-learning storyboard.](image)

The design in each process in Fig. 2 serves its own purposes and is projected in particular forms, as described in Table 4:

3.3.2. **E-learning storyboard design templates**

A storyboard for e-learning content requires organization. The style guide should also reflect key points for e-learning applications, such as navigation, text and layout style, narration, interaction and graphics (Brandon 2004). Similarly, templates should provide attributes that
are significant to the storyboard process (Truong, Hayes, & Abowd, 2006). In this study, the proposed storyboard design template shown in Fig. 3 is used as an object presented to the IDs during simulation technique. It is constructed with a PowerPoint application.

It projects six structures of elements as follows:

- **Course code and instructor’s name**: refers to the areas in the storyboard template where SMEs need to insert their course names, course codes, and their names (Fig. 3 – ➀).
- **SCO no.**: refers to the sharable content objects. In this study, SCO refers to the slide number and that of the total slides for the learning contents (Fig. 3 – ➁). For example; SCO 5/25 represents the fifth out of 25 slides.
- **SCO title**: represents the learning material in the screen area (Fig. 3 – ➂). In the context of the scenario, the SMEs need to provide a different SCO title for each slide. If the content needs to be explained in more than one screen, the same title should be stated in those new screens.
- **Screen area**: the area where learning materials are placed (Fig. 3 – ➃). The learners may only see the content and activities after the whole storyboard is published by the multimedia designers.
- **Graphics and animation**: refers to the instructions about the content in the screen area in text and pictures (Fig. 3 – ➄).
- **VO scripts area**: refers to the voice-over scripts which represent the narration (Fig. 3 – ➅). It is used to illustrate scripts of the screen show animation in the area Graphics and animation mentioned above.

3.4. **Instrument supplies**

Instruments that are used include: an electronic whiteboard for presenting the task diagram, knowledge audit, and simulation tables for the IDs; an audio-recorder using Adobe Audition for recording the interview session; and a simulation of e-learning storyboard design templates.

3.5. **Timeline planning**

The total time conducted for each set of ACTA techniques is 2 h 50 min. The task diagram requires 20 min, knowledge audit 60 min and simulation technique 90 min.

4. **Data results and findings**

This section presents the results and findings of the ACTA study.

<table>
<thead>
<tr>
<th>Column title</th>
<th>Questions asked in knowledge audit technique.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples</td>
<td>This is an example of a situation where you experience cognitive task difficulties</td>
</tr>
<tr>
<td>Cues/strategies</td>
<td>In this situation, what cues and strategies would you rely on?</td>
</tr>
<tr>
<td>Why difficult</td>
<td>In what way would this be difficult for an SME? What makes it difficult to do?</td>
</tr>
</tbody>
</table>
4.1. First technique (task diagram)

Fig. 4 shows the task diagram of the e-learning storyboard task and process. The processes that require cognitive skills are identified as VO script documents and storyboard review reports. The IDs stated that these two elements required heavy cognitive skills, particularly for problem solving. On the other hand, all the IDs agreed that the tasks in document analysis, storyboard design development and pre-test post-test questions of the e-learning storyboard do not require as many cognitive skills as the two identified processes. The problem-solving skills identified in VO scripts and storyboard review reports are presented in the knowledge audit table.

4.2. Second technique (knowledge audit)

The knowledge audit table (shown in Table 5) shows the detailed aspects of problem solving in VO script documents and storyboard review reports. The task difficulties in VO scripts include translating the content materials to VO scripts, handling the storyboard templates, and difficulties in differentiating and prioritizing graphic elements in relation to VO scripts. In the storyboard review templates, the review process is difficult when SMEs are located in different geographical areas. IDs also claimed that the SMEs are not familiar with the instructional design process which leads to a larger number of iterations in the e-learning storyboard process.

