Can structured representation enhance students’ thinking skills for better understanding of E-learning content?

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\textbf{A B S T R A C T}

This paper proposes an e-learning model to assess the effects of online structured representation of content on learners’ understanding. We designed a structured representation based on the theory of distributed cognition that provides seven segments for reading research articles. The study hypothesized that motivation, attention, and interactivity are essential factors that affect students’ thinking skills for understanding e-learning content. To investigate and confirm the effect of these factors on the students’ thinking skills, we designed a survey and analyzed the responses of 210 university students concerning the proposed structured representation. The results revealed that motivation, attention, and interactivity did contribute to the students’ thinking skills. They also demonstrated that the structured representation helped students achieve an adequate level of thinking skills as they read research articles, which had a positive effect on their understanding. This finding demonstrates that structured representation has significant potential as a learning tool and that structure-based e-learning can influence students’ metacognitive activities and facilitate their understanding.

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1. Introduction

The introduction of virtual learning environment has revolutionized the educational arena. Namely, the introduction of online fora for electronic learning (e-learning) and interactions have brought about a paradigm shift in how educational technology is now offered and impact learners across all ages (Brown & Liedholm, 2002; Fulford & Zhang, 1993; Johnson, Aragon, Shaik, & Palma-Rivas, 2000; Kulik et al., 1985; Picciano, 2002; Swan, 2003), as well as learning outcomes based on cognitive motivational shifts (Bork, 1986; Clark & Paivio, 1991; Halpern, 1999; Pintrich, 1988; Shavelson, 1974). There have been arguments about the non-linear presentations on these e-learning sites and lack of an organized approach, thus creating entropic state giving rise to the superficial impression of a lack of regulation while organizing the contents of these e-learning environments (Benbunan-Fich & Hiltz, 1999; Thomas, 2002). Herein, we present evidence that may not necessarily be the case, and topical organization of e-learning environment may be framed by careful control of parameters involved in its design to enhance student motivation, interactivity, and attention.

E-learning technology is widely employed by educational institutions to create platforms that present onscreen content (in the form of text and/or graphics) for learners. The aim of e-learning is to retrieve, process, and deliver knowledge to the end user online. The current integration of instructional design theories into e-learning has led to platforms that are based on how learners interact with the representation of content during a particular task and how the representation fits into their learning process. Content management systems (CMSs), for example, are tools for producing, tracking, and classifying academic content on the Web (Vovides, Sanchez-Alonso, Mitropoulou, & Nickmans, 2007). Learning management systems (LMSs) range from procedures for administering training/educational details to software that provides collaborative features for e-learning in distributed courses (Coates, James, & Baldwin, 2005; Mittal, Krishnan, & Altman, 2006). Learning CMSs (LCMSs) provide templates for authoring and indexing learning content such as courses and reusable content objects. They can also be used to produce and customize content provided by LMSs (Khan, 2005) and to produce the learning content itself in different formats (Abazi-Bexheti, 2008).

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However, despite the advantages of e-learning, students may lose attention and focus for learning. These adverse effects, which negatively impact students’ engagement with e-learning, are likely the result of student’s needs for multiple forms of support (Lehtinen, 2003; McCombs & Vakili, 2005). The adverse effects may also arise from a failure to use appropriate design strategies for representing learning content (Botturi, Cantoni, Lepori, & Tardini, 2006; Hwang, Tsai, & Yang, 2008; Martinez, 2003). In research directed at determining the role that students appear to have in online classes and how this differs from their role in traditional lecture classes, Dutton, Dutton, and Perry (2002) found that a high percentage of students who begin e-learning courses do not complete them. Preliminary studies have investigated the reasons why students were less willing to engage in e-learning after their initial experience. For instance, Giannoukos et al. (2008) reported that current e-learning tools do not adequately support student interaction, which leads to students being insufficiently motivated, and this one of the reasons why they shift away from e-learning. Hardt (2009) posits that we lack a solid understanding of how certain forms of learning might help students understand content in e-learning.

In addition, most university students who rely on the resources available in e-learning environments struggle academically (Grundén, 2011), particularly during the first year of their studies, and many higher education faculties intend to address the challenge how they can help students learn in these environments. Some researchers have suggested that the problem may be that e-learning environments do not support the types of representation that are necessary for developing student thinking about learning content (Felix, 2005; Mandinach, 2005; Vrasidas, 2004). The metacognitive processes that students need for understanding contents may not be operant when they read in e-learning environments. The research reveals that metacognition-based student thinking is an essential element for the transfer of knowledge in e-learning, and that standard e-learning platforms may therefore not provide the most suitable way to represent every type of online content.

