Integrating Annotations into a Dual-slide PowerPoint Presentation for Classroom Learning

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ABSTRACT
This study introduces a learning environment integrating annotations with a dual-slide PowerPoint presentation for classroom learning. Annotation means a kind of additional information to emphasize the explanations for the learning objects. The use of annotations is to support the cognitive process for PowerPoint presentation in a classroom. The construction of the learning environment is based on cognitive theory of multimedia learning so as to figure out the impact of using annotation in classroom learning. PowerPoint materials and their corresponding multimedia annotations can be simultaneously displayed in the environment. While teaching the current PowerPoint slide, it is displayed through one channel (or projector) and the related annotation or its previous slide is exhibited through the other channel (or the other projector). This manner can scaffold learners’ coherent mental representations so as to enhance their learning performance. In this study, an exploratory method was conducted with 170 sophomore and junior students ranging in age between 18 and 21 years. Survey results indicated that the proposed system based on cognitive theory can effectively help students in the experimental group to have better learning efficacy for lectures with dual-slide PowerPoint presentation than that of the conventional group.

Keywords
Annotation, Cognitive load, Multimedia instruction, PowerPoint

Introduction

The use of computers in today’s multimedia-based instruction is being widely applied in the blended learning environment to improve learning (Liao, 2007; Mayer, 2001). The multimedia learning environment uses several types of representation including text, audio, graphs, photographs, animation, or video. The multimedia teaching content is readily and effectively communicated between teachers and learners using popular presentation devices such as monitors or projectors (Bartsch & Cobern, 2003; Russell, 1998). In recent years, many researchers have focused on constructing multimedia instructional environments such as electronic classrooms (Leidner & Jarvenpaa, 1993), virtual classrooms (Hiltz & Wellman, 1997), and interactive multimedia environments (Armstrong & Curran, 2006). The projector is a common component of these multimedia instructional environments. It is easy for teachers to use projectors to present the visual information of their lectures. This method, of simply projecting a lecture onto a screen in front of a classroom has shown to provide excellent results. Multimedia teaching contents can be easily made using Microsoft PowerPoint, and has a high potential for reinforcing students’ learning (Apperson, Laws, & Scepansky, 2008). As a result, the way teachers utilize projectors to display their PowerPoint created lectures on a screen has become an essential component of the multimedia instrumental environment of today’s learning classroom (Susskind, 2008; Szabo & Hasting, 2000).

In the past decade, giving a lecture using PowerPoint has become a more convenient presentation method than writing on a whiteboard or using transparencies and an overhead projector (Savoy, Proctor, & Salvendy, 2009; Susskind, 2005). The convenience lies in the fact that teachers now spend less time in writing, changing transparencies, or maintaining lecture contents. A PowerPoint presentation makes a lecture flow easier and smoother, and provides structure to the presentation (Pippert & Moore, 1999). In other words, teachers that employ PowerPoint produce their lectures slides in the appropriate sequence and pace. In addition, PowerPoint makes it easy to present clear summaries (Lowry, 1999; Susskind, 2005). The use of PowerPoint in a lecture has shown that it can improve the note-taking ability of students while they study the teaching materials (Frey & Birnbaum, 2002). In addition, PowerPoint presentations can be effective for students’ self-efficacy and attitude towards learning (Susskind, 2008).

Although PowerPoint lectures can emphasize the key points of the teaching material, many studies demonstrate that there is no increase in the learning performance of students for using PowerPoint lectures (Apperson, Laws, &
According to Scepanisky, 2006; Bartsch & Cobern, 2003; Susskind, 2005; Tufte, 2006). Generally, teachers should decide what the message is they want to communicate. The message should be kept simple on the screen, and, each slide should have no more than 6 lines of texts or one-to-two pictures (Dodds, 2004). On the other hand, some researchers are of the opinion that students may have difficulty understanding every slide if they only contain some simple content and some key information. Some studies concluded that PowerPoint presentations do not promote the learning performance of students (Frey & Birnbaum, 2002; Susskind, 2005; Szabo & Hastings, 2000). This seems to be due to the fact that the teacher presents the teaching materials without applying the spatial or temporal contiguity principles of multimedia learning (Reed, 2006). More specifically, students often fail to understand the contents conveyed by the lecture because they have difficulties reconstructing their referential links between the visual and verbal information, thereby degrading the relevance and coherence of the mental model (Erhel & Jamet, 2006).