4.3. Third technique (simulation interview)

Table 6 shows four identified challenging tasks in e-learning storyboard design templates. They are: VO scripts, graphics, animation and storyboard reviews. Generally, the IDs stated that the template needs integration of the opinions and actions of all team members (including the SMEs). The IDs stated that the storyboard template needed enhancement, which may reduce the challenge of communication and cooperation. As regards VO scripts, graphics and animation, the IDs indicated that SMEs usually insert too many or too few scripts, graphics and animations, necessary for the e-learning content. On the other hand, the storyboard review process that requires feedback from reviewers and proofreaders takes a long time. This leads to a delay in submission to the development team responsible for the e-learning multimedia content.

The simulation shows that the SMEs have difficulties in developing a storyboard using the templates because they are not trained as IDs. The SMEs also lack skills in technologies, ignore the guidelines of the storyboard, and lack skills in developing VO scripts, graphics and animation. The potential error may be due to the non-attendance of SMEs at training sessions on developing e-learning courses using storyboard templates.

4.4. Final technique (cognitive demand table)

The cognitive demand table provides a comprehensive view of the cognitive task difficulties and expertise experienced by IDs. Table 7 shows four difficult cognitive elements integrated from the previous two techniques.

Storyboard templates, VO scripts, graphics, animation and the storyboard review process are five difficult cognitive elements summarized in the study. These difficulties are caused mainly by lack of assessment skills and thinking skills, which require years of experience in terms of developing a good e-learning storyboard. For example, SMEs who use storyboards to develop e-learning content will need to know effective ways of translating the content of the textbook. They also need to differentiate and prioritize graphic elements in relation to the VO scripts. The findings from this table pinpoint the cause of the errors often noticed by IDs who have experience and expertise in instructional design.

<table>
<thead>
<tr>
<th>Column title</th>
<th>Questions asked in task simulations technique.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event</td>
<td>The events that you identified as difficult and challenging</td>
</tr>
<tr>
<td>Actions</td>
<td>What actions would you take at this point?</td>
</tr>
<tr>
<td>Situation assessments</td>
<td>What is going on here? What is your assessment of the situation?</td>
</tr>
<tr>
<td>Critical cues</td>
<td>What pieces of information led you to this situation assessment and these actions?</td>
</tr>
<tr>
<td>Potential errors</td>
<td>What errors would an SME make?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Event</th>
<th>Questions asked in task simulations technique.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action</td>
<td>What actions would you take at this point?</td>
</tr>
<tr>
<td>Situation assessment</td>
<td>What is going on here? What is your assessment of the situation?</td>
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<td>Critical cue</td>
<td>What pieces of information led you to this situation assessment and these actions?</td>
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<td>Potential error</td>
<td>What errors would an SME make?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process of storyboard</th>
<th>Purpose</th>
<th>Forms projected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis documents</td>
<td>To analyse the document information. The SME provides the course outline and list of reference books to the ID.</td>
<td>Word document</td>
</tr>
<tr>
<td>Storyboard design development</td>
<td>The SME develops the early sketch content of subject content. The storyboard consists of elements as shown in Fig. 2. The contents are to be developed by the ID and the development team.</td>
<td>PowerPoint/Word document</td>
</tr>
<tr>
<td>VO scripts</td>
<td>To complement the content on the storyboard. It is used to elaborate the subject matter of the storyboard content.</td>
<td>Word document</td>
</tr>
<tr>
<td>Pre and post-test questions</td>
<td>To project the test prior and after the subject content. It is used to test the subject matter of the storyboard content.</td>
<td>Word document</td>
</tr>
<tr>
<td>Storyboard review report</td>
<td>To consolidate materials of the documents in storyboarding process. It is intended to ensure the SMEs submit all documents required.</td>
<td>Word document</td>
</tr>
</tbody>
</table>
5. Discussion and recommendations

This section discusses the findings of two aspects of e-learning storyboards in this study: cognitive task difficulties and expert skills. It also provides some recommendations for a proposed e-learning storyboard system.