It appears that an approach may be adapted to provide the students with the necessary support to help them develop the thinking skills that they need for understanding learning content and to increase their awareness of their own thinking processes. Different factors have been examined which proposes contents of e-learning environment (Jiang & Ting, 2000). Here, we introduce a novel approach with an aim to create an adaptable and effective e-learning environment. We have designed a Structured Content Management System (SCMS) e-learning tool that displays the content of research articles in segments, based on the ideas of distributed cognition theory (Hutchins & Lintern, 1995). We also designed a model for assessing students’ understanding of structured online content in the e-learning environment. The model consists of five factors: motivation, attention, interactivity, thinking skills, and understanding, and we examined these factors to determine whether presenting e-learning content with a certain structure facilitates better understanding.

2. Research model

This research proposes an e-learning model to assess the effects of online structured representation on the cognitive skills learners need for understanding content. The model consists of three major components: (1) external variables (motivation, attention, and interactivity), (2) metacognition (thinking skills), and (3) understanding. The aim of this study was to confirm that structured representations for e-learning can have a positive effect on the metacognitive skills students need for understanding content. The following sections explain the model’s factors and the relations between them.

2.1. Metacognition

Metacognition generally refers to the ability to understand, control, monitor, and manipulate individual cognitive processes to facilitate learning (Reeve & Brown, 1985; Romainville, 1994). Metacognition can help e-learners enhance their understanding of how their knowledge is constructed (Veenman, Prins, & Elshout, 2002) and enables learners to significantly increase their understanding based on active and conscious control of how they process learning content. According to Brown (1987), metacognition affects understanding based on the level of reflection that results from learner’s attention being directed to the representation of learning contents. By focusing on cognitive aspects of the mind, metacognition helps individuals develop and synthesize their own thinking skills. This suggests that the structured representation constructed for e-learning content should be based on the premises of cognitive instructional design theories, since not all instructional theories are concerned with cognition.

The main purpose of developing thinking skills is to promote the abilities to understand, evaluate viewpoints, and solve problems (Maiorana, 1992). Many researchers (e.g., Browne & Freeman, 2000; Elder & Paul, 1994; Liaw, 2007; Selwyn, 2007) have acknowledged the importance of thinking skills in fostering learners’ ability to develop their understanding. This understanding is established by the inferences learners embed in their learning practices, and by examining these, learners can uncover the underlying assumptions (Paul & Elder, 2012). Therefore, it is important to foster learners’ thinking skills related to processing and understanding e-learning content through the way the content is structured and represented, and this can be done through different instructional materials and design elements. However, the design need not presume that e-learners approach the material without previously developed thinking skills. It may be assumed that learners approach e-learning with a variety of thinking skills they have developed through previous experience, because “thinking skills are increasingly required for success in a knowledge-based society” (Liaw, 2007, p. 51). Liaw proposed that inadequate representations of learning material may affect the students’ thinking skills in relation to the material. Hence, we concluded that learners’ thinking skills might enhance their understanding when content is structurally represented in the e-learning environment. The present study aims at supporting learners’ thinking skills by enabling them to become more critical about evidence, think more flexibly, and make reasoned judgments and decisions, all of which will result in a deeper understanding of the topics they study. We hypothesized students’ thinking skills with regard to structured representation will effect their understanding by virtue of their being motivated, paying attention, and interacting with the e-learning content.

2.2. Motivation

The motivation to learn is considered an essential factor that affects a learner’s cognitive ability to understand content, including immediate learning, by encoding the content within the domain (Mayer, 1992, 1999). Boulay et al. (2010) and Schunk and Zimmerman (1994)
both note that learners’ motivation and metacognition when learning various subjects are strongly related to their thinking ability. Motivational practices that depend on the individual’s cognitive processing include using different methods to representing learning content online (Hardré, 2001), varying presentation formats (Moshinskie, 2001), and incorporating a simple and easily understood navigation system for the learning experience (Reeves & Hedberg, 2003). These motivational practices provide e-learning with a representation that encourages the independent development of cognitive thinking that can be exercised when understanding content. Additionally, Roda and Nabeth (2005) reported that the motivation to learn different subjects influences learner’s thinking skills by establishing a direct relation between the bias stimulus and the learner goal. Various researchers (e.g., Bekele, 2010; Guri-Rosenblit, 2006; Laurillard, 2006; Tham & Werner, 2005) have found that successful e-learning in higher education usually depends on student’s achievements, motivation, satisfaction, and thinking skills as well as online interactions and more. All of this research suggests that motivation is a critical factor for productive learning and that it also affects the acquisition and exercise of higher thinking skills (Facione, 2000; Paul, 2005; Paul & Elder, 2001a, b). Thus, we concluded that motivating students through structured representation might affect their thinking skills in relation to understanding content in e-learning.

