LEARNING EFFECTIVENESS AND COGNITIVE LOADS IN INSTRUCTIONAL MATERIALS OF PROGRAMMING LANGUAGE ON SINGLE AND DUAL SCREENS

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ABSTRACT
The teaching and learning environment in a traditional classroom typically includes a projection screen, a projector, and a computer within a digital interactive table. Instructors may apply multimedia learning materials using various information communication technologies to increase interaction effects. However, a single screen only displays a single teaching view to learners. In this study, we proposed a dual-screen learning environment to present multiple learning contents simultaneously and investigated learning effectiveness and cognitive loads of learners between single- and dual-screen learning environments. We compared different instructional materials in programming language instruction using two types of learning environments with single and dual screens. We designed three types of instructional materials, descriptive material, progressive material, and worked-example material, to arrange the instructional slides of programming language course. The results of this study showed significant differences in learning effectiveness, and the degrees of clarity and difficulty of instructional materials in both learning environments. This study may help explain the learning effects between single- and dual-screen environments, and provide instructors with a better understanding of how a dual-screen learning environment affects learning effectiveness and cognitive loads in programming language instruction.
Keywords: learning effectiveness; cognitive load theory; programming language instruction; dual-screen learning environment

INTRODUCTION
An instructor typically makes use of a single projection to present and instruct a series of instructional slides in a traditional classroom. The instructor instructing a programming language course may utilize the corresponding programming development software to demonstrate an example for explaining the presented instructional slides. To clarify the instructional content, the instructor must repeatedly switch to present the teaching content between textual explanations from presented slides and operate the screen view while using the programming development software. The rapid switching and successive presenting between the presented slides and the programming development software may affect the knowledge construction of learners. The successive and simultaneous presentations may also lead learners to increase their cognition load to compensate for the limited human memory system. Previous studies refer to multiple images presented simultaneously in presentations as multi-image presentations (Atherton, 1971; Westwater, 1973; Jonassen, 1979; Burke & Leps, 1989). These studies are based on the Perrin theory of presenting multiple images to enhance learning effects of learners in learning multimedia materials (Perrin, 1969). He pointed out that presenting images simultaneously allows learners to select their own learning sequence. However, instructional materials are not limited to multiple images on a single display (or screen) with increasing technologies for presentation. Recently, multimedia learning technologies have been widely used in the traditional classroom. Instructors can use these technologies to present richer and more meaningful instructional materials. Mayer (2005) indicated that learners can easily refer to connections in the working memory during simultaneous presentation of texts and images in multimedia instruction. Multimedia instruction includes multi-image presentations that display multiple correlated instructional materials to assist learners in constructing knowledge. Many previous reviews (Kulik et al., 1980; Khalili & Shashaani, 1995; Bayraktar, 2002; Liao, 2007) on the effects of computer-assisted instruction using multimedia learning technologies suggest that multimedia improves learning effectiveness, irrespective of subject matter. The effectiveness of multimedia instruction has been associated with factors such as knowledge

level and aptitude (Mayer & Gallini, 1990; Najjar, 1996; Mayer, 2005; Atkinson et al., 2009; Seo & Woo, 2010).

We believe that multi-image presentations designed into multimedia instruction can assist learners to construct knowledge with multiple correlated instructional contents displaying on two adjacent screens. Some studies have provided multi-image presentations with graphic software, animation, or webpage, to help learners conceptualize mathematic instruction activities (Yerushalmy, 1991; Borba & Confrey, 1996; Adydin, 2005). Researchers have also evidenced the usefulness of learning strategies with multimedia technology for learner cognitive processes (Lee et al., 2006; Van Gerven et al., 2006). The information processing system has pointed out the limited capacity of the human memory system (Klatzky, 1980). The human memory cannot simultaneously process two information streams encoded with only one code of dual channels (verbal and visual channels). The various sources of materials, which could be text and text, or text and mathematical equations, or different multimedia material formats, may cause learning effects such as split-attention and worked-example effects in learner cognition. Based on the above suggestions and findings from previous studies, this study investigated critical impact factors in learning effectiveness and cognitive loads between learners processing information using one or two screens in the classroom.

