A Comparison of Single- and Dual-Screen Environment in Programming Language: Cognitive Loads and Learning Effects

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ABSTRACT

A learning environment having more than one screen enables users to display and compare various sources of learning information with two adjacent screens illustrating the development of interrelated concepts and showing their relationships. This proposed technique could provide higher quality resources for learners by addressing physical and psychological factors. However, attention is a limited mental resource meaning that humans cannot always focus on simultaneous presentations of information. Cognitive load in humans may become profoundly heavy while processing rich information from multiple sources simultaneously. Therefore, the aim of this study is to investigate the split-attention effect, worked examples effect, and learning achievement of using single- and dual-screen learning environments in a programming language course. Results of this study showed significant differences of two learning effects and learning achievement of learners between two learning environments. To conclude, this study may provide evidence toward explaining the influences of split attention of learners and their learning with worked examples and the effects of learning in a dual-screen environment, as well as in providing users with another suggestion for using two adjacent screens in teaching and learning.

Keywords

Split-attention effect, worked examples effect, cognitive load theory, dual-screen learning environment, programming language instruction

Introduction

The ability of technology to facilitate the availability of information effectively and offer a convenient learning environment has long been discussed and developed. However, in such a learning environment, the results of related studies depend on the information processing approach to explain individual cognitive abilities (Lee, 2004; Moreno & Mayer, 2000). Colvin et al. (2007) stated that the use of multiple screens was more beneficial than single screens on task performance and usability of users. They also indicated that the three-screen display showed no significant advance over the two-screen condition. The study of Hutchings and Stasko (2007) pointed that the advantages of using the integrated extension of an additional screen were to support tasks, execute applications, and present images simultaneously. Setting an additional screen in a learning environment should provide teachers more display space to teach more learning materials simultaneously.

The learning environment in this study provides teachers additional instructional space to instruct multiple materials simultaneously in a programming language course through the use of two adjacent projection screens. That is, multiple materials instructing programming skills can be presented on screens, such as instructional slides, programming language codes, or executable programming instances of working examples. Through displaying multiple materials on two adjacent screens simultaneously, teachers could instruct the concepts of a programming language by demonstrating programming examples and learners might learn intuitively the programming concepts from these examples. Perrin (1969) stated that the multi-image presentation with an effective information density allows learners to process larger amounts of information in a short time. If the density of presented information is increased, learners will effectively obtain the increased information. Smith (2001) stated that, given the presenting complexity of multimedia and its close relationship to cognitive and information processing theories, it is helpful to review a perspective known as cognitive load theory to understand the possible implications of multiple-channel processing on cognitive structures. Based on the suggestions of cognitive load theory, the split-attention (Clark & Mayer, 2008; Cierniak