2.3. Attention

Researchers have characterized attention as the component of cognitive processing that assists in the selection of incoming perceptual information in order to avoid overloading the cognitive system (Driver, 2001; Meyer & Kieras, 1997; Posner, 1993). It has also been characterized as the allocation of processing resources. This suggests that structuring learning content can affect the level of attention learners direct to the content (Bartsch & Cobern, 2003; Hosam, Abbas, & Naufal, 2010; Neuhauser, 2002). Hence, the representation of instructional content must be brief, clear, and quantifiable with outcome assessments. Sulaiman, Atan, Idrus, and Dzakiria (2004) reported that learning through the Web is likely to be more metacognitive. For instance, a particular student who is provided with the necessary learning materials and tools can focus effectively on the content. Thus, asynchronous e-learning support such as help functions (Renkl, 2002), multiple segments (Plaza, 1995), structured representation (Hosam et al., 2010), and preview windows (Cress & Knabel, 2003) might have direct or indirect effects on the development of learners’ thinking skills. Thus, we concluded that students’ attention to a structured representation of content in e-learning might affect their thinking skills for understanding that content.

2.4. Interactivity

Interactivity, along with its relation to the development of individual’s cognitive functions, was first introduced by Sweller (1994, 2010) as a mechanism in intrinsic cognitive load theory for learning different subjects. According to Moore (2002), cyclic relations involving interactions between learners and e-learning content usually promote the development of the necessary metacognition for understanding content and thus learning in the e-learning environment. Sweller pointed out that learners’ interactivity is related to the use of certain learning tools and that thinking skills cannot be learned in isolation. According to Sweller, “the more elements that interact, the heavier the working memory load” (p. 124). This suggests that learners who are trying to understand components of a research article (e.g., problem, objective, or method) usually expect these components to be simultaneously presented because they are interconnected. Therefore, it is recommended that the elements of most schemas be structurally represented simultaneously so that learners interact with them and develop their thinking skills. This led us to believe that a high level of interactivity helps students develop their thinking skills. Therefore, we concluded that students’ level of interactivity with a structured representation in e-learning might affect their thinking skills in relation to understanding learning content.

2.5. Understanding e-learning content

Understanding refers to the ways that the content available in different learning contexts is converted to knowledge through absorption, action, interaction, and reflection (Murray & Kujundzic, 2005). Most students who struggle with their university studies can significantly improve their understanding if the learning process is supported with a well-designed learning structure or template. According to Burns, Clift, and Duncan (2011) and Mayer, Heiser, and Lonn (2001), some instructional materials do not have a significant effect on learners’ understanding. These researchers also found that the inclusion of unnecessary elements in instructional representation may distract learners and negatively affect their performance. This suggests that presenting content with a good structure can influence learners’ attention, which in turn may cause them to think deeply and help them achieve understanding. In addition, Ehmann (2005), Horton (2011), and Rohrbach (2010) argued that the appearance of content can promote learners’ perception and understanding. Several studies have investigated these effects on students’ understanding and learning. For example, Sirintongthaworn and Krairit (2004) found that students’ success in e-learning depends on the composition of the user interface, specifically, three main factors: human-to-human interactions, human-to-nonhuman interactions, and duration of access. Paul and Elder (2012) found that students can develop their thinking skills by examining the inferences they make and then determining the assumptions that lead to understanding. As students do this, they begin to gain command over their thinking. Hence, the present study aims to determine whether the structured representation of content in e-learning can help students to better understand the content through the development of their thinking skills.

In summary, the development of learners’ understanding can be characterized by the motivation, interactivity, and attention required for developing their thinking skills. Fig. 1 shows the e-learning model we constructed for our initial hypotheses and how the specific external variables and metacognitive effects that we tested in our study fit into this model. We customized the structured representation of content for the e-learning environment based on distributed cognition theory. Section 3 elaborates on this design.