Before comparing the differences in learning effects between single- and dual-screen environments for teaching a programming language course, we constructed a digital interactive table (DIT) in a computer classroom for instructors to use both learning environments. This DIT included a control system to control the connections between multiple computers and projectors. The dual-screen learning environment (DSLE) was used to present instructional slides and demonstrate a screen view of programming development software simultaneously on two adjacent screens. The single screen learning environment (SSLE) was also applied to display the presented instructional slides and demonstrate a screen view of programming development software successively on a single screen. In this case, the major difference between DSLE and SSLE are the presentation modes of instructional materials. SSLE is a linear and successive presentation with two instructional materials on a single screen and DSLE is a simultaneous presentation with two instructional materials on two adjacent screens.

This study adopted a multi-image presentation and multimedia learning theory to display instructional materials simultaneously. The aim was to assist learners in their learning concept of programming language by simultaneously presenting various instructional materials as textual explanations and demonstrating operational procedures as programming worked examples. The theoretic positions in this study aimed to provide an answer to questions about using various textual explanations corresponding to operational procedures between single- and dual-screen learning environments. The textual explanations consisted of three types of instructional materials, descriptive material, progressive material, and worked-example material. The primary research question addressed whether various textual explanations presented in both learning environments would affect learning effectiveness and cognitive loads of learners. Thus, the experiment was investigated in two learning groups (SSLE and DSLE) whose learners received these three types of instructional materials. This experiment was divided into three parts, learning effectiveness, the degree of clarity, and the degree of difficulty of presented instructional materials. Learning effectiveness expected to understand the learning factors of various instructional materials in programming language instruction. The degrees of clarity and difficulty were used to realize the cognitive loads of learners under diverse presentations. This study may lead to a better understanding of the learning effects of teaching with descriptive, progressive, and worked-examples instructional materials in a dual-screen learning environment.

THE STUDY

This study constructed a teaching environment with dual screens in programming language instruction. The main ideas of this environment were to extend teaching space and improve learning effectiveness. The following sections describe the setting of the dual-screen learning environment and the background of programming language instruction in this learning environment.

Setting of DSLE

Integrating technology into the classroom implies that instructors should strive to understand appropriate ways to support meaningful learning in technology-rich classrooms (Keengwe et al., 2008). This study developed the DSLE to present rich and meaningful information in instructional slides and to demonstrate the screen view of programming development software onto two adjacent screens. Low (1968) stated that no single image can establish certain memory combinations, but a multi-image with a group of images perceived simultaneously often recalls long forgotten memories. The multi-image presentation of Perrin (1969) includes three significant characteristics: a larger screen to contain more information, simultaneous images to display multiple images, and appropriate information density to present rich and complete information. This type of multiple image presentation has been evaluated with various multimedia learning materials (Mayer, 2005). Many previous reviews (Kulik et al., 1980; Khalili & Shashaani, 1995; Bayraktar, 2002; Liao, 2007) have investigated the learning effectiveness of multimedia information, suggesting that learners aided by computer-assisted instruction performed better than those who received instruction through traditional classroom lectures.

A traditional classroom for computer-assisted instruction to present multimedia information consists of a single projector system within the digital interactive table. Thus, a larger screen or dual screens are needed to build assisted teaching equipment in the classroom for presenting rich information for multimedia learning. The multimedia learning environment is typically built with a digital interactive table (DIT) in the classroom. The DIT has been used in classroom learning to assist the instructor in presenting written or electronic multimedia materials. The traditional DIT consists of one computer, a projector, a control device, or an interactive handwritten system constructed inside an integrated table. Instructors have widely applied multimedia instruction with various multimedia learning materials in the classroom learning environment for enhancing learning. Multimedia learning materials present in various formats (such as texts, graphics, audio, animations, or videos) to meet the needs of various courses. Therefore, a traditional classroom with a single projection screen presents some limitations. An instructor who presents two or more multimedia materials using a single screen has to switch the presented view frequently. The presented information density increases when the instructional materials include too much information. Thus, learners must search for learning content while the instructor is teaching. Finally, since a single projection screen limits the amount of multimedia material that can be presented, the instructor cannot present rich and complete learning materials to learners.