When a teacher presents a PowerPoint slide that includes several related learning objects, it can cause two problems: information load and presentation holding (Mayer & Moreno, 2003). An information load problem is where a PowerPoint slide contains too many learning objects. In order to overcome this problem, learning objects are distributed over two or more slides. This in turn creates a presentation holding problem where the slide presentation does not follow spatial and temporal cognitive principles. For example, a textual description is presented in the present slide and its corresponding explanations (annotations) are presented in the next slide. Therefore, students must hold the information represented by the textual description in their working memory while reading the corresponding explanations. If they don’t, their referential links between the textual description and the explanations will decrease, thereby degrading their learning performance. Consequently, either one of these problems reduce the students’ abilities to solve problems, think, and reason (Allen, 2000; Mayer & Moreno, 2003).

Moreno’s study (2004) showed that simply presenting information does not promote a student’s understanding of a particular knowledge in a certain context. Thus, there is a need to integrate annotations into a PowerPoint presentation. Annotations refer to the additional data, information or knowledge in the form of explanations for a specific part of the content (Verhaart & Kinshuk, 2006). Previous research reported that in general the use of annotations is helpful to improve learning (Jones & Plass, 2002; Wallen, Plass, & Brünken, 2005; Yeh & Lo, 2009). However, other reports found that supplemental information may increase a learner’s information load, thereby reducing his/her learning performance (Plass, Chun, Mayer, & Leutner, 2003). The above mentioned studies focused mainly on the web-based learning environment, and only a few of them focused on how to integrate annotations in a PowerPoint presentation for the physical classroom. Therefore, this study focused on two issues. First, how can a learning environment using a PowerPoint presentation accompanied by annotations be constructed so as to help students to comprehend their learning material? Second, what are the perceptions of students that find themselves in the PowerPoint accompanied by Annotations Presentation (PPAP) learning environment?

The construction of the PPAP learning environment, based on cognitive theory of multimedia learning, was applied to present the contents of the courses, “Introduction to the Art”, “Calculus”, and “Management Mathematics”. Furthermore, an exploratory study was conducted with 170 sophomore and junior students ranging in age between 18 and 21 years to figure out the impact of annotation in the classrooms. The rest of this paper is organized as follows. Section 2 briefly reviews cognitive theory of multimedia instruction. Section 3 describes the PPAP learning environment. Section 4 shows the survey results. Finally, Section 5 draws conclusions.

Background

Cognitive theory of multimedia learning

Multimedia learning is defined as learning from verbal and visual information (Mayer & Moreno, 2003). The verbal information includes the written form of printed words and the oral form of spoken language. The visual information can be represented by pictorial forms such as illustration, coordinate, diagram, photo, animation, and film. Mayer (2001) proposes a cognitive theory of multimedia learning, as shown in Figure 1, to explain how to learn from verbal and visual information. These critical processes are proposed for multimedia learning. The first cognitive process called selecting, which is applied to collect relevant verbal and visual information and then construct a text based and image based representations. The second process called organizing, which is applied to organize the selected verbal information into a coherent verbal mental model and the selected visual information into a coherent visual mental
model. The third process called integrating, which is applied to integrate the newly built verbal and visual models by creating connections between prior knowledge and corresponding events in visual and verbal models.

**Figure 1. The multimedia learning system**

**Cognitive load during learning**

The learning process occurs in the working memory and imposes a cognitive load which is essential for learning (Baddeley, 2002; Chandler & Sweller; 1991; Plass, Chun, Mayer, & Leutner, 2003). The cognitive load is related to the human information processing capacity. According to the properties of the task being performed, the cognitive load can be divided into three categories, intrinsic, germane, and extraneous (Sweller, 1999). The intrinsic cognitive load refers to the burden imposed on the learner to construct a semantic context required for a particular learning task. In a teaching context, a lesson cannot take place without two elements: the content knowledge to be taught in the lesson and the pedagogy itself (Feldon, 2007). The germane cognitive load refers to the learning activities that are related to schema acquisition and automation, such as asking students to compare solution procedures in structurally similar but contextually different situations (Kalyuga, 2007). On the other hand, the extraneous cognitive load stands for the ineffective structure or semantic contents that occupy the working memory, thereby reducing the capacity of working memory available for learning activities.

The intrinsic cognitive load can not be altered during leaning. An appropriate instructional design increases the germane cognitive load but decreases the extraneous cognitive load (Hasler, Kersten, & Sweller, 2007). An increased extraneous cognitive load is the result of poor instructional design. For example, if the presentation of the teaching materials with PowerPoint is artificially separated in space and/or time, it will lead to the related learning elements not being processed simultaneously to allow understanding of the instructional information. In addition, many new learning elements are selected too quickly to be successfully transferred into the semantic knowledge of the long-term memory. Finally, novice students do not have the appropriate prior knowledge to deal with this rapid introduction of new learning elements, and in addition the instructions do not provide sufficient external guidance. A high extraneous cognitive load will cause novices to use random search procedures, resulting in a poor learning performance (Hasler, Kersten, & Sweller, 2007; Kalyuga, 2007).