5.1. Cognitive task difficulties

In the study, four sub-elements of e-learning storyboards which demand cognitive skills were identified, namely: storyboard templates, VO scripts, graphics and animation, and review process.

5.1.1. Storyboard template

The IDs found that most SMEs seem to ignore the guidelines provided in the storyboard, and some of them claimed that they were not well-informed of the procedure, although the guidelines handed to the SMEs consist of specific documentation regarding procedures and design. The IDs also stated that the storyboard templates seem difficult for SMEs to handle because of the features of the PowerPoint application. IDs reported that SMEs had insufficient room to add more inputs to VO scripts and graphics animation areas. IDs also said that the SMEs are not able to decide on the amounts of each element required in storyboard templates to accommodate the e-learning content. Although some works report the efficiency of a PowerPoint application for design and presentation (Atkinson, 2007; Holzl, 1997), the application of PowerPoint alone to assist IDs and SMEs with e-learning content is inadequate and unable to provide collaboration and communication between IDs and SMEs.

5.1.2. VO scripts, graphics and animation

In terms of the prescriptive interaction components in the storyboard, the IDs found that SMEs seem to include too many or not enough objects and prescriptions of VO scripts, graphics and animation. The IDs also indicated that SMEs rely more on text descriptions from reference books and Internet images. Some of the SMEs use the graphical tools available in the PowerPoint application. The IDs stated that SMEs need skills in prioritizing which VO scripts, graphics and animation are appropriate for the storyboard. The findings show that there are some cognitive task difficulties required in e-learning storyboards.

Table 5

<table>
<thead>
<tr>
<th>Sub-tasks</th>
<th>Cues and strategies</th>
<th>Why difficult?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example: VO scripts</td>
<td>SMEs do not have knowledge in handling voice scripts. SEMs have problems with storyboard templates. The storyboard templates show the SCO no., which makes it difficult to proceed with longer VO scripts. SMEs also have difficulties in handling graphics and their relations with VO scripts. Strategies: Most of SMEs convert all materials from textbooks to storyboard. SMEs tend to copy a lot of graphics to the storyboard.</td>
<td>Difficult to translate content materials to VO script. Difficult to handle the storyboard templates. Difficult to differentiate and prioritize graphic elements in relation to VO scripts.</td>
</tr>
<tr>
<td>Example: Storyboard review</td>
<td>Many SMEs refuse to do amendments after the review process. SMEs do not understand their roles as storyboard designers, and leave all tasks to the ID. SMEs assume ID will guide and refine the storyboard. The storyboard reviews need to be reviewed by many members of the team, which includes the instructional designers, SMEs, multimedia designers, and graphics designers. Strategies: ID need to communicate very often with the SMEs to get a clear view of the contents. ID need discuss every SCO with SMEs.</td>
<td>Difficult to reach SMEs. Some SMEs are resident in other institutions. IDs are not SMEs. Thus, some of them do not understand the subject content of the storyboard. It is difficult to determine the number of entries for graphics and VO scripts in the screen areas, due to the style of storyboard templates.</td>
</tr>
</tbody>
</table>
are three factors contributing to the difficulties of SMEs’ tasks in terms of prescriptive interaction components: 1) SMEs are not trained as IDS, 2) SMEs do not have skills in technology which makes it difficult for them to create storyboard contents and 3) SMEs do not attend the training provided for storyboard designers, which makes it difficult for them to comprehend the task of storyboard development. According to Ertmer et al. (2009), novices and experts in instructional design differ in terms of their abilities to arrive at ill-defined problems, and their speed and efficiency in doing the task. The use of scaffolds or guidance may leverage an inexperienced e-learning storyboard designer to analyze and solve instructional design problems.

