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Using the Multi-Display Teaching System to Lower Cognitive Load

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ABSTRACT

Multimedia plays a vital role in both learning systems and the actual education process. However, currently used presentation software is often not optimized and generates a great deal of clutter on the screen. Furthermore, there is often insufficient space on a single display, leading to the division of content. These limitations generally increase cognitive load. In this research, a multi-display teaching system was developed, based on the design principles proposed by cognitive load theory (e.g., Sweller, Van Merriënboer, & Paas, 1998) and the cognitive theory of multimedia learning (e.g., Mayer, 2005), to address the need for simultaneous, focused display of multimedia content. The multi-display teaching system was deployed on multiple projectors in real educational environments in order to prove that it is effective in improving learning efficiency. An experiment was carried out with 120 college students as participants. Results showed that multi-display instructional material significantly reduced cognitive load and enhanced learning effectiveness.

Keywords

Multi-display, Multimedia computer assisted learning, Cognitive load, Teaching system, Design principles

Introduction

Teaching materials have diversified from traditional paper and whiteboards into multimedia formats often presented on projection screens. Studies (Lai, 1998; Mayer, 1993, 1997; Mayer & Gallini, 1990; Mayer & Sims, 1994) have shown that integrated multimedia instructional material is beneficial for learning. Similarly, combining text with dynamic multimedia (such as animation or videos) can result in better learning (Chanlin, 1997; Lai, 2000; Poohkay & Szabo, 1995; Rieber, 1990). To explain findings like these, Daft and Lengel (1984, 1986) proposed *information richness theory*, which indicates that richer communication media convey information more effectively. Liu, Liao, and Pratt (2009) integrated the *technology acceptance model* with *information richness theory* and found that the learner's degree of concentration increases as presentation formats become more diverse. These new forms of teaching materials, which integrate text, graphics, video, and audio, have been shown to engage the audience much more effectively than traditional means, promoting reading interest and willingness to learn (Vichuda, Ramamurthy, & Haseman, 2001). However, the often limited display space available for projection devices and software that is not user friendly to operate often result in multimedia instructional material being less effective. Instructional materials must often be split into separate pieces in order to fit into available display space. As multi-monitor displays mature, the corresponding software requires prior limits to be transcended and a more flexible environment for multimedia instructional material design to be constructed. This research is aimed to develop a system that supports the presentation and operation of multimedia instructional materials on multiple screens. With properly designed material, the cognitive load of learners can be effectively lowered through the use of this multi-display teaching system.

Theories of cognitive load

There are three main types of cognitive load according to previous theoretical work: *intrinsic cognitive load*, *extraneous cognitive load*, and *germane cognitive lo*ad (Gerjets, Scheiter, & Cierniak, 2009; Miller 1956, Sweller, Van Merriënboer, & Paas, 1998). Intrinsic cognitive load involves the difficulties inherent in the information itself (stemming from the complexity or difficulty of or the interaction between the material to be learned) and the learners' degree of expertise (knowledge base or experience) (Sweller et al., 1998). If elements of knowledge are isolated and do not connect with other elements, intrinsic cognitive load will be lower due to this low *element interactivity*. Conversely, if information is not easily taught on its own and requires complex connections with other elements, learning will require more working memory (a higher intrinsic cognitive load) due to this high element interactivity. Take learning language for instance: intrinsic cognitive load is low when learners simply learn the meanings of vocabulary items that exist in a language (which has low element interactivity). When learning grammar, in contrast, element interactivity increases, because grammar constitutes the connections among vocabulary items and involves interactions in their meaning. Thus, the same teaching materials may make learners with good related-and-basic knowledge feel that the material is simple and incur little intrinsic cognitive load, while others feel that it is hard and incur more. In this way, intrinsic cognitive load is mainly affected by the connections among elements of the learning objective and by the learner's intellectual level. Intrinsic cognitive load is hard to alter by means of an instructional design for the reasons that it is mainly caused by learned objects itself (Kalyuga, 2009; Paas, Tuovinen, Tabbers, & Van Gerven, 2003).

Extraneous cognitive load mainly comes from bad material design or low-quality interfaces, which cause learners to consume additional cognitive resources on unrelated information processing during the learning activity (Paas et al., 2003). For instance, some electronic materials are designed with hyperlinks to other websites. Learners who are untrained or inexperienced in computer operation will spend time and effort to learn how to open these links in their browser. Such situations cause learners to need to incur extra effort to learn skills that are irrelevant to the knowledge they are trying to acquire; therefore, extraneous cognitive load is also called "ineffective cognitive load." This kind of cognitive load can be improved through better design and organization of material.