**The principles of multimedia instruction**

Multimedia includes different formats such as text, graphic, image, video, and sound. Nowadays, teaching materials with multimedia can increasingly provide richer instruction. Multimedia instruction can be regarded as a computer-based narrated animation that illustrates how a causal system works such as how pumps work or how the human respiratory system works (Mayer & Moreno, 2003). A way of using multimedia presentation can build referential connections between written and pictorial information. Several articles indicated the way multimedia can improve students’ learning effects (Mayer & Anderson, 1991; Muthukumar, 2005). Most important principles being considered in the design of multimedia instruction are: (a) multimedia principle (students learn better from words and pictures than from words alone); (b) modality principle (students learn better from animation and narration than from animation and on-screen text); (c) spatial contiguity principle (students learn better when corresponding words and pictures are presented near rather than far from each other on the page or screen); or (d) temporal contiguity principle (students learn better when corresponding words and pictures are presented simultaneously rather than successively) (Astleitner & Wiesner, 2004; Reed, 2006). Following the instruction, Mayer’s experiment results show
that students possess better retention, understanding, and inference capabilities (Mayer & Moreno, 2003; Reed, 2006).

**Multimodal learning environment**

Recently, the multimodal learning environment is being employed in the construction of the learning environment. The multimodal learning environment uses two different modes, verbal (e.g., printed words, spoken words) and non-verbal (e.g., illustrations, photos, videos, and animations), to represent the content knowledge (Moreno & Mayer, 2007). The large-display, which is shown in Figure 2(a), presents more visible information to the students and is more comfortable to read due to the size of the display area (Tan, Gergle, Scupelli, & Pausch, 2006). Students can comfortably view two or more different documents in a side-by-side fashion. Tyndiuk et al. (2004) examined an experiment involving 40 high-school students and found that the large-display effectively assisted in tasks with difficult interaction. In addition, Tan et al. (2006) examined an experiment and found that an advantage could be obtained by applying a 3D navigation presentation on a large-display. However, setting up a large-display system results in high cost, and as a result, its use has been limited. In addition, there are several problems with the traditional large-display system as listed below (Czerwinski et al., 2006; Robertson et al., 2005).

- Task management problem: users have to operate or control more complex tasks, and therefore require better task management mechanisms.
- Window management problem: leads to notification and window-creation problems. Windows and dialog boxes pop up in unexpected places.
- Losing the cursor: hard to keep track of the cursor.
- Bezel principle: visual distortions are introduced in switching windows and when shifting the cursor.
- Configuration problem: the user display interface is complex and difficult to use. At present it is difficult to deal with the heterogeneity of the monitors, such as different size or pixel density.

Dual-display refers the presentation of documents using two physical display devices such as monitors or projectors. This means that more visual information can be displayed than on a single monitor. The dual-display is less expensive and is easier to control than a single large-display. One kind of dual-channel display is the span-display, as shown in Figure 2(b). It shows a document which can be enlarged and can be shown across two monitors. However, when a document crosses two monitors, it creates a reading problem. In addition, it is necessary that the two monitors are set up with the same span-display settings, such as resolution, color, and refresh rate. The other dual-channel display is called the extended-display, as shown in Figure 2(c), and allows for different settings of the two monitors. It presents two documents on two individual monitors, respectively.

![Figure 2(a). The large-display](image)

![Figure 2(b). A span-display with two individual monitors having the same settings](image)

![Figure 2(c). The extended-display with two separate monitors having different settings](image)
Constructing a PPAP learning environment

The acronym PPAP means PowerPoint accompanied by Annotations Presentation. Figure 3 shows the PPAP learning environment consists of a notebook/PC, two projectors, and the context display management (CDM) system. In the environment, the current screen shows the slide the teacher presents at that moment. The other screen is called the annotation screen which displays the corresponding previous slides or annotations.

The CDM system

The CDM system (as shown in Figure 3) was developed and applied for the PPAP learning environment. Here consistent with previous studies on text annotations, the current slide and the relevant annotations are presented close to each other so as to avoid splitting the attention of the student, (Plass et al., 2003). The CDM system provides a flexible and useful presentation by offering two functions, the authoring and the presenting functions for creating a presenting sequence for instruction in the use of PowerPoint files. Two main components of the authoring function are the Conceptual Association Component and the Annotation Component. The presenting function is divided into three parts: Mouse Control, Switch Cursor, PowerPoint Presentation, Handwriting, Window Control, and Panel Control. These components are addressed in the following context.