5.1.3. Review process

Results from the study show that the reviews take into account feedback from the reviewers and proofreaders. These reviews take too long to complete, which makes the cycle of the storyboard process longer and subject to delay. The IDs stated that the standard operation of completing an e-learning storyboard should take up to three months but, owing to the long review process, the task takes six months to a year to complete. The factors that contribute to the delay in the review process were identified as follows:

- Many SMEs refuse to do the amendments after the review process.
- SMEs do not understand their roles as storyboard designers, and leave all tasks to the IDs. SMEs assume IDs will guide and refine the storyboard.
- The storyboard reviews need to be reviewed by many members of the team, which includes the IDs, SMEs, multimedia designers, and graphics designers.
- SMEs are difficult to contact. Some SMEs are members of other institutions.

This finding is supported by Kam (2008) who studied the roles expected to be assumed by SMEs versus the actual roles that should be performed by SMEs. Kam (2008) stated that SMEs expect to provide all information including the unavailable content, explain concepts related to subject-matter, provide examples and analogies, and provide answers to all content-related queries. The author also explained that the different roles are one of the reasons why the review process in e-learning storyboards is delayed. Another study by Saroyan (1992) stated that there are differences between IDs and SMEs’ ways of reviewing evaluations. IDs act as generalists and use a comparative method of review which is directed by the heuristics of an instructional systems design model. On the other hand, SMEs act as specialists and use a sequential method of review which is directed by domain knowledge. The literature also explains that the different methods of review are a result of the different backgrounds and expertise.

5.1.4. Expert skills in e-learning storyboards

In the study, the IDs justified why training in e-learning storyboards should be given before tasks are assigned to the SMEs. The skills provided may provide an insight into how to perform in the design and the process of e-learning storyboards. Difficulties occur, however, if the training is not attended by SMEs. Some related comments from IDs include:

*Most of the SMEs are not well-informed of the procedure in e-learning storyboards.*

The IDs claim that the skills required can affect the interaction between IDs and SMEs. For example:

### Table 6

The simulation interview table.

<table>
<thead>
<tr>
<th>Major challenging tasks</th>
<th>Actions</th>
<th>Situation assessment</th>
<th>Critical cues</th>
<th>Potential errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storyboard templates</td>
<td>Integrate opinions and actions from all teams</td>
<td>It is challenging because it needs communication and cooperation from all team members.</td>
<td>Communication Cooperation</td>
<td>Ignore the guidelines in the storyboard Not well-informed about the procedure</td>
</tr>
<tr>
<td>VO scripts</td>
<td>There are too many or too short scripts</td>
<td>It is challenging because it needs skills in prioritizing VO scripts appropriate for the storyboard</td>
<td>Too many VO scripts Not enough/too few VO scripts</td>
<td>Not enough skills in VO scripts, graphics and animation</td>
</tr>
<tr>
<td>Graphics and animation</td>
<td>There are too many or few graphics and animations</td>
<td>It is challenging because it needs skills to prioritize VO scripts appropriate for the storyboard</td>
<td>Too many graphics and animations Not enough/too few graphics and animations Many SMEs rely on animations, media and graphics from textbooks, and internet Some SMEs use the graphical tools available in the power point application</td>
<td>Unavailable to identify and differentiate tasks of storyboard designers and subject content providers</td>
</tr>
<tr>
<td>Storyboard reviews process</td>
<td>Reviews are a long process</td>
<td>The standard of operation requires the storyboard to be completed within 3 months; some lag up to 6 months or a year behind</td>
<td>The reviews take into account feedback from the reviewers and proofreaders Some reviews take too long to complete which makes the cycle of the storyboard process longer and delays it</td>
<td>Delay review process</td>
</tr>
</tbody>
</table>
We need to communicate very often with the SMEs to get a clear view of the contents. We need to sit down and point every SCO toward the SMEs, should there be any amendments to be made to the storyboard.

According to You and Telehaimanot (2001), developing e-learning course design is effective under the following conditions: 1) SMEs believe that working with IDs prepares them for the implementation of best practices in e-learning course design and delivery; 2) SMEs work with IDs for multiple purposes, such as technological and pedagogical support, and 3) SMEs work with IDs individually, either in a face-to-face consultation sessions or via phone and e-mail. They explain that the effective interaction of IDs and SMEs can lead to leveraging of the skills of SMEs in the design and the process of e-learning storyboards.