Germane cognitive load is also called "effective cognitive load." As noted for extraneous cognitive load above, learners consume cognitive resources during learning activity. Germane cognitive load is caused by material design that assists learners to build a knowledge base including things such as repetition, organization, comparison, and deduction, among others, to help memorization. Germane cognitive load helps with the construction of schemata of learning objects, whereas extraneous cognitive load is in this regard useless. Although germane cognitive load consumes personal cognitive resources, it is effective for learning unless total cognitive load exceeds working memory (Kalyuga, 2009).

Gerjets and Scheiter (2003) determined the relationship among the three types of cognitive load, visualized in Figure 1; it shows that intrinsic cognitive load is mainly affected by complexity of information or knowledge and not improved by teaching style or the design of teaching materials. In contrast, extraneous and germane cognitive load are improved by enhancing teaching methods and materials. Moreover, Paas et al. (2003), Kalyuga (2006), and Van Gog and Paas (2008) have indicated that the extraneous and germane cognitive load can be directly managed by the material designer. An effective instructional design should lower extraneous cognitive load. This accords with the perspective of multimedia learning theory in Mayer (2005) and optimized learning in Van Gog and Paas (2008). How to achieve the purpose of lowering cognitive load and achieving effective learning through a better instructional design has been discussed in the section on instructional design principles below.

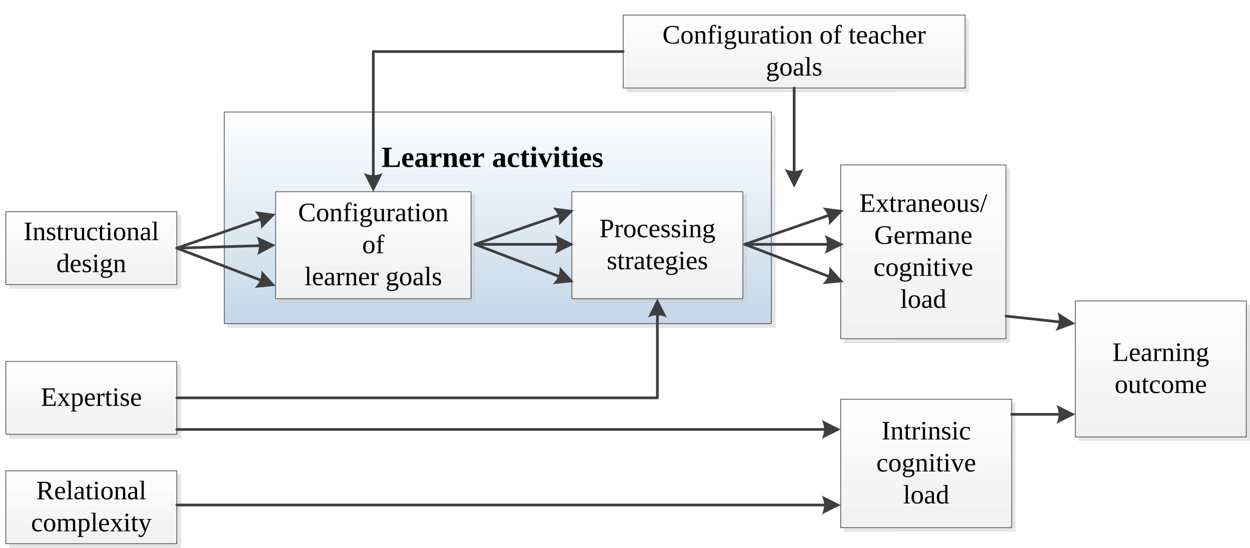


Figure 1. Intrinsic cognitive load, learning complexity, materials, and expertise

The measurement of cognitive load

A measurement method is necessary to confirm whether a constructed system can reduce cognitive load caused by teaching material. However, there is no standard measurement of cognitive load. Paas and Van Merriënboer (1994) divided cognitive load into two dimensions: the *task-based dimension* (*mental load*) and the *learner-based dimension* (*mental effort*); both affect learning effectiveness. Wierwille and Eggemeier (1993) proposed three methods for reducing cognitive load: *subjective techniques*, *physiological techniques*, and *task- and performance-based techniques*. Subjective techniques provide learners with a scale for reviewing the learning process. This method, which is the one most commonly used, can quickly record the cognitive process and evaluate it using a single score. Physiological techniques measure subjects' heartbeats, brainwaves, eye movements, and blood pressure. These physical variations are used to evaluate both cognitive and physical occupational workloads. Task and performance-based techniques measure load based on learners' performance and the complexity of the tasks involved.