A traditional classroom with a single projector typically uses a VGA cable to connect to the computer. This study used a control device to integrate multiple VGA signals as three inputs and displays on two screens as two outputs and set the control matrix, called the multiple-screen hub device, inside the DIT. Instructors can present two different types of multimedia materials simultaneously such as instructional slides, instructional videos, or camera views. This device allows instructors to use one or two computers to connect with the DIT to provide richer and more complete multimedia materials. The control matrix allows for choosing two of three inputs to display on two outputs. Figure 1 shows the setting of the DIT which consists of the multiple-screen hub device and the projector control system of two projectors and screens. Using the DIT setting for dual screens in the classroom, the instructor can control two VGA signals from the computer(s) to project onto two screens effectively. The DIT described here could serve as the basis for a study using single and dual screens in programming language instruction. The following section theoretically illustrates how programming language instruction in a DSLE affects learners from a cognitive perspective.

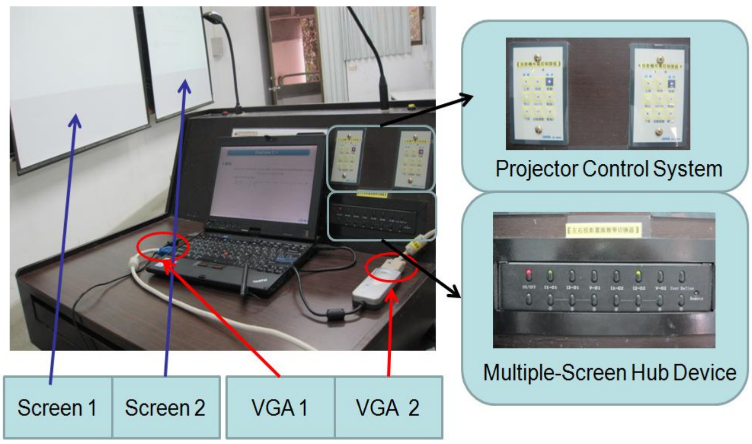

Figure 1. Setting of the digital interactive table (DIT)

Programming Language Instruction in a DSLE

In a traditional computer classroom with a single projection system, the instructor faces the problem to simultaneously instruct both views of instructional slides and demonstrating corresponding worked examples in programming language instruction. It will lead to limit the instructional effects between them. As mentioned above, the instructor has to present two instructional views successively and frequently, which may confuse learners in their knowledge construction during frequent learning content switches between both instructional views. In this study, the DSLE primarily involved two adjacent projection systems in a computer classroom as shown in Figure 2. Two projection screens displayed two types of instructional materials with the same instructional objectives from the PC or laptop of the instructor. The instructor could use the right screen to display instructional slides as textual explanations and the left screen to show programming development software as corresponding visualizations simultaneously. The designed objective of DSLE was to present richer textual and visual materials simultaneously as a multi-image presentation in a short teaching time. The cognitive theory of multimedia learning by Mayer (2005) pointed out that learners can easily refer to connections between two views of adjacent projection screens without splitting their attention. This study focused on two learning effects derived from the cognitive load theory, split-attention, and worked-example effects, to improve the learning effects and to reduce the cognitive loads of learners.

Why should split-attention and worked-example effects be considered in the design of a dual-screen learning environment? Split-attention effect is an instructional technique developed from cognitive load theory to facilitate learning (Chandler & Sweller, 1992; Lee et al., 2006; Van Gerven et al., 2006). Chandler and Sweller (1992) found that when learners are required to split their attention between various sources of information, this effect would be evident. They also used an empirical study to prove that integrated text and diagrams without split attention format effectively reduced cognitive load. Based on this suggestion, we used one screen to present instructional material integrating text and diagrams and another screen to present the corresponding worked examples adjacently. Demonstrating a worked example is another effective method for instructors to instruct learners in problem solving skills (Sweller et al., 1990; Renkl & Atkinson, 2003). They have suggested a way to use worked examples and found that integrating text and diagrams within worked examples reduces extraneous cognitive load. The worked example effect suggests that learners gain a deeper understanding of a skill domain when they receive worked examples at the beginning of cognitive skill acquisition (Lewis, 2005; Renkl, 2005; Sweller, 2006; Schwonke et al., 2010). The split-attention and worked-example effects closely relate to numerous interacting elements (Sweller, 2010). The interacting elements associate with searching for critical features (integrating text and diagrams or demonstrating a worked example) within an instructional material and should be eliminated.