3. Representation-based distributed cognition

Distributed cognition theory posits cognitive processes distributed across multiple agents that structure certain representations of content (Hutchins & Lintern, 1995). This theory has been used as the basis for representations of instructional learning content. For example,
Giere (2002) and Liaw (2007) contend that instructional learning content must be presented in a way that provides the learner with multiple opportunities to understand the content. Furthermore, if too many unnecessary multimedia elements are used to represent instructional content, learners become distracted and their thinking skills and consequently their understanding actually decline (Karns, 2005; Kekkonen-Moneta & Moneta, 2002). Based on the idea of distributed cognition, learning content can be appropriately represented either by combining learners’ understanding of the content or by providing interactions with learning objects that are segmented into different forms (or both). We believe that the use of distributed cognition to structure research articles into segments is promising, and that such structures should not be restricted to distributing a cognitive object across multiple learners, but should also include distributing a cognitive object between a single individual and the representation. Based on distributed cognition theory, we formed objects through their roles, so that each carries a certain learning template or structural representation, and we used multiple agents to distribute seven segments or objects based on these roles.

Fig. 2 shows the front and backend of the proposed system which we have incorporated into an e-learning system called the Structured Content Management System (SCMS). The development of the SCMS took place on 2010-2011. As demonstrated in Fig. 2, the system consists on students’, instructors’, and administrators’ functionalities representing the client part. The query part consists of agents for tracking, mapping, analyzing, and classifying the client queries to be processed with the database. The database part consists of the agents for recording, managing, and retrieving articles. The system classifies the article contents into seven segments: (1) title, (2) introduction, (3) problem, (4) objective, (5) method, (6) analysis, and (7) result, which can be retrieved by the students in the same form. Other additional features were also included, such as keywords, downloads, hits, etc. to help students understand information about the article. The system enables learners to navigate through available research articles, based on keywords related to a definite subject, using search engines and categories as shown in Fig. 3.

We predicated the distribution of the proposed representation segments on our personal teaching experience and related research models such as those proposed by Atman and Bursic (1996), Gillani (2003), Hardré (2001), Jones (1992), Ryberg, Niemczik, and Brenstein (2009), Beetham and Sharpe (2007). The segments are as follows:

i) Title: presents the main title of the research article

ii) Introduction: provides a general overview of the article
iii) Problem Statement: outlines the main issues the article tries to solve
iv) Objective: presents the article’s aims or objectives
v) Method: summarizes the method adapted or developed in the article
vi) Analysis: summarizes the analysis techniques used in the article
vii) Result: summarizes the result

This distribution assumes that these segments already exist in the student’s cognitive structure, particularly in the case of students pursuing graduate studies. In addition, these segments are presented in research articles using specific formats and a set of concepts or phrases for section headings such as “Problem,” “Literature Review,” and “Data Analysis.” Fig. 4 shows our proposed structured representation of the research article segments.

4. Hypotheses

Given the relations between our study’s external variables, thinking skills, and understanding discussed in Section 2, we formed the following four hypotheses:

H1: There is a direct effect between students’ motivation regarding the structured representation and their thinking skills in relation to understanding e-learning content.
H2: There is a direct effect between students’ attention toward the structured representation and their thinking skills in relation to understanding e-learning content.
H3: There is a direct effect between students’ interactivity with the structured representation and their thinking skills in relation to understanding e-learning content.
H4: There is a direct effect between students’ thinking skills regarding the structured representation and their understanding of e-learning content.
5. Materials & method

5.1. Sample

We conducted a survey of students’ understanding of SCMS’s structured representation of research articles at a university in southern Malaysia, during the first semester of the academic year 2011–2012. We selected a total of 245 students majoring in four programs: Pure Sciences, Applied Sciences, Pure Art, and Applied Art. Given these major courses of study, we expected that the participants’ computer skills would be highly developed because a majority of the students had prior experience using e-learning systems as primary tools to assist their learning. We implemented a one-month online learning activity in which journal articles were represented with the structured representation.