Brunken, Plass, and Leutner (2003) proposed that methods used to measure the cognitive load could be divided by two perspectives: the *objectivity* and *causal relationship* scopes. The scope of objectivity includes methods for subjective self-depiction of information, namely observation of objective behavior, actual conditions, and performance. The causal relationship includes methods of measuring direct value and indirect physiological characteristics (Table 1).

Table 1. Classification of methods for measuring cognitive load (Brunken et al., 2003)

Scopes	Causal relationship	
	Indirect	Direct
Subjective	Self-reported invested mental effort	Self-reported stress level Self-reported difficulty of materials
Objective	Physiological measures Behavioral measures Learning outcome measures	Brain activity measures (e.g., fMRI) Dual-task performance

Studies from Paas and Van Merriënboer (1994) indicate that subjective techniques are convincible, interference-free, and sensitive to tiny differences. After weighing the costs associated with physiological techniques, we decided to adopt subjective and performance-based techniques to evaluate the effectiveness of the system constructed for this study.

The rating scale technique adopted in this study has been widely used to measure working memory load and mental effort (Paas et al., 2003; Sweller et al., 1998; Van Gog & Paas, 2008), and has been proven to be a reliable measure of both reliability and validity in cognitive load research. This study adopted a subjective cognitive load rating approach modified from previous studies (Cerpa, Chandler, & Sweller, 1996; Kalyuga, Chandler, & Sweller, 2000; Paas, 1992). This scale consists of four questions on a five-point Likert-type scale in two domains, reflecting *degree of clarity* from 1 (very clear) to 5 (very unclear) and *degree of difficulty* from 1 (very easy) to 5 (very difficult). The lowest degree of clarity (the highest score number) represents the heaviest extraneous cognitive load, and the highest degree of difficulty (highest number) represents the heaviest intrinsic cognitive load.

In terms of learning achievement, this experiment evaluated learners by their score on a pretest and a posttest as a transfer assessment designed by the teacher for this experimental course. Transfer assessment was measured by asking students to solve problems using information presented in the instruction. The analysis of results between the pretest and posttest determines the germane cognitive load between the experimental group and the control group.

The design principles of instructional material

Many research efforts have been devoted to finding instructional formats that reduce extraneous load, because it is imposed by processes that do not contribute to learning. While intrinsic cognitive load caused by inherent difficulties and complexities of instructional materials seems unavoidable, extraneous and germane cognitive load can be reduced by improving teaching flow, the teaching methods, the teaching style and the design of instructional materials. To help us understand this situation in more detail, Sweller et al. (1998) proposed several methods that help to improve learning: the *goal-free effect*, the *worked example effect*, the *completion problem effect*, the *split-*

attention effect, the *modality effect*, the *redundancy effect*, and the *variability effect*. Well-designed materials that utilize these effects to better convey information to learners help reduce cognitive load. Mayer and Clark further proposed multiple principles for multimedia learning (Clark & Mayer, 2011; Mayer, 2002). The success of some of these principles depends on the professional experience of the teachers. For example, in the case of the redundancy effect and Mayer's *coherence principle* (put related material closely with less interruption), the teacher decides which content should be included depending on his/her own professional knowledge and teaching experience.

Some principles suggest that display arrangements should involve multiple sensory stimulation. Sweller et al. (1998) and Mayer (2005) both recognized that the simultaneous display of images and sound can heighten learning effects. For instance, Mayer (1997), as well as Tiene (2000) indicated that the modality effect is less easily incurred if these different types of information are displayed sequentially. When instructional knowledge requires learners to reference additional information, make comparisons with others, or integrate some key effects, the simultaneous display of all related information is important to reduce germane cognitive load. Traditionally, limits on display space force teachers to split all related information into chunks. During lectures, teachers demonstrate this information sequentially, thus distracting learners attempting to process each individual piece of information and in turn lowering learning effectiveness. Based on this, teaching assistance systems should support the simultaneous display of multiple multimedia formats. Moreover, Mayer also formulated the *signaling principle*, which assists with conveying key points from among all display content. The instructor may write down certain points or draw charts to assist learners with organizing information during the lecture. Table 2 summarizes these design principles and the related system requirements.

Table 2. The functionality list according to teaching design principles

Sweller's effects	Mayer's principle	Cognitive load type	System requirements
Modality	Multimedia	Germane	Display multiple multimedia formats in a single program to lower working memory load
Split-attention	Spatial contiguity & temporal contiguity	Extraneous	Place course content or information together with commentary and present them at the same time
Worked example	Signaling	Germane	Provide colored pens to mark points or provide tips

The limits of existing teaching systems

Following the proliferation of computers, multimedia teaching styles have become popular, because they integrate multiple display methods and make teaching more exciting. However, there are limits to their actual use in practice. The resolution of most projectors is 1920 x 1080, which is not enough to present multiple multimedia content side-by-side. The most common solution is to split all related content into pages, but this degrades communication, for instance by forcing users to separate content and analysis (Kjeldsen, 2006; Lanir, Booth, & Tang, 2008; Parker, 2001; Tufte, 2003), as visualized in Figure 2.