The Sweller and Chandler study (1994) argued that element interactivity is an important factor of cognitive load theory. Element interactivity refers to the number of elements simultaneously processed in working memory for understanding information. If information possesses a high degree of element interactivity, elements cannot individually process in working memory, making the material more difficult to understand. In contrast, the working memory can process and understand information with low element interactivity without considering other elements. Thus, element interactivity drives the intrinsic load. The demands on working memory capacity imposed by element interactivity are intrinsic to processing information (Paas et al., 2003). Excess element interactivity also causes extraneous load and cannot be eliminated without altering information procedures, such as instructional activities. However, a germane load could result in the working memory recourse to deal with element interactivity associated with intrinsic load. Sweller (2010) argued that total element interactivity generated by intrinsic and extraneous loads determines total working memory load. Our research design used the ranking scale technique to investigate learner working memory loads in cognitive load measurement between various instructional materials and learning environments in our experimental course.

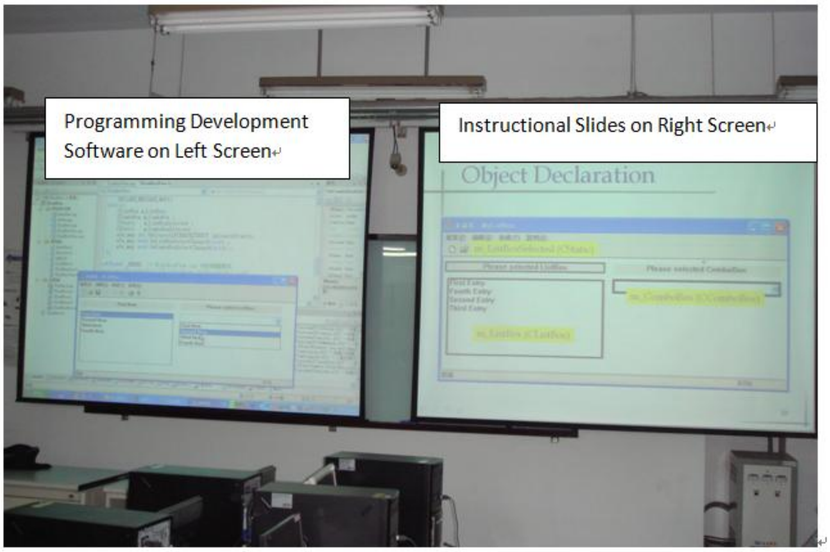

Figure 2. A programming language instruction in DSLE

RESEARCH DESIGN

This study used the quasi-experimental design to measure learning effects, including learning effectiveness of learners, and the degrees of clarity and difficulty of learner cognitive loads in three types of instructional materials. The following describes the research design details about the participants, instructional materials, procedures, and instruments.

Participants

Forty-two students enrolled in the undergraduate-level course, "Windows Programming in Microsoft Visual Studio Dot Net 2005", participated in this study. All participants were randomly assigned to two groups: one group (twenty-three students), the SSLE group, was taught in a traditional classroom with single-screen instruction and another group (nineteen students), the DSLE group, was assigned to learn via dual-screen instruction. Their ages ranged from twenty to twenty-two years. The participants only possessed basic programming ability of C/C++ programming language and were novice learners in Windows programming. This course focused on advanced programming skills of C/C++ and visualized design of Windows programs. After completing the course, participants could understand complicated design flows of object-based programming language and the data structure of Windows programming, to solely implement a complete Windows application.

Instructional Materials

Participants of both groups were taught eight instructional units of basic windows controls in Windows programming, such as CView, CDocument, CList, CMap, CButton, CEdit, CListBox, CComboBox, CStatic, and CTime, which are the basic data and user-interface object classes of Microsoft Foundation Classes (MFCs) developed by Microsoft. These units were designed into three types of instructional materials, descriptive material, progressive material, and worked-example material, to arrange instructional slides. The descriptive material presented static textual and visual content. Figure 3 shows the learning content of the descriptive material. The progressive material was designed with dynamic textual and visual content as animation objects within PowerPoint slides. Figure 4 shows the stepwise learning content of the progressive material. Figure 5 shows the worked-example material in PowerPoint slides used a worked example, which is an executable programming instance of designing a basic calculator. Learners can simultaneously study the programming concept through a workable sample.