5.2. Procedure

One week prior to the study, the selected students received a notification of the upcoming activity. Respondents from the selected schools were given a demonstration of the e-learning system (SCMS) developed at the Centre for Instructional Technology and Multimedia at Universiti Sains Malaysia. In every school computer lab, there was 30 min live demonstration given by the researcher to the students, following which they were given 45 min to practice individually with the system using all the features. The demonstration practice phases was designed to provide students with an understanding of the capabilities of the SCMS and how they can use it in finding the summary of research articles related to their field. The researcher also gave a demonstration on how to access the major functions consisting of exploring the key components of the system, searching (for example, how students can find the article from the category page, advance search page, and structured page), participate in online chats, and download articles. During the practice phase, students had continuous anytime/anywhere access to learning materials. However, each student used a guest account that provided hands-on access to all of the above-mentioned functionalities. Instructors informed students about the upcoming activity, as the students were also able to post their questions about the learning activities (summarizing research articles) or technical issues. Immediately after the practice phase, the survey instrument was administered to each student who had been using the SCMS for one month starting from 15 August 2011 and ending in 16 September 2011. After the learning activity, they completed a questionnaire that asked them whether the structured representation used by SCMS enhanced their understanding of the learning content. The students were assured that their responses would be kept confidential. A total of 225 of the 245 participants returned their questionnaires. Our first showed that the questionnaire responses of 15 participants were not valid because data were missing. We therefore deleted these responses so that the result would be valid, which left a final total of 210 questionnaires.

5.3. Measures

We used a survey research method to collect data from the sample in this study. We constructed a questionnaire by modifying items from previous studies related to the use of e-learning so that they would be appropriate for our study’s setting. These included items from Bures, Abrami, and Amundsen (2000) for motivation, from Schepers (2007) for attention, from Arbaugh and Duray (2002) for interactivity, and from Bernard, Brauer, Abrami, and Surkes (2004) for thinking skills. In addition, we constructed items for understanding based on recommendations in Prosser and Trigwell (1999) and Rohrbach (2010), who both argued that the structure and organization of learning content influence students’ learning. We designed the items related to understanding to focus on how thoroughly the students were able to discover facts and relations in each segment, how well they thought the structured representation allowed them to extract and remember information from the segments, how well they could mentally manipulate and elaborate the provided content, and whether they thought the structured representation enabled them to develop a complex and interrelated knowledge network that impacted their understanding of the content.

We conducted a pilot test before distributing the final version of the questionnaire to the participants. The pilot questionnaire contained 22 items to ensure the appropriateness of the research instrument, and 45 participants responded to this questionnaire. After analyzing the results, we deleted two items from the questionnaire because their scores did not meet the normally acceptable reliability thresholds with Cronbach’s alpha <0.6 (Moss et al., 1998). We used exploratory factor analysis (EFA) to analyze the results based on the principal component technique with varimax rotation. We extracted five factors with eigenvalues larger than 1.0; this explains 75% of the total variance, which is considered high (Hair, Black, & Babin, 2006). The factor loading results in Table 1 show that all the item loadings exceeded 0.70, as recommended by Nunnally (1978). We conclude that the assumptions concerning the factorability of the data were adequate. Items with low loadings or low communalities were eliminated for data reduction and for determining the embedded factor structures for each variable. The reason for the reduction was that the factor loading result was not working well for these variables. This helped ensure high communalities for the data, as recommended by Dunteman (1989), which supports the validity of the items used.

5.4. Data analysis

We used structured equation modeling (SEM) to test the research hypotheses and identify the direct and indirect effects, using Amos 17.0 to perform all SEM statistical procedures. We analyzed the data in two steps, as recommended by Gerbing and Anderson (1988). In the first step, we analyzed the measurement model by using confirmatory factor analysis (CFA) to indicate the construct’s scale validity and reliability. In the second step, we analyzed the structured model to measure the hypothesized relationships between the constructs.
6. Results and discussion

6.1. Evaluation of the measurement model

We conducted CFA to assess the overall measurement model. Our finding shows that there was no significant problem concerning the data multivariate normality, as characterized by Kline (2005). Additionally, for the measurement model to have a sufficiently good model fit, the ratio of the chi-square value to degrees of freedom (CMIN/df) should not exceed 3; the comparative fit index (CFI), Tucker-Lewis index (TLI), and non-normed fit index (NNFI) should all exceed 0.9; and the root mean square error of approximation (RMSEA) should not exceed 0.05. The results of the CFA (\(\chi^2 = 186.815, \frac{\chi^2}{df} = 1.168, \text{CFI} = 0.989, \text{TLI} = 0.987, \text{NNFI} = 0.929, \text{RMSEA} = 0.028\)) show that our hypothesized model fit the data and was suitable for SEM.

6.2. Reliability and convergent validity

We used three principles recommended by Fornell and Larcker (1981) to examine the convergent validity of the scales: (1) all indicator loadings should be significant and greater than 0.7; (2) the total value of construct reliability (CR) and Cranach alpha should be greater than 0.7; and (3) the average variance extracted (AVE) for each construct should be above 0.5. The factor loading results in Table 1 show that all items exceeded the recommended level of 0.7. The CR values (ranging from 0.766 to 0.779) and Cranach \(\alpha\) values (ranging from 0.738 to 0.881) exceeded the generally accepted value of 0.70, and the AVE values (ranging from 0.546 to 0.739) exceeded the generally accepted value of 0.5. Thus, the factor loadings and CR, Cranach \(\alpha\), and AVE values show that all items met the three principles for convergent validity, and this supports the conclusion that the structured representation of e-learning content has significant potential as an assisted learning tool for learners.