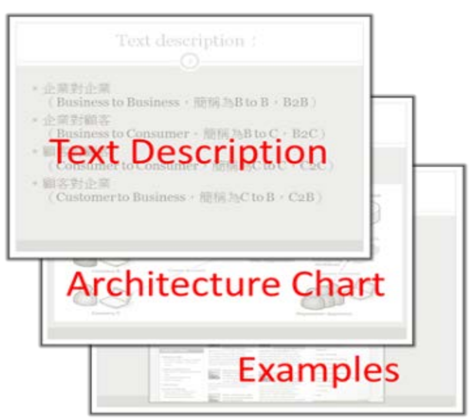


Figure 2. Splitting related content into pages

Splitting content is the least desirable method of displaying it, because it works against instructional design principles that suggest that related information should be displayed closely together. Furthermore, the number and diversity of knowledge formats have increased as information technology has evolved. Teachers inevitably find a need to reference various kinds of files, such as webpages, PDF documents, or videos, to help them explain the material. Studies by cognitive scientists state that spatial and temporal grouping of related items is important for learning (Mayer, 2003): instructors need to allow learners to view the construction of each entity but also to allow them to view entities simultaneously for comparison purposes. Slides do not facilitate this practice easily (Lanir, Booth, & Findlater, 2008).

To address issues like these, Mayer (2005) notes that readers can simultaneously preserve text and images in working memory; and to add some reference points for learners, Erhel and Jamet (2006) suggest the addition of popup windows connected to instructional slides to highlight the focal points of learning) Popup objects can place textual explanations as labels near a corresponding graphical object.

However, a major limitation of popup objects is that they may obstruct the view of texts and images (Chang, Hsu, & Yu, 2011). One may also introduce videos or animations, for instance to introduce real cases related to the material under study. With limited display space, popup windows will make instructional slides appear as shown in Figure 3. Currently, presentation software has little support for features involving cross-type displays; that is, different types of documents cannot be displayed together in the presentation frame. Whenever teachers open referenced material using other programs, the discontinuity and the extra adjustments needed to the display cause extraneous cognitive load. In addition, existing presentation software does not support mouse-track signals across multiple opened windows. To achieve the functionality presented in Table 2, there is thus a need to build a new presentation system.

Figure 3. Overlapping windows in a single-screen environment

Multiple-monitor display techniques and the presentation system

Compared to traditional desktop displays, information presented on multi-display systems is typically separated at a much wider visual angle. Additionally, since displays are often placed at different depths or framed by physical bezels, they introduce physical discontinuities in the presentation of information (Tan & Czerwinski, 2003). Multiple monitors are widely used in the stock market as well as in surveillance systems. This research constitutes a similar attempt to extend display space by connecting multiple projectors in an educational context. A multi-display system benefits teaching efficiency in the classroom because it enlarges the workspace (Seufert, 2003). That is, instructors need much more workspace when presenting multimedia materials contained in several windows, and using multi-display they can place these windows side-by-side on the desktop instead of clicking on the Windows toolbar to constantly switch among windows. A multi-display system contributes more than a single large display because it provides partitions separated by the bezels of the displays, so that instructors can classify their teaching materials naturally by deploying windows showing different media or content to different displays. Students can absorb different pieces of information efficiently on the basis of this classification by instructors and better connect it with their own knowledge (Pobiner, 2006).

As multiple-monitor setups become more cost-effective and flexible, multiple-screen displays are becoming increasingly common. However, there are only a few presentation software programs available that support expanded display space. Although Microsoft Office PowerPoint, Apache OpenOffice Impress, Apple Keynotes, and cloud-based Acrobat Labs Presentations, Google Docs, and Prezi have developed into mature products, they mostly support no more than two screens. This leads to a situation where one screen, usually a projector, displays the material while another displays the backup notes, intended for the instructor only. Research has revealed that two display screens can not only help improve learners' recognition memory and peripheral awareness (Robertson et al., 2005), but also result in better task performance and usability (Colvin, Tobler, & Anderson, 2004). Some presentation techniques that have been shown to improve learning effectiveness in this context include reference to previously presented content, visual comparison between different concepts, and non-linear movement through presentation content (Lanir et al., 2008). Hutchings and Stasko (2007) pointed out that another advantage of the multi-screen setup is the ability to support tasks, execute applications, and present images simultaneously.