The authoring functions of the CDM system

Conceptual Association Component allows teacher to build the conceptual association map (CAM) among slides. An example is shown in Figure 4. Teacher can edit and view the CAM which displays presentation structure of slides through the graphical user interface. Teachers use the component to edit the displaying chains for teaching units. This way can help teachers to present the related learning elements simultaneously. This is helpful to reduce student’s extraneous cognitive load (Kalyuga, 2007; Hasler, Kersten, & Sweller, 2007). Besides, when the related textual and pictorial learning elements are presented simultaneously, students can keep the visual and verbal mental
representations simultaneously (Bartsch & Cobern, 2003; Cavanaugh et al., 2008; Jones & Plass, 2002). That is, the referential connections between the visual and verbal mental representations can be built for the teaching contents by using Conceptual Association Component. Therefore, while displaying teaching contents, teachers can easily present materials for students so as to help them to build the coherent mental representations corresponding to materials.

Annotation Component allows teachers to insert various kinds of multimedia annotations in each slide of teaching materials. Annotations, including text, image, handwriting, video, and audio, are extra explanations to key terms in slides of a PowerPoint file. The purpose of using annotations is to offer students with different cognitive functions such as remembering, thinking, and clarifying (Koroghlanian & Klein, 2004; Verhaart & Kinshuk, 2006). Many researches have shown that a slide, which includes the media annotations, is better comprehended that without them (Kennewell & Beauchamp, 2007; Jones & Plass, 2002). Therefore, the CDM system provides an edit function to add various formats of annotations in slides.

![Figure 4. The structure of the conceptual association map edited by using graphical user interface](image1)

![Figure 5. The control panel of the authoring function](image2)

![Figure 6. The arranged annotation sequence](image3)

The CDM system offers synchronous and asynchronous presentations. The synchronous annotations can be displayed and disappeared at arranged steps during a predefined time period and the asynchronous annotations can be popped up anytime. Whenever an annotation is no longer needed, the instructor can immediately make them
invisible. Here, teachers can use the CDM system to present PowerPoint slide in one of the two projectors and pop up those annotations in the other projector. This way can offer sufficient external guidance (Feldon, 2007) and also avoid the situation that small annotations for instructional texts are jammed in a slide (Erhel & Jamet, 2006; Sakar & Ercetin, 2005). For instructors, this situation can provide instructional hints for teaching references while lecturing. Figures 5 and 6 show the operation control panel and an example of an arranged annotation sequence, respectively.

The presenting functions of the CDM system

Using the control panel of the CDM system, teachers easily operate the mouse moving and window displaying in a large display (three monitors) or dual-channel display (two monitors) learning environment. Figure 7 shows the control panel of the CDM system. The components of the presentation functions of the CDM system are as follows.

- Mouse Control: Lock the working area of the cursor in the designated working window.
- Switch Cursor: Transfer the working priority of the cursor to the current screen.
- PowerPoint Presentation: Presents two or more different PowerPoint files simultaneously or two slides from a PowerPoint file, into the screen assigned by the user.
- Handwriting: Writing, editing, or operating the handwriting tool and then synchronously or asynchronously display them onto the assigned screen selected by the user.
- Window Control: Displays the window into the assigned screen and calls the window back from one of the two screens to the current screen.
- Panel Control: Hides, shows, anchors, and closes the panel.

![Figure 7. The control panel of the CDM system](image)

A comparison for the three display modes

Using the CDM system, instructors can easily control the displayed window in the annotated learning environment. Table 1 shows a comparison of Microsoft solution and the CDM system for the large-display mode, span-display mode, and extended-display mode.

<table>
<thead>
<tr>
<th>Problems</th>
<th>Microsoft</th>
<th>The CDM system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large-display</td>
<td>Span-display</td>
</tr>
<tr>
<td>Cost</td>
<td>High</td>
<td>Middle</td>
</tr>
<tr>
<td>Cursor moving</td>
<td>Difficult</td>
<td>Difficult</td>
</tr>
<tr>
<td>Bezel principle</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Management problem</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Method

Participants

The students from six classes, using three faculty members in a technology college in Taiwan participated in this experiment. They totaled 170 sophomore and junior students (94 males and 76 females). Each faculty agreed to teach two classes using the same instructor and the same course. Each of the two classes for each faculty was randomly matched to either the experimental group or the conventional group. The experimental group (three classes, 87
students) was lectured using the PowerPoint presentation accompanied by annotation screen for displaying the previous slides or annotations. The conventional group (three classes, 83 students) was lectured without using the annotation screen. The two groups were lectured with the same teaching materials. The courses were “Introduction to the Arts”, “Calculus”, and “Management Mathematics” and they ran for four months. The PowerPoint materials were to supplement these three courses which were designed as face-to-face courses. The classes met three times a week for 50 minutes each session. Although this type of design does not completely follow a randomized selection and assignment design, it is often necessary in educational settings because classes are often intact and already formed before the research is begun (Gall, Gall, & Borg, 1999).