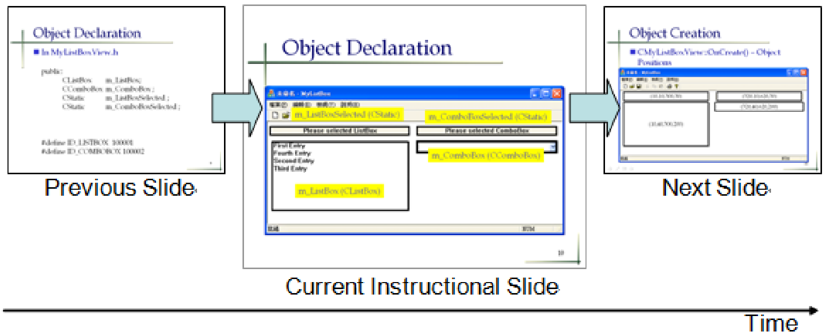

Figure 3. Descriptive material with static textual and visual content

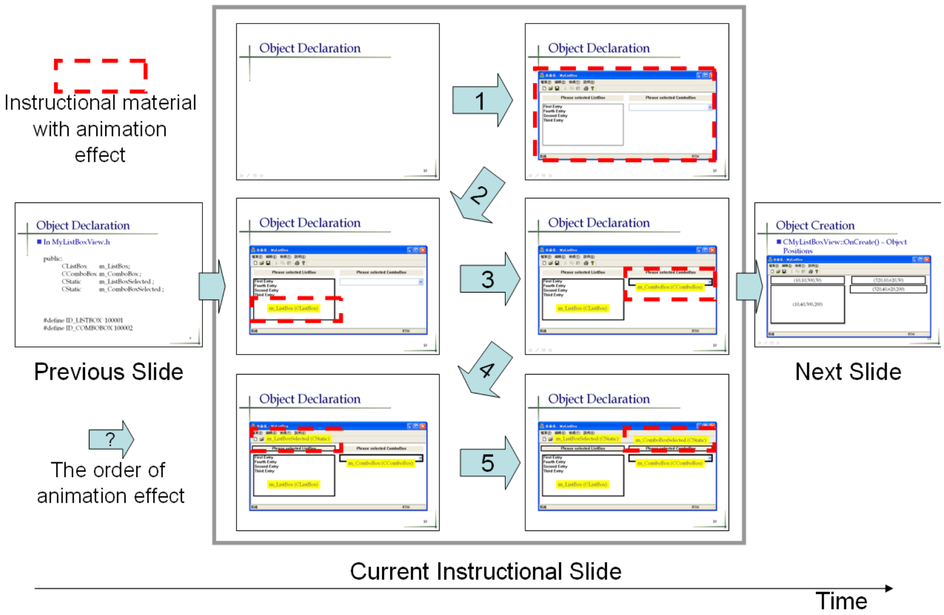

Figure 4. Progressive material with animation effects on textual and visual contents