Many universities and conference centers accommodate lecture halls and conference rooms equipped with multiple high-resolution display systems. Most presentation software does not yet take full advantage of these facilities; in fact, many lecture halls simply default to broadcasting the same slideshow on all of the displays (Lanir et al., 2008). The present research is therefore aimed at the construction of a multi-display system with novel functionality to help teachers adhere more closely and effectively to instructional material design principles. In order to fully utilize the advantages of a multiple-display space, the constructed system includes an editor function with an instinctive interface, meaning one that is easy to operate for the purpose of designing multi-display-fitted materials.

The multi-display teaching system design

According to the system requirements discussed in the previous section, the system design details are described as follows:

Display different types of multimedia contents

There is no uniform format for multimedia files. For example, video is often used in different formats such as MP4, AVI, and MPEG, among others, not to mention with various encoding techniques. In the system proposed here, a display and viewer object (DVO) is built to handle different format elements. The DVO contains different display components that are responsible for displaying the related file type. Usually the file type is recognized by the file extension name. If the file extension name is unknown, the DVO attempts to display it with a web browser. This also enables the user to configure different display components for the purpose of displaying specific file formats (Figure 4).

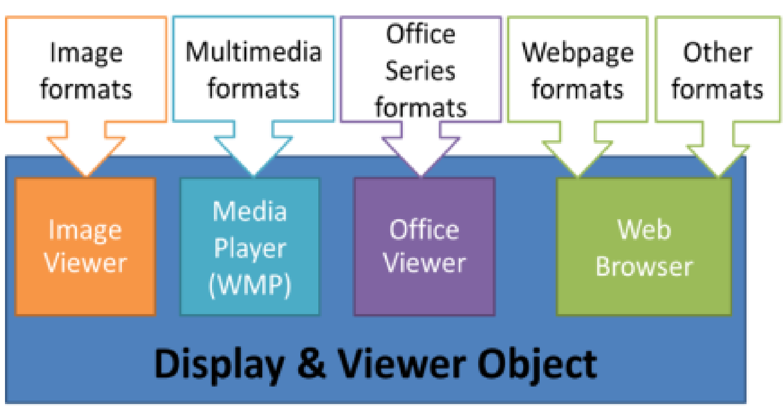


Figure 4. The DVO architecture

Display related multimedia content side by side

To display a larger amount of relevant content, this system utilizes multiple projectors and screens to expand the display space. The system dynamically supports the required number of display screens, depending on the classroom space. Here, we adopted three display screens to demonstrate a usage scenario. The design principles listed in Table 2 were addressed by assigning related content to specific display screens (Figure 5) so that the material could be presented simultaneously. With the display material prepared and configured in this way using the system, instructors can reduce the effort required to open different files in different windows and to arrange the position of each window. Therefore, they can focus more on the content of their lectures rather than the logistics.

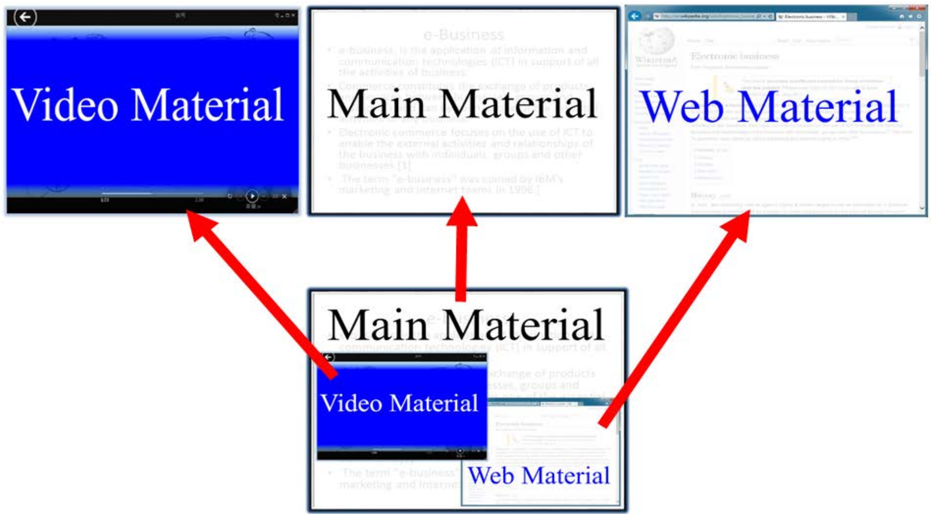


Figure 5. Expanding the display space to display related content

Provide colored pens to mark key points and provide tips

Since the display space is expanded, teachers can better utilize it to make markings on instructional material, thus using the signaling principle to assist students in focusing on key points during the lecture. There is a transparent layer upon which to record pen marks across different screens and even across different multimedia display objects, as shown in Figure 6.