Table 1
Results from the tests of measurement model, reliability, and validity.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Factor loading</th>
<th>CR (&gt;0.70)</th>
<th>AVE (&gt;0.50)</th>
<th>Cranach (\alpha) (&gt;0.70)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bures et al. (2000)</td>
</tr>
<tr>
<td>I become motivated to use the structured representation because...</td>
<td>0.767</td>
<td>0.547</td>
<td>0.881</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It incorporated important concepts for my understanding of the content.</td>
<td>0.799</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It has simplified my review activities in reading the articles.</td>
<td>0.805</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It has motivated me to learn quickly.</td>
<td>0.812</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It was easy for me to find the connection between the article components.</td>
<td>0.816</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Schepers (2007)</td>
</tr>
<tr>
<td>My attention has increased because...</td>
<td>0.766</td>
<td>0.546</td>
<td>0.880</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The information arranged on the pages helped to keep my attention.</td>
<td>0.801</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The representation allowed me to concentrate on more than one segment at a time.</td>
<td>0.811</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The representation helped me to concentrate for long periods.</td>
<td>0.796</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The representation enabled me to focus on the details because my level of concentration increased.</td>
<td>0.815</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interactivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Arbaugh and Duray (2002)</td>
</tr>
<tr>
<td>My interactivity regarding the structured representation...</td>
<td>0.768</td>
<td>0.546</td>
<td>0.884</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enabled me to understand the contents.</td>
<td>0.794</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enabled me to learn more about my research.</td>
<td>0.823</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enabled me to use summaries and compare them with others’.</td>
<td>0.814</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Enabled me to discover different methods in a short time.</td>
<td>0.808</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thinking skills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bernard et al. (2004)</td>
</tr>
<tr>
<td>I became confident that using structured representation...</td>
<td>0.769</td>
<td>0.546</td>
<td>0.887</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assisted my learning.</td>
<td>0.825</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Helped me to learn in the best manner possible.</td>
<td>0.804</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Helped me set my goals for learning.</td>
<td>0.808</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased my skills in understanding the learning contents.</td>
<td>0.810</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rohrbach (2010); Prosser and Trigwell (1999)</td>
</tr>
<tr>
<td>I feel the structured representation...</td>
<td>0.771</td>
<td>0.546</td>
<td>0.889</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allowed me to discover various facts and relations about my research.</td>
<td>0.832</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allowed me to extract and remember information from many sources.</td>
<td>0.821</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allowed me to mentally manipulate and elaborate on the information provided.</td>
<td>0.840</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Made me think for a short period and helped develop a complex and interrelated knowledge network.</td>
<td>0.779</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.3. Reliability and convergent validity

We conducted CFA to assess the overall measurement model. Our finding shows that there was no significant problem concerning the data multivariate normality, as characterized by Kline (2005). Additionally, for the measurement model to have a sufficiently good model fit, the ratio of the chi-square value to degrees of freedom (CMIN/df) should not exceed 3; the comparative fit index (CFI), Tucker-Lewis index (TLI), and non-normed fit index (NNFI) should all exceed 0.9; and the root mean square error of approximation (RMSEA) should not exceed 0.05. The results of the CFA (\(\chi^2 = 186.815, \frac{\chi^2}{df} = 1.168, \text{CFI} = 0.989, \text{TLI} = 0.987, \text{NNFI} = 0.929, \text{RMSEA} = 0.028\)) show that our hypothesized model fit the data and was suitable for SEM.