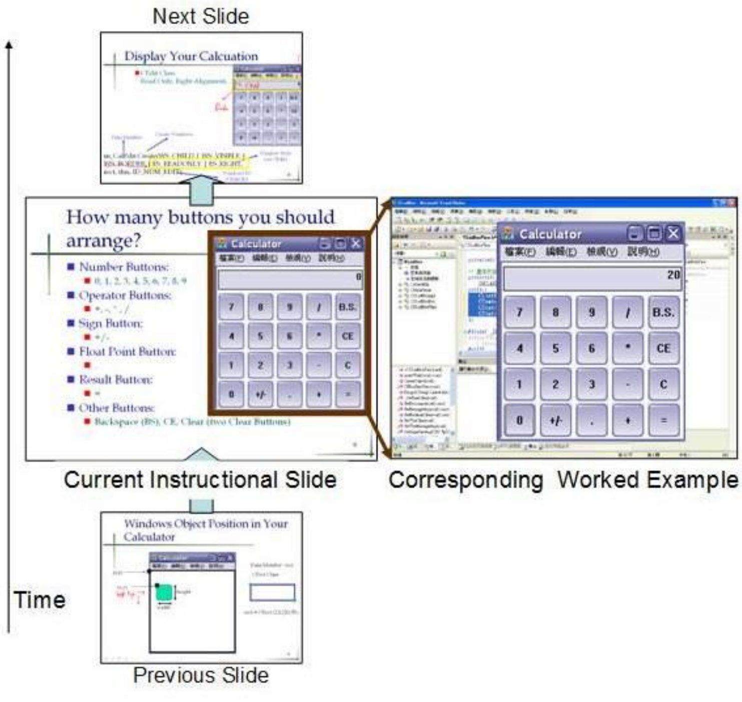

Figure 5. Worked-example material with an executable program instance

The instructor teaching these three types of instructional materials in SSLE uses a single projector to display the instructional contents, which requires carefully switching the screen view between explaining instructional materials and using the programming language software to demonstrate the corresponding programming codes. Thus, learners can only see one of these two views without information searching, and the instructor has to switch the view in a single projection screen. In contrast, the instructor can use two adjacent screens to simultaneously instruct with material slides and demonstrate a worked example using programming language software without interleaving these two instructional contents in DSLE. Therefore, learners can simultaneously see both screen views as multi-image presentations, and the instructor can change both screen views to instruct immediately.

Procedures

Participants in the two groups were assigned to study the three types of instructional materials in three weeks, described in the above section as descriptive material, progressive material, and worked-example material. In the SSLE, the instructor frequently interleaved the screen view of instructional slides such as PowerPoint slides and the screen view demonstrating a worked example using programming development software (Microsoft Visual Studio Dot Net 2005). In the DSLE, the instructor simultaneously showed these two screen views and chose one of the two screen views to teach. The instruments in this study were used to address learning effectiveness and cognitive load measurement. Participants were asked to complete the instruments after learning these three types of instructional materials. The instruments measured learning effectiveness and two degrees of cognitive load for each material.

Instruments

We examined participant learning effectiveness and cognitive loads by comparing the differences between SSLE and DLSE in learning three types of instructional materials. Each measurement consisted of various items according to the features of these eight instructional units mentioned above. In the descriptive material designed for the descriptive knowledge of these units, there were 14 items for learning effectiveness, three items for the degree of clarity, and three items for the degree of difficulty. In the progressive material for the conceptual knowledge of these units, there were nine items for learning effectiveness, three items for the degree of clarity, and three items for the degree of difficulty. In the worked-example material for providing executable examples to explain basic windows controls, there were 12 items for learning effectiveness, two items for the degree of clarity, and two items for the degree of difficulty.

Learning effectiveness of multimedia instruction was modified based on three main factors: specific skills, learning ability, and easy-to-learn (Hui et al., 2008). Hiltz et al. (2000) referred to learning effectiveness as the extent to which a learner believes s/he has acquired specific skills in learning programming language. We also considered learning ability to represent a critical dimension of learning evaluation (Bødker & Graves Petersen, 2000). In the study of Martin-Michiellot and Mendelsohn (2000), instructional materials delivered in an easy-to learn fashion can enhance the learning effectiveness learners. All question items in the learning effectiveness measurement were based on a 5-point Likert-type scale, with 1 as strongly disagree and 5 as strongly agree.

In terms of measuring cognitive load, the degrees of clarity and difficulty investigated the intrinsic and extraneous cognitive loads of learners. The degree of clarity refers to the extraneous cognitive load regarding the clarity of multiple-information displayed on the screen. The extraneous load (Sweller & Chandler, 1994) is associated with the presentation of learning materials. The degree of clarity of learning materials affects these two forms of learner cognitive load. The degree of difficulty refers to the intrinsic cognitive load regarding the difficulty of multimedia learning materials. Sweller (2010) described intrinsic load as the mental work imposed by complexity. Therefore, we investigated the learning effects of learners on the degree of difficulty of learning materials using diverse presentations. This study adopted the experimental measurement modified for previous studies (Paas, 1992; Pollock et al., 2002). The rating scale technique has been widely used to measure working memory load and mental effort within cognitive load researches (Gopher & Braune, 1984; Paas et al., 2003). The rating scale is a very reliable measurement in cognitive load researches according to reliability and validity analysis. The modified measurement in this study was designed on a 7-point Likert-type scale in two dimensions, the degree of clarity from 1 (strongly clear) to 7 (strongly unclear) and the degree of difficulty from 1 (strongly easy) to 7 (strongly difficult). The degree of clarity represents the highest score as the highest extraneous cognitive load. The degree of difficulty represents the highest score as the highest intrinsic cognitive load.