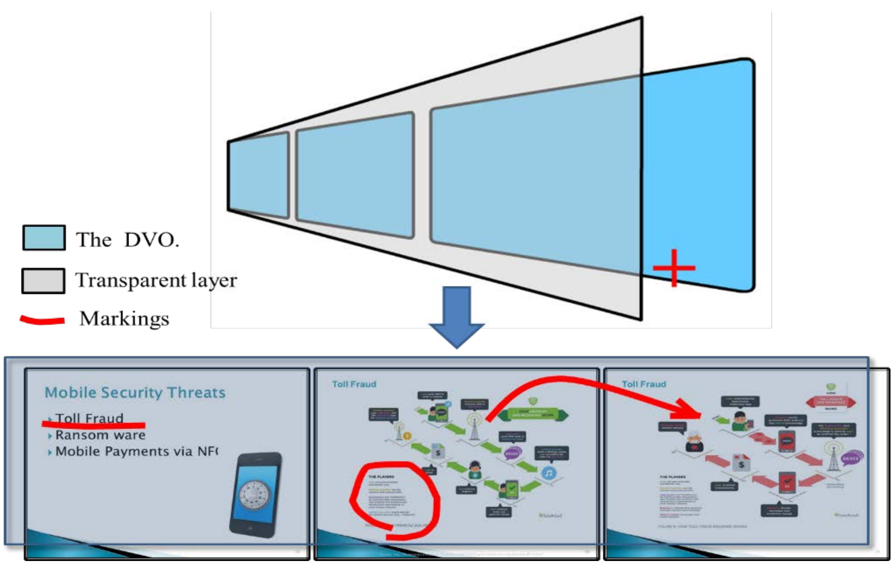
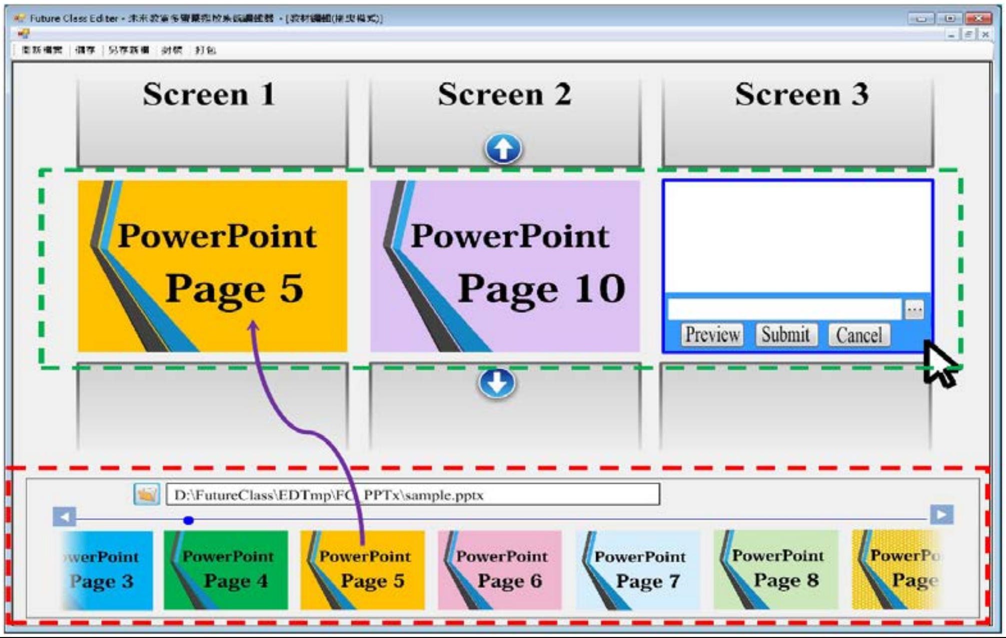


Figure 6. Transparent layer for drawing lines

Teaching material editor

For better editing and design of material, this system also implements an editing interface. In Figure 7, each row represents a display screen with a sequence from top to bottom. Each column indicates the flow of content to be displayed on each screen simultaneously and in sequence. The operation of this editor is intuitive: users can click on each screen and input the address of a file or webpage. The system supports preview during editing, and users can also drag/import existing PowerPoint files. After the edits are complete, the system will package all files in an FCM file format, portable for use in different places.