Table 2
Correlations and discriminant validity. Square root of AVE reported along diagonal in bold type.**Significant at the .01 level.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Motivation</td>
<td>-1.025</td>
<td>0.773</td>
<td><strong>0.739</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Attention</td>
<td>-0.790</td>
<td>0.687</td>
<td><strong>0.308</strong></td>
<td><strong>0.738</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Interactivity</td>
<td>-0.783</td>
<td>0.360</td>
<td><strong>0.330</strong></td>
<td><strong>0.204</strong></td>
<td><strong>0.738</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Thinking skills</td>
<td>-1.165</td>
<td>2.047</td>
<td><strong>0.422</strong></td>
<td><strong>0.371</strong></td>
<td><strong>0.315</strong></td>
<td><strong>0.738</strong></td>
<td></td>
</tr>
<tr>
<td>5 Understanding</td>
<td>-1.446</td>
<td>2.890</td>
<td><strong>0.409</strong></td>
<td><strong>0.444</strong></td>
<td><strong>0.308</strong></td>
<td><strong>0.546</strong></td>
<td><strong>0.738</strong></td>
</tr>
</tbody>
</table>
6.3. Discriminant validity

We evaluated the discriminant validity of the scales based on the guideline recommended by Fornell and Larcker (1981); the square root of the AVE values for the constructs should be greater than the variance of any of the interconstruct correlations. Table 1 presents the correlations among the constructs, with the square root of the AVE on the diagonal. The results show that the AVE value for each construct is greater than the correlation coefficient of that construct with all the other constructs in the model. This suggests that all of the indicators demonstrated a satisfactory convergent and discriminant validity for this study. The skewness and kurtosis mean values displayed in Table 2 were less than the prescribed levels (skewness < 3.0 and kurtosis < 10.0) recommended by Kline (2005).

6.4. Assessment of the structured model

We assessed the structured model in two steps. The first step tested the goodness of fit of the hypothesized model using the chi-square value, and the result showed that the model yielded a chi-square value of 211.251 with 163 degrees of freedom ($\chi^2/df = 1.296$). All fit indices of the structured model were satisfactory (CFI = 0.980, TLI = 0.977, NNFI = 0.920). Table 3 shows the analysis results for standardized causal effects of each dependent variable in the final structured model, including direct (path coefficients), indirect, and total effects, path significances, and variance-explained ($R^2$) values.

The second step examined the significance of each hypothesized path in the research model. The examination revealed that motivation ($\beta = 0.32, p < 0.01$), attention ($\beta = 0.29, p < 0.01$), and interactivity ($\beta = 0.19, p < 0.01$) had significant effects on thinking skills, thus supporting hypotheses H$_4$, H$_6$, and H$_8$. These determinants accounted for approximately 36% of the variance of thinking skills (Fig. 3). The results also showed that thinking skills ($\beta = 0.64, p < 0.01$) had large and significant direct effects on understanding content, in support of hypothesis H$_4$. The model accounted for approximately 41% of the variance of content understanding. Fig. 5 presents the hypothesis testing results.

The analyzed data in Tables 1–3 show that students’ motivation, attention, and interactivity with respect to the e-learning structure directly affect their thinking skills, which in turn directly affect their understanding.

The impact of e-learning systems’ structured representation is consistent with the influence of general system design representations reported in studies of other system designs (Benbunan-Fich & Hiltz, 1999; Thomas, 2002) and is similar to those discussed in studies of interface design (Adams et al., 2008; Cho, Cheng, & Lai, 2009; Ravenscroft, 2001; Thorpe & Godwin, 2006; Zaharias, 2006). Meanwhile, design influence on motivational enhancement and acceptance of e-learning has been extensively examined in literature (Chang & Lehman, 2002; Condy, 1977; Keller, 1999, 2008; Maehr, 1976; del Soldato & du Boulay, 1995). Such is also the case when emotional factors are objectively utilized, which can significantly impact on learning process (Arbaugh & Duray, 2002; Kaplan & Pascoe, 1977; O’Regan, 2003). Other researchers such as Shneiderman and Ben (2003) state that students learn practical principles and guidelines needed to develop high quality interface designs characterized by easy understanding, prediction and control. Furthermore, Keller and Suzuki (2004) acknowledge that e-learning design enhances learner motivational outcomes and interactions. Cho, Cheng and Lai (2009) justify how enhancement and organization of interface design can help in stimulating learner motivation and increases their ability to process learning tasks. Ravenscroft (2001) and Thorpe and Godwin (2006) address how design of representation can increase learners’ interaction to learn. In addition, Adams et al. (2008) conducted a study on how design of e-learning systems in terms of cover layout, tool use, help and representation can help capture attention of students to learn effectively.

The results of the current study demonstrates that structured representation has significant potential as an assisted learning tool for learners, which in turn reveals that structure-based learning theory influences students’ metacognitive activities and facilitates their understanding content in e-learning environments. It appears that although students believe that the structured representation of the e-learning content (research articles) is a useful assisted learning tool, they are concerned about the potential of SCMS for motivation, attention, and interactivity. This suggests that university students need more interactive, motivated, and attention-grabbing representations in e-learning. In addition, the results in Table 3 indicate that the students achieved a high level of thinking, reflected in their understanding of the structured representation. Finally, the results demonstrate that learners’ understanding of learning content can be increased by greater levels of motivation, attention, and interactivity for developing thinking skills in the e-learning environment.