5.2. Recommendations

Based on the discussion above, three recommendations are offered to improve cognitive tasks and leverage the skills of SMEs in the design and the process of e-learning storyboards: 1) training development, 2) graphics and animation development, and 3) interaction design and document development.

5.2.1. Training development

The ACTA findings in this study have uncovered the skills and knowledge necessary to perform the cognitively challenging work of the e-learning storyboard. The findings have also highlighted differences between expert and novice performance, thus examining how SMEs as novice designers can more quickly be brought to the performance level of experts.

One of the suggestions is to provide proper training for SMEs. This is supported by a study by Albi (2007) which investigates the real-life experiences of four professors in discovering how they either learned instructional design or adapted an instructional design process to design and develop their online courses. The study findings that these participants, who were self-taught IDs and developers, would have been more effective IDs and developers if they had received instructional design and development training prior to their first online instructional design experiences (Albi, 2007). This study also concluded that administrators at institutions of higher education should encourage their institutions to offer a variety of training opportunities for their online instructors. It showed that training should not only include how to teach online courses effectively, but also how to design and develop online courses and course materials. This training can be incorporated in future e-learning storyboard systems.

5.2.2. Prescriptive interactive component development

VO scripts, graphics and animation are difficult for SMEs because they rely on multimedia elements, such as animations, media and graphics from textbooks and the Internet. In this study it was shown that an e-learning storyboard should include the prescriptive interactive component. This is supported by Liaw, Hung and Chen (2007) who found that multimedia instruction, such as voice media instruction, image media instruction, animation media instruction and colorful text media instruction, is one of the critical factors that lead to e-learning performance. On the other hand, Gümüş and Okur (2010) proposed that the number of multimedia objects in e-learning content should also be appropriate because it provides high interaction with the students. In this study, some SMEs also used the graphical tools available in PowerPoint applications. The search for the right multimedia elements has led to a longer storyboard review process. The standard of operation requires completion within three months but this may take from six months to one year. The reason may be the inadequate understanding of multimedia objects such as text, audio, video and graphics. One of the suggestions for solving these difficulties is to apply Mayer’s (2002) principles of multimedia learning based on cognitive theory. Recommendations for improving VO scripts in animations are stated as follows (Mayer, 2002, p.63):

<table>
<thead>
<tr>
<th>Difficult cognitive elements</th>
<th>Why difficult?</th>
<th>Common errors</th>
<th>Cues and strategies used</th>
</tr>
</thead>
</table>
| Storyboard templates        | Difficult to translate content materials to VO scripts. | Ignore the guidelines in the storyboard. | Cues:  
SMEs do not have knowledge in handling voice scripts.  
SMEs have problems with storyboard templates.  
The storyboard templates show the SCORM no., which makes it difficult to proceed with longer VO scripts.  
SMEs also have difficulties in handing graphics and its relation to VO scripts.  
SMEs tend to avoid doing amendments after the review process. |
| VO scripts                  | Difficult to handle the storyboard templates. | Not well-informed of the procedure. | SMEs do not have knowledge in handling voice scripts. |
| Animation and graphics      | Difficult to differentiate and prioritize graphic elements with relation to the VO scripts. | Not enough skills in VO scripts, graphics and animation. | SMEs have problems with storyboard templates.  
The storyboard templates show the SCORM no., which makes it difficult to proceed with longer VO scripts. |
| Storyboard review process   | Difficult to reach SMEs. | SMEs are not trained as instructional designers. | SMEs do not have knowledge in handling voice scripts. |
| SMEs are resident in other institutions. | Some SMEs do not have knowledge in handling voice scripts. | Some SMEs do not have skills in technology which makes it difficult for them to create storyboard contents. | SMEs have problems with storyboard templates.  
The storyboard templates show the SCORM no., which makes it difficult to proceed with longer VO scripts. |
| ID’s are not SMEs. Thus, some of them do not understand the subject content of the storyboard. | SMEs assume ID will guide and refine the storyboard. | Some SMEs do not attend the training provided for storyboard designers which makes it difficult for them to comprehend the task of storyboarding development. | SMEs tend to avoid doing amendments after the review process. |
| It is difficult to determine the number of entries for graphics and VO scripts in the screen areas, due to the style of storyboard templates. | Unable to identify and differentiate tasks of storyboard designers and subject content providers. | SMEs assume ID will guide and refine the storyboard. |