	Buttons for switching pages
	Editing pages to be displayed at the same time
	The referenced PowerPoint file
	Cursor tracking of drag-and-drop for quick adding of referenced material to the display space
	Input column for addresses of referenced webpages/files

Figure 7. The editing interface of this teaching system

Experiments and evaluation

To verify whether or not the system presented in this research would achieve the expected results, an experiment was carried out using a quasi-experimental method. A subjective approach as well as task- and performance-based techniques were used to evaluate the learners' cognitive load. We reference the subjective measurement scales proposed by Kalyuga et al. (2000) and Cerpa et al. (1996) and modify them into a five-point Likert-type scale. The scale allows learners to score their cognitive load incurred by learning in the following areas: "The difficulty of the course," "The effort you made in class," "The extra effort you made outside of class," and "The pressure you felt in class." There are no dependencies among the items in the scale. Learners were asked to recall the learning process they underwent in the course and then answer the questions using the scale.

Participants

The participants in this experiment were 120 college students enrolled in an electronic business class. The content designed under the conditions above and delivered in the class introduces electronic business architecture and related theories, includes specific terms, architectural figures of business models, animations representing the concepts, and a video of actual cases. This course required cross-reference between multiple files, and as a result was considered suitable as a context for the implementation of this teaching system to teach and to deliver composite knowledge.

Experimental design

The research method used is called a "non-equivalent pretest–posttest control group" design. Two groups of students were given a pretest to record their cognitive load level before exposure to the target material. The experimental group was lectured in a classroom equipped with three projectors using the multi-display system (Figure 6). The control group was lectured in a classroom equipped with a single projector. The teachers prepared integrated material edited with the teaching material editor for the experimental group. In contrast, the material prepared for the control group was a PowerPoint presentation with target materials, webpages, and pictures all embedded or integrated in sequential order. The experiment lasted four weeks, three hours every week. The experimental group took class at 8:00 in the morning on Wednesdays and the control group on Thursdays. The course content covered in the first week was an introduction of course guidelines, letting students get familiar with the system. The course proper started in the second week. According to Marcus's (1996) suggestion, cognitive measurement should be taken immediately after the course to reduce to a minimum the loss of work memory load. Therefore, after every week's lesson, we used subjective cognitive load rating to measure the cognitive load of students in both groups. In the last week (the fourth week), the posttest was given after the subjective cognitive load rating in order to evaluate the learning effectiveness of the method. The questions in pretest and posttest were selected from the Techficiency Quotient Certification and passed validation by three experts. To control to the degree possible other factors affecting the experiment, the course material and teacher were kept constant in both groups. During the class, the teacher was requested to only use the drawing line function and change page function. Table 3 lists the design and control factors for this experiment.

Table 3. The experimental design pattern

Group	Pretest	Methods	Scale of cognitive load	Posttest
Experimental group	O1	X1	O2	O3
Control group	O1	X2	O2	O3

O1: Both groups were given the pretest.
O2: Both groups were given the measurement of cognitive load.
O3: Both groups were given the posttest.
X1: The experimental group was taught using the proposed teaching system.
X2: The control group was taught with a PowerPoint and single-screen setup with various types of multimedia.

Experimental results

The four cognitive load scale results from after the four-week teaching experiment are shown in Table 4.

Table 4. Cognitive load scale results

Group	Items	Average (higher number means more pressure)		
		2nd	3rd	4th
Experimental group	The difficulty of the course	3.03	3.03	3.15
	The effort you made in class	2.93	3.25	3.13
	The extra effort you made outside of class	2.88	3.07	3.12
	The pressure you felt in class	2.97	3.02	3.05
	Average	11.85 (3.30)	12.37 (2.73)	12.45 (2.97)
Control group	The difficulty of the course	3.37	3.38	3.43
	The effort you made in class	3.37	3.50	3.40
	The extra effort you made outside of class	3.40	3.52	3.50
	The pressure you felt in class	3.25	3.37	3.30
	Average	13.38 (3.30)	13.77 (2.85)	13.63 (3.22)

Next, we analyzed the cognitive load measurement scores with an independent-samples *t*-test. The result is shown as Table 5, showing that the cognitive load of students taught with the MSPS teaching system is lower than that of the control group.

Table 5. *t*-test results for cognitive load measurements

	2nd Week	3rd Week	4th Week
Results of analysis ($\alpha = .05$)	$t = 2.09$, $p = 0.04$	$t = 2.75$, $p = 0.07$	$t = 2.54$, $p = 0.01$

Task- and performance-based techniques can indirectly measure the cognitive load of students by analyzing their learning performance. The descriptive statistics for the pretest and posttest scores are shown in Table 6.