ANALYSIS AND RESULTS

The analysis used the statistical software package, SPSS. The One-Sample Kolmogorov-Smirnov test was used to test the normal distribution between SSLE and DSLE groups due to the few samples of less than 30 participants in both groups. The p-values of each item in these two groups were all higher than .05. The items in the SS and DS groups were all normally distributed and the independent t-test analysis was used to test the differences between these groups. Reliability as a measure of internal consistency was then calculated. In the descriptive material, the alphas for learning effectiveness, the degree of clarity, the degree of difficulty were .93, .89, and .90 respectively. In the progressive material, the alphas were .91, .83, and .92 respectively. The alphas of the worked-example material were .94, .92, and .93 respectively. Finally, the independent t-test and effect size were computed to find the differences between SSLE and DSLE in learning these types of instructional materials. Table 1 shows the results for these materials analyzed by t-test and effect size analyses. Effect size is a measure of relationship strength between two variables. Following the suggestion of Cohen (1988), we considered an effect size of .2 to be small, .5 to be medium, and .8 to be large. Cohen's *d* was also computed to determine the effect size where a positive effect size represents improvement and a negative effect size represents deterioration.

Table 1: T-test analysis of the degree of clarity, the degree of difficulty, and learning effectiveness

Material	Perspective	Source	Mean	SD	T-value	Effect size Cohen's *d*
Descriptive material	Learning effectiveness	SSLE (23)	45.96	7.47	-1.535	
		DSLE (19)	49.84	8.93		
	The degree of clarity	SSLE (23)	7.61	2.78	4.858**	1.53^{L}
		DSLE (19)	3.95	1.93		
	The degree of difficulty	SSLE (23)	12.70	2.79	.541	
		DSLE (19)	12.05	4.52		
Progressive material	Learning effectiveness	SSLE (23)	29.26	4.77	-2.551*	-.79^{M}
		DSLE (19)	32.94	4.53		
	The degree of clarity	SSLE (23)	6.87	2.38	2.502*	.78^{M}
		DSLE (19)	5.05	2.30		
	The degree of difficulty	SSLE (23)	13.07	2.94	1.177	
		DSLE (19)	11.74	4.46		
Worked-example material	Learning effectiveness	SSLE (23)	37.04	5.73	-4.408**	-1.35^{L}
		DSLE (19)	45.74	7.05		
	The degree of clarity	SSLE (23)	5.47	1.78	3.843**	1.34^{L}
		DSLE (19)	3.26	2.10		
	The degree of difficulty	SSLE (23)	8.39	1.85	1.647	
		DSLE (19)	7.05	3.12		

* p<.05; ** p<.005; ^{L}: Large effect size; ^{M}: Medium effect size

In learning with all three materials, learners in the DSLE group exhibited enhanced learning effectiveness and recognized that the learning materials were clearer and easier than those in the SSLE group. The t-test of learning with the descriptive material showed a statistically significant difference between the SSLE and DSLE groups in the degree of clarity perspectives (t (41) = 4.858**, p<0.005; large effect size=1.53), but with no significant difference in both learning effectiveness (t (41) = -1.535, p>.05) and the degree of difficulty perspectives (t (41) = 0.541, p>.05). The t-test of learning with the progressive material showed statistically significant differences between the SSLE and DSLE groups in both learning effectiveness (t(41)=-2.551*, p<.05; medium effect size=-.79) and the degree of clarity perspectives (t(41)=2.502*, p<.05; medium effect size=.78), but with no significant difference in degree of difficulty perspectives (t(41)=1.177, p>.05). The t-test of learning with the worked examples material showed statistically significant differences between the SSLE and DSLE groups in both learning effectiveness (t(41)=-4.408**, p<.005; large effect size=-1.35) and the degree of clarity perspectives (t(41)=3.843**, p<.005; large effect size = 1.34), but with no significant difference in the degree of difficulty perspective s (t(41)= 1.647, p>.05).