Materials

The responses from the students regarding their learning perceptions from lectures with PowerPoint presentation were obtained at the end of the semester. The purpose of the questionnaire assessed their general attitudes, interest, efficacy, and taking notes across their learning experience for the PowerPoint presentation. This was a 16-item survey using a 7-point Likert-type scale (with 1 being Strongly Disagree and 7 being Strongly Agree). The items in the survey were similar to those contained in previous surveys (Apperson, Laws, & Scepanisky, 2006; Loyd & Gressard, 1986; Susskind, 2008). All items are presented in Table 2. Internal consistency reliability of the questionnaire was assessed by Cronbach's alpha ($\alpha = .83$). The significance level, $p$ value, was taken as 0.05. Since the items included positive and negative statements, the values of the negative statements were reorganized prior to grouping them. Thus, in explaining the survey result, the higher scores indicate more positive learning perceptions toward the PowerPoint presentation. After the experiment, the experimental group was asked to provide open-ended comments about the lectures using the PowerPoint presentation accompanied by CDM and annotations.

According to Bloom’s revised taxonomy, the achievement test was designed to measure the students’ factual knowledge, their conceptual comprehension, and higher-level understanding on the taxonomy levels of evaluation, synthesis, and creation (Wallen, Plass, & Brünkener, 2005). First, a pretest was designed to assess the students’ prior knowledge, and then two learning achievement tests (a formative test and a summative test) were designed to measure the students’ learning outcomes.

Instructional content preparation

Figure 8 shows the operation procedure for instruction content preparation involving the CDM system. The procedure of authoring teaching contents is summarized as follows.

![Figure 8. The operation procedure involving the CDM system](image)

**Step 1.** PowerPoint creation: Instructor creates a PowerPoint file.

**Step 2.** Project creation: Instructor creates a new CDM project or opens an existing project by using Project Manager in main menu. An example is illustrated in Figure 9.

**Step 3.** Slide management: Instructor uses Conceptual Association Component to edit the tree structure for PowerPoint slides. The operation in the Conceptual Association Component includes adding, deleting, and modifying nodes. Also, the Conceptual Association Component offers instructor to make a link between two slides and then forms the tree structure of slides for easily presenting sequence followed by the spatial and temporal cognitive principles (Kester, Lehnen, Van Gerven, & Kirschner, 2006; Mayer & Moreno, 2003). The operations can be easily performed through graphic use interface (see Figure 4).
Step 4. Annotation management: Instructor uses Annotation Component to add, delete, edit, and arrange the sequence of the digital annotations in the PowerPoint slides (see Figure 10).

Step 5. Instruction rehearsal: Instructor uses the control panel of the presentation function of the CDM system (see Figure 7) to rehearse the PowerPoint materials before instruction.

Procedures

In order to verify the learning perceptions of the PowerPoint presentation complete with CDM and annotations, an exploratory study was conducted. The experimental procedure is described as follows.

(1) The first period of the semester: Before starting the course, the students' prior knowledge was assessed. For the first four weeks of the semester, all students were taught via a traditional lecture method where the instructors lectured course-related contents and wrote notes on a whiteboard. The instructors encouraged students to ask and discuss the questions about the contents of the lecture during the class.

(2) Assignment: At the beginning of the fifth week, classes with the same course title were randomly assigned to either the experimental group or the conventional group. The two groups were lectured with the same teaching materials. A major difference of the learning environment between the experimental group and the conventional one is that the experimental group was lectured with annotation screen for displaying the previous slides or annotations. In contrast, the conventional group was lectured without using the annotation screen.

(3) The remainder of the semester: From the fifth week of the semester onwards, students were taught by the same instructors. The instructors encouraged students to ask and discuss questions about the contents of the course during the class.