Table 6. Learning performance statistics

	Groups	*N*	*M*	*SD*
Pretest	Experimental group	60	77.33	8.80
	Control group	60	74.13	6.32
Posttest	Experimental group	60	82.53	9.88
	Control group	60	78.73	9.81

Furthermore, we analyzed the pretest and posttest grades with an analysis of covariance (ANCOVA). We exclude the influence of pretest grades (the covariate) on posttest grades (the dependent variable), achieving the standard level of significance ($F = 4.60$, $p = 0.034$). Also, the grades of the experimental group were higher than those of the control group, showing that the MSPS system certainly helps improve learning effectiveness.

In this research, total cognitive load score were analyzed in relation to the pretest and posttest grades through Pearson's correlation. Refer to Table 7 below.

Table 7. Pearson's correlation statistics

	Pretest and total score	Total score and posttest
Experimental Group	-0.747^{**}	-0.761^{**}
Control Group	-0.862^{**}	-0.837^{**}

Based upon the above results, which indicate an obvious negative correlation, prior knowledge did affect intrinsic cognitive load during the learning process. This result supports the theories of cognitive load presented above.

Discussion

In this study total cognitive load was measured as the sum of intrinsic cognitive load and extraneous load (Sweller, 2010). There is no process for separately measuring these three cognitive loads (Paas et al., 2003). In this research, we adopted the same material for both groups in the experiment; therefore, the intrinsic load was assumed to be the same. Since cognitive load as measured by the scale represents total cognitive load, we can deduce that different display modes of material affect extraneous cognitive load directly and analyze the results further to determine if the developed system can reduce the learners' cognitive load.

Another method to estimate cognitive load during the learning process is through (pretest and posttest) learning performance (Wierwille & Eggemeier, 1993). In this research, the only uncontrollable part was difference in talent/expertise/relational complexity of students. Analysis of covariance was therefore adopted to eliminate these uncontrollable variables. The analyzed results can thus also be deduced to represent the effect of extraneous cognitive load caused by different display methods.

As concluded above, this study demonstrates that the theory Mayer (2005) and Sweller et al. (1998) proposed separately in 2003 and 1998 respectively, claiming that presenting related words and pictures simultaneously and closely is better than presenting them isolated on the other pages, is correct. The multi-display system is able to enlarge the displayable content and make more room for multimedia content in particular to be presented clearly. Although the same effect can be achieved if one has a large enough monitor, high-resolution projectors are expensive, and it costs less to build a 5760 x 1080 pixel presentation space (for instance) by utilizing three common projectors with resolution of 1920 x 1080 dpi. Moreover, Pobiner (2006) thinks that teachers can classify their teaching material naturally through a multi-displayed system by deploying different media windows to different displays. This can help students absorb different pieces of information and organize this information pre-classified by instructors to form their own knowledge.

Marcus, Cooper, and Sweller (1996) pointed out that in teaching activity, cognitive load is determined by prior experience, nature of the material, and organization. Teachers can only lower the cognitive load through good design and editing of teaching materials and good methods of presentation, though there is not enough evidence to conclude for sure that integrating multiple multi-media benefits the learning process (Bartscha & Cobern, 2003; Mayer, Heiser, & Lonn, 2001; Rieber, 1996; Sweller et al., 1998). Merely adding various media does not make learning more efficient; a teacher's experience and professional judgment are needed to divide teaching materials into proper lesson-sized portions and to edit them effectively. This study proposes a novel application of a multi-screen system to offer teachers a more flexible tool.

The experimental results show that the multi-display teaching system proposed in this paper does actually decrease cognitive load and efficiently improve learning performance. The system can be extended not only to teaching but also to other tasks such as business presentations. In an interview, the teacher who participated in this experiment pointed out that this approach takes more time and effort than transferring a traditional linear teaching style into a mode divided into previous and next pages or right and left screens. This transfer of material display from a time series dimension to a simultaneous space dimension leads the teacher to need to consider the spatial configuration and choreography more closely. Nevertheless, the teacher saw the learning efficiency of the system as high, and expressed a desire to continue using the system in future teaching.

Due to time limitations, the experiment only lasted for four weeks, with 120 students involved, with a given portion of content (a series of e-commerce course lectures). More precise inferences and larger-scale longer-term experimental realizations need to be carried out in the future to get a more detailed sense of the effects of the system and of potential improvements.

Conclusion

Based on design principles for multimedia teaching material elaborated in previous studies, this research built a multi-display teaching system. The system not only allows multiple pages to be presented simultaneously on multiple screens but also enables multiple media to be opened and used in a uniform manner. The system further supports the drawing of functions across screens and media types. Moreover, the teaching system includes an editing interface to improve the design of multi-display instructional material. Ultimately, the purpose of this multi-display teaching system is to lower cognitive load, a benefit that has been verified elementarily in our experiment. This system will be promoted in schools and will be continuously improved as we receive more user feedback.

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