Table 7
The cognitive demand table.
5.2.3. Interaction design document development

In this study, the problems in e-learning storyboard design templates are mainly due to the design factors (e.g. insufficient room for VO scripts and graphics areas). Due to its characteristic of being a two-way communication medium, the challenge is to develop a design instruction document to maximize the amount of interaction in e-learning storyboarding materials. This is justified by Misanchuk (1992) who concludes that e-learning instructional materials should be used with language more like that used for speaking than for writing journal articles or books. The guidelines for writing e-learning instructional materials have been detailed further, and includes: using short sentences, avoiding compound sentences and excess information in sentences, using active voice point forms and writing the instruction as if they were spoken. On the other hand, Misanchuk (1994) suggests a course introduction for all e-learning materials. Suggestions include: the instructor’s background information, a course overview, course objectives, the textbooks, reference books or ancillary learning materials, and information about assignments, examinations, and grading.

With regard to the design problems in a multimedia e-learning storyboard, two ways to solve these difficulties are by referring to Marie and Klein’s (2008) detailed design and Truong et al.’s (2006) effective storyboard guidelines. Marie and Klein (2008) provide a detailed design for developing storyboards that lead to faster client approval and fewer edits during the design and development process: it is known as WBT/CTB detailed design and storyboard documents. The detailed storyboard design which aims to maximize the efficiency of a team's development, offers three levels of activities: e-learning challenges, detailed design development steps and storyboard templates steps. Each activity is guided with a detailed design document which serves as a roadmap for developing the storyboard. Effective guidelines are proposed by Truong et al. (2006, p.15) as follows:

- **Level of details:** three considerations must be taken into account: the number of objects present in a particular frame, the level of photorealism incorporated by designers and the designer’s decision to display the entire scene or only details of the interface.
- **Inclusion of text:** texts can be included through tagline narrations for each panel or within individual frames. Alternatively, designers can depict the storyboard entirely using visual elements with no text.
- **Inclusion of people and emotions:** the storyboard can include renditions of human users demonstrating interactions with an interface. Designers can also use these characters to build empathy for potential users, display motivation, or convey other intangible elements, such as how the application affects the user. Alternatively, designers can also build empathy by removing people entirely and drawing the interaction as though the reader is the actor.
- **Number of frames:** the optimal size for panels for conveying a single feature or activity should be three to six frames only. Only multiple storyboards depict multiple features and activities in the frames.
- **Portrayal of time:** the time passing or transitions that convey changes over time should be explicitly indicated. Pardew (2004) emphasizes that written directions for the movement of each frame are important as they indicate the gradual increase and decrease of storyboard transitions.

6. Conclusion

According to Klein and Militello (2001), pp. 163–199, a cognitive task analysis project needs to have three criteria for success: provide an important discovery, represent effective communication of the discovery and achieve meaningful impact resulting from the communication
We would like to thank the three anonymous instructional designers at Multimedia Production Unit in Multimedia University Malaysia for participating in the study. We would also like to thank Dr Choo Yee Ting, Nur Syarafina Rusli, and Noor Natasha Mohd. Irwan Serigar for, their invaluable help and support in data collections and writing assistance. The research is funded by Multimedia University Malaysia (Mini Funding No. IP20110707004) and University of Malaya (Postgraduate Research grant).

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