The experimental group was taught using PowerPoint presentation complete with CDM for annotations. Instructors used the CDM system to edit and manage the slides and the annotations and to control the presentation of the materials in the PPAP learning environment. By using the CDM system, instructors assisted students with annotations with coherent references that enhanced their cognitive development. Instructors presented the current slide and simultaneously displayed the annotations in the other monitor (Figure 11 (a)). For example, when the information content of the current slide is not sufficient to allow for processing the information, the instructors supported it with annotations to facilitate learning. The instructors presented textual or pictorial annotations to construct mental representations in a coherent episode (Baddeley, 2002). Instructors presented handwriting annotation to lead students into deeper understanding similar to the traditional method where the instructors wrote on the whiteboard. Moreover, if there were any cross-references between the information presented on the current slide and the previous slide, the instructors would simultaneously present both slides (Figure 11 (b)). Students, who possess low prior domain knowledge, can hold the presented slide in their working memory in order to organize and integrate its contents while the following slide is being taught (Kalyuga, 2007; Mayer & Moreno, 2003). This is positive because it prevents presentational holding. Students have enough time to learn the contents, take notes, and
obtain a conceptual understanding of the previous slide. The conventional group was taught via a traditional PowerPoint lecture method where the instructors presented course-related contents to students but without the annotation screen. Most of the PowerPoint slides contained texts that described equations or taught concepts. In addition, some of the contents were images, pictures, and tables for conveying concepts.

(4) Post-test: A formative test was conducted immediately after class and a summative test was done at the end of the course, respectively. Students were asked to complete the Learning Perception Survey and provide some open-ended comments at the end of the semester.

(5) Data analysis: The questionnaire was given to all students in both groups and 170 completed questionnaires were received. The questionnaire data were analyzed using an analysis of variance (ANOVA).

![Figure 11. The CDM presentation](image)

**Results**

**Learning Perception Survey**

Analysis of Variance (ANOVA) and the effect size analyses (Cohen’s $d$) were conducted to assess the effects of the annotation presentation on the 16 survey items related to the learning perceptions. Table 2 shows the results of the experimental analysis, which indicate that students in the experimental group thought that the instructor puts key terms and their corresponding explanations and annotations on the display, $F(1, 168) = 18.81, p < 0.001, d = 0.67$. It may be that students can get additional information from the annotation screen. They also thought that the presentations promote their understanding of the learning contents, $F(1, 168) = 6.47, p < 0.05, d = 0.39$. It may be that the annotations can support the cognitive processes of slide, with a function to aid either the process of selecting relevant information, organizing the information in memory, or integrating information with prior knowledge. They felt the multimedia presentations were helpful in increasing learning in the classroom, $F(1, 168) = 3.94, p < 0.05, d = 0.30$.

According to the modality of instructional design (Moreno & Mayer, 2007; Mayer, 2001), the mixed-modality presentations that combined verbal and non-verbal representations of the knowledge are the most effective learning environments. They found that visual elements (e.g., pictures, charts, graphics, or tables) were helpful in presentations, $F(1, 168) = 7.13, p < 0.01, d = 0.41$. It may be that the annotation presentation keeps students actively involved in the learning process rather than focusing solely on printed texts or spoken words. According to the cognitive theory of multimedia learning (Mayer, 2001), students learn better from words and pictures than from printed or spoken words alone. The slides usually presented continguously and simultaneously corresponding words and pictures, $F(1, 168) = 12.42, p < 0.01, d = 0.54$. According to the spatial and temporal contiguity principles of multimedia learning (Astleitner & Wiesner, 2004; Reed, 2006), the students well received the relevant verbal (e.g., printed words, spoken words) and non-verbal (e.g., illustrations, photos, video, and animation) annotations (Mayer & Moreno, 2007). They took more notes, $F(1, 168) = 4.97, p < 0.05, d = 0.34$. It may be that the annotation display is helpful to make meaning, so they enhance students’ note-making.
Students provided open-ended comments about the presentation in the learning environment. Some of students’ positive opinions are given as follows: I can simultaneously read two slides for cross reference; I can clearly understand the solution while simultaneously displaying the mathematical question and its background knowledge in the annotated learning environment; teacher can offer the corresponding annotations while lecturing; and I can compare the contents in the current display with those in the annotation one.

**Achievement Test**

A one-way analysis of covariance (ANCOVA) was conducted on the achievement test, with the pretest scores as prior knowledge used as a covariant. Table 3 shows the means (M) and standard deviation (SD) of the learning achievement test scores. Here the prior knowledge is regarded as a covariant in order to exclude the factor of prior knowledge by the students. This factor affects the assessment of the students’ learning achievement. An ANCOVA was performed after confirming the requirement of homogeneity of within-cell regressions, $F(1, 166) = 0.015$; $p > 0.05$. The results of the ANCOVA revealed a statistically significant difference for the formative test, $F(1, 167) = 4.918$, $MSE = 183.87$, $p < 0.05$. The finding indicates that students in the experimental group had a higher formative test than those in the conventional group. It was found that the PPAP learning environment facilitates student learning in class. However, there was no significant difference between the two groups on the summative test, $F(1, 167) = 0.249$, $MSE = 93.78$, $p > 0.05$. This may be due to the ceiling effect because both groups studied very hard and spent sufficient time in learning for the summative test (final examination) no matter what kind of tools were provided.