Our findings enrich the theory of distributed cognition on usage of multi objects or segments in structuring the representation of the e-learning systems, and provide e-learning developers and designers with insights on how to attract learners to use their e-learning tools.

<table>
<thead>
<tr>
<th>Endogenous variables</th>
<th>Determinant</th>
<th>Standardized causal effects</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Direct</td>
<td>Indirect</td>
</tr>
<tr>
<td>Thinking skills ($R^2 = 0.38$)</td>
<td>Motivation</td>
<td>0.32</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Attention</td>
<td>0.29</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Interactivity</td>
<td>0.19</td>
<td>–</td>
</tr>
<tr>
<td>Understanding ($R^2 = 0.41$)</td>
<td>Thinking skills</td>
<td>0.64</td>
<td>–</td>
</tr>
</tbody>
</table>

7. Implications of the study

This study found that structured representation of e-learning systems plays a critical role in helping students develop their thinking skills for understanding content. This has several implications. First, it validates the importance of using distributed cognition theory in designing system representation when e-learning systems are developed. That is, learners who perceived that the system had a more organized representation not only indicated that the system motivated them to become more active, but also reported paying greater attention when
using the system for distance education purposes. Second, it suggests that specific types of structuring should be used in the representation of research articles. Developers and designers of e-learning systems should consider using these, and they should be targeted by educational institutions before implementing e-learning systems. For instance, learners who perceived that the structured representation of the e-learning system had a positive effect in enhancing their motivation, attention, and interactivity agreed that the structured representation played an important role in developing their thinking skills and helped them to comprehend the content of research articles. Therefore, the system’s importance is not limited to how representative it is, but also extends to the role of its structure in helping attract students’ attention, making them active in their learning in addition to motivating them in both supplementary and distance learning.

Overall, the findings about structured representation of e-learning system emphasize on the need for the developers, designers and education institutions purchasing such systems to consider the end users, and ensure that their representation meets the students’ specific learning needs. Compatibility between the way of structuring the system’s representation and user requirements has been found to enhance system adoption in other contexts (Cho et al., 2009; Zaharias, 2006), and is in line with the recent findings on the importance of design enhancement of e-learning systems (Adams et al., 2008; Ravenscroft, 2001; Thorpe & Godwin, 2006).

Furthermore, the findings related to other model determinants also have effects. First, this study confirms the importance of structured representation in developing students’ thinking skills through motivation, drawing their attention to learning and leading to active participation in learning activities. This suggests that faculties should describe how the structured representation of a system will benefit students and help them to understand the course content, as students who perceived the well-structured representation of the system were supported in developing their thinking skills in order to understand the content of research articles. Second, after analyzing the importance and positive effects of e-learning structured representation to students, e.g., motivation, attention, interactivity, thinking skills, and understanding, it becomes clear that successful use of a well-structured e-learning representation is not inched on a student’s background. As few studies have addressed the impact of representation of e-learning systems, additional research is necessary to confirm the impact of structured representation examined in this study.

8. Conclusion

This study showed that there is an opportunity to incorporate structured representation of learning content for students in e-learning environments. A total of 210 students participated in this study to evaluate the effect of critical factors for developing students’ thinking skills in e-learning environments. We designed a new structured representation of content that divides the content of research articles into seven segments. Based on the concept of distributed cognition (please include a ref for distributed cognition), we provided concise key points for each of the segments for quick and easy onscreen reading. The course instructor and the researcher prepared three items for this study’s evaluation. First, we used the SCMS tool to create a scenario representation by inserting the article contents into the proposed template. Second, we formulated a detailed activity description and instruction package to guide the students towards successful learning. Third, we created the questionnaire for participants to fill out in class. The results of our evaluation show that learners’ understanding can be characterized by the levels of motivation, interactivity, and attention that are required for developing their thinking skills with respect to content in an e-learning environment. We also confirmed our hypotheses about the variables of our proposed model by statistically examining the fitness: in e-learning, students’ motivation, attention, and interactivity with our proposed structured representation had a positive effect on their thinking skills, which in turn positively affected their understanding. Designers of e-learning systems may consider the present classification in designing e-learning systems rationally incorporating tenets for cognitive development.

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References