DISCUSSIONS

The empirical findings present the results of learning effectiveness and cognitive loads in the degrees of clarity and difficulty and the effects of instructional material between the SSLE and the DSLE. Three significant findings by reviewing the above findings are worth summarizing:

Our research suggested three types of instructional materials for multi-image presentation in SSLE and DSLE in order to find the impacts of learning effectiveness and cognitive loads in learning programming language course. Results of previous research comparing linear and simultaneous presentations indicate investigation of only a few significant differences (Atherton, 1971; Westwater, 1973; Burke & Leps, 1989). This study adopted the Perrin theory (1969) to provide two simultaneous views of screens and richer learning content to increase information density. The t-test of learning effectiveness showed statistically significant differences between the SSLE and DSLE groups in learning with progressive and worked-example materials. These results indicated that presenting progressive and worked-example materials in a DSLE benefitted learner specific skills, learning ability, and ease in learning programming language. These finding are in accord with the results of the previous studies which have test learning effectiveness, despite the fact that these studies performed multimedia instruction in different learning domains (Adydin, 2005; Liao, 2007).

The intrinsic load for each type of instructional material showed no difference between SSLE and DSLE for the degree of difficulty. These results imply no difference in the intrinsic loads of learners in the two learning environments in learning these instructional materials. In the study of Sweller and Chandler (1994), the intrinsic load focused on learners understanding natural complexity. This study found that learner intrinsic loads in learning programming language were not affected, whether the instructional materials were presented in a SSLE or a DSLE. The extraneous load was imposed from non-optimal instructional procedures (Sweller et al., 1998; Sweller, 2010). This study used the degree of clarity to examine participant perception of instructional procedures in learning programming language with single or dual screens. Results from the degree of clarity perspective showed significant differences on these three types of instructional materials between a SSLE and a DSLE. Based on these results, the interactive element in DSLE is lower than SSLE, particularly in learner extraneous loads. However, learners in a DSLE did not accumulate extraneous loads searching for interactive elements presented on two screens simultaneously. These findings indicate that presentations in a DSLE could provide a clearer environment to reduce learner extraneous loads in learning programming language.

The effect sizes of these three types of instructional materials showed that the worked-example material exhibited large effect sizes on learning effectiveness and the degree of clarity than other types of materials. This finding accords with the results of previous tested effectiveness and cognitive loads in programming language instruction, although these studies used various measures of worked-example materials. The principle of worked examples in multimedia learning asserts that learners gain a deeper understanding of a skill domain when they receive worked examples at the start of cognitive skill acquisition (Lewis, 2005; Renkl, 2005; Schwonke et al., 2010). Lewis (2005) proposed an animated form to demonstrate worked examples. The animated worked examples were primarily useful for training complicated cognitive skills to learners. Schwonke et al (2010) used the different ratios of worked solution steps and to-be-solved problem steps on cognitive skill acquisition in geometry. They found that no ratio of worked steps in examples was most beneficial for the acquisition of procedure knowledge related to a difficult principle. These findings of this study and the previous studies lead us to believe that more worked examples should be used to design instructional materials which could increase the learning effects of learners in multimedia instruction.

CONCLUSIONS

This study examined the learning effectiveness and cognitive loads of participants in learning programming language using three types of instructional materials and found some significant differences between SSLE and DSLE. Based on the above findings, learners in a DSLE group showed enhanced more effective and recognized clearer and easier learning materials than those in the SSLE group. The t-test of the degree of clarity showed statistically significant differences between SSLE and DSLE groups in learning using all three types of instructional materials, especially in learning with worked-example material. The results of this study could be useful for instructors responsible for instructing programming language courses in multimedia learning environments, regardless of whether the classroom uses single or dual screens. The limitation of this study is rooted in the small group of participants who were investigated in this experiment. Due to the study involving only two small groups, the results could not be generalized as representative of the population. Thus, generalization of the results to other populations with various instructions may be limited. Future studies should be aware of the limitations of this study.

Although the sample in the current study was small, the following recommendations could serve as suggestions for researchers experimenting with dual or multiple screen environments in a similar context. We recommend that DSLE is not only suitable to visualize Windows programming courses, but also for other types of programming languages. For example, when instructing networking-programming language courses, one screen can present learning materials for instructing programming illustrations, while the other screen can simultaneously display executable examples on the web browser. A dual-screen learning environment can be designed to extend the windows view of a large map to introduce the geographic distribution of the entire map, without segmenting displays. Such the learning environment can also be implemented in an online video conference room with triple screens. One screen could display the video view of the speaker. The second could present the speaking slides, and the third could present the introductory slides of the speaker or supplements to the conference, such as slides for translation. Although the set up cost of the DSLE is more expensive than single screen environments, the use of a dual-screen environment might provide an efficient and usable environment for teaching and learning.

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