**Table 2. The analysis on Learning Perception Survey for experimental group (EG) and conventional group (CG)**

<table>
<thead>
<tr>
<th>Item</th>
<th>EG ($N = 87$) M (SD)</th>
<th>CG ($N = 83$) M (SD)</th>
<th>$F$</th>
<th>Effect size Cohen’s $d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lectures were more organized.</td>
<td>4.49(1.45)</td>
<td>4.23(1.36)</td>
<td>1.51</td>
<td></td>
</tr>
<tr>
<td>The lectures were effective in maintaining students’ interest.</td>
<td>4.46(1.24)</td>
<td>4.34(1.48)</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>I felt easily hitting important concept more.</td>
<td>5.05(1.13)</td>
<td>5.07(1.06)</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>I can focus on the teaching material.</td>
<td>4.52(1.27)</td>
<td>4.76(1.57)</td>
<td>1.22</td>
<td></td>
</tr>
<tr>
<td>The instructor put key terms with explanations and annotations completely well on PowerPoint slides.</td>
<td>5.13(1.16)</td>
<td>4.37(1.10)</td>
<td>18.81</td>
<td>0.67</td>
</tr>
<tr>
<td>The presentations promote my understanding of the learning contents.</td>
<td>4.23(1.33)</td>
<td>3.76(1.07)</td>
<td>6.47</td>
<td>0.39</td>
</tr>
<tr>
<td>I generally felt slides that only provided key phrase outlines of the lecture material.</td>
<td>3.85(1.03)</td>
<td>4.04(1.23)</td>
<td>1.14</td>
<td></td>
</tr>
<tr>
<td>The presentations were clear.</td>
<td>5.52(1.17)</td>
<td>5.23(1.20)</td>
<td>1.74</td>
<td></td>
</tr>
<tr>
<td>The multimedia presentations were helpful in increasing learning in the classroom.</td>
<td>4.24(1.20)</td>
<td>3.84(1.41)</td>
<td>3.94</td>
<td>0.30</td>
</tr>
<tr>
<td>I generally found visual elements (e.g., pictures, charts, graphics, or tables) helpful in presentations.</td>
<td>4.95(1.35)</td>
<td>4.39(1.42)</td>
<td>7.13</td>
<td>0.41</td>
</tr>
<tr>
<td>The slides usually presented contiguously and simultaneously corresponding words and pictures.</td>
<td>4.80(1.35)</td>
<td>4.06(1.40)</td>
<td>12.42</td>
<td>0.54</td>
</tr>
<tr>
<td>I can easily make notes.</td>
<td>4.39(1.36)</td>
<td>4.49(1.49)</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>I took more notes.</td>
<td>4.75(1.60)</td>
<td>4.19(1.64)</td>
<td>4.97</td>
<td>0.34</td>
</tr>
<tr>
<td>I have more time to organize notes.</td>
<td>4.52(1.24)</td>
<td>4.24(1.53)</td>
<td>1.69</td>
<td></td>
</tr>
<tr>
<td>My notes were easier to understand.</td>
<td>4.32(1.29)</td>
<td>4.35(1.31)</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>My notes were more useful for exams.</td>
<td>4.07(1.28)</td>
<td>4.02(1.36)</td>
<td>0.50</td>
<td></td>
</tr>
</tbody>
</table>

$^{a}p<.05$, $^{b}p<.01$, $^{c}p<.001$

**Table 3. Learning achievement test scores**

<table>
<thead>
<tr>
<th>Achievement test</th>
<th>EG $n$ M SD</th>
<th>CG $n$ M SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>87 35.71 11.22</td>
<td>83 33.73 9.53</td>
</tr>
<tr>
<td>Formative test</td>
<td>87 61.52 12.93</td>
<td>83 56.92 14.11</td>
</tr>
<tr>
<td>Summative test</td>
<td>87 73.70 15.34</td>
<td>83 70.76 14.81</td>
</tr>
</tbody>
</table>
Discussion and Conclusion

Students in our case study pointed out that PowerPoint presentations complete with CDM and annotations is helpful in the classrooms. The findings of this study are consistent with Mayer’s (2001) cognitive theory of multimedia learning, and we extended this theory to the PowerPoint presentation complete with CDM and annotations. Three points are evident from this experiment. First, the annotations, with a more skilled presentation, could facilitate learning. The instructors contiguously and simultaneously presented the written words and the corresponding pictures. According to Mayer’s (2001) cognitive theory of multimedia learning, students who selected from words annotated in both pictorial and written modes were able to build more referential connections between the verbal and visual mental representations. In addition, different students learn efficiently but in different ways. Therefore, multimedia environments that provide annotations may be most effective for students because then the students can select the annotations that best fit their needs and preferences, thereby reinforcing their learning (Jones & Plass, 2002). Thus, the PowerPoint presentation accompanied by CDM and annotations will help students to acquire more information and remember more ideas from the pictorial and written annotations than if there were no annotations.

Second, a good presentation for students means being coherent, explicit, and systematic. This is suitable for a low rate of information transfer (Tufte, 2003). The PPAP learning environment facilitates students’ learning in class. For example, an instructor needed two or more slides to contain the handwriting solution to a mathematical question. Students reflected that they clearly understood the solution as a result of the simultaneous display of the mathematical question and its background knowledge in the annotated learning environment. In the traditional PowerPoint display environment, students needed to vacate the contents of the previous slide in the working memory after a certain time, to make room for the next slide. Sometimes instructors may not roll slides back and forth while explaining two successive slides. This may result in reducing a student’s capacity to solve a particular problem. In the PPAP learning environment, students can simultaneously read two slides for building coherent references, thereby helping the cognitive process in the comprehension of the content being taught (Hasler, Kersten, & Sweller, 2007; Wallen, Plass, & Brünken, 2005).

Finally, the PPAP environment helps students to see two sequential slides simultaneously. This situation can present clear and large words and graphs and also display the slides display for a longer time period. This makes students have sufficient time to take notes, thinking, and reasoning. Some results of this study were similar to the traditional PowerPoint presentation. For example, the students indicated that they found that the lectures were well organized and that the key points were emphasized with the use of the PowerPoint presentation in the classroom (Susskind, 2008). Some results also were similar to the results of Apperson, Laws, and Scepansky (2006). Students preferred the fact that instructors added visual elements such as pictures, graphics, charts, or tables in their PowerPoint Presentations.

The following conclusions can be drawn from this paper. This study utilized the CDM system to construct an annotated learning environment to promote the positive effects of the dual-slide PowerPoint presentation in classroom learning. The PPAP is suitable for the learning situations which include very large groups of students, one teacher and a large room. Within traditional teacher-centered instructional designs, this kind of technical solution improves the students’ ability to actually construct learning, rather than that merely becomes learning objects for transmission. To students a good presentation means being coherent, explicit, and a clear structure. An optimal presentation requires the right amount of context overlap, and slides with coherent annotations that stimulate the students’ active inference. The CDM system can simultaneously display PowerPoint slides and annotate corresponding multimedia materials to assist the students with their learning efficacy in an instructional environment. An advantage of this environment is that the presentation sequence of the PowerPoint slides and their annotations can be edited beforehand. The ability to simultaneously display the current slide and its corresponding annotation is helpful to support cognitive processing (Hasler, Kersten, & Sweller, 2007). Therefore, while lecturing in this environment, students have a better chance to understand the learning contents. In addition, this learning environment is suitable for those students who need more time to understand the slides presented. In addition, this learning environment allows students to create more cognitive paths to facilitate the construction of referential links and mutual references between two channel representations. Consequently, the proposed learning environment can scaffold learners to construct coherent mental representations. Finally, the survey results of this study have shown that the proposed system, which is based on cognitive theory and the congruity principle of multimedia learning can effectively help students to reach a better learning performance of lectures employing a dual-slide PowerPoint presentation.
Like in any study, this study also has a few limitations. First, it was necessary to limit the number of annotations to obtain a reliable and valid measure. Second, we do not know the actual levels of the cognitive load because it was not measured directly. Finally, participants were not randomly grouped. Students were enrolled in a class and the group equivalence was not possible like in a study using quasi-experimental research. The students posed different questions and discussion opinions, so the contents slightly differed in each class. In the future, this study could further apply the CDM system to other courses taught, or apply it to other cultures. The PPAP environment is suitable for illustrated courses such as engineering drawing, program design, and video game programming. The teacher can present the program on one screen and its result on the other screen simultaneously. Moreover, future study could investigate the integration of the interactive whiteboard with the multimodal learning environment.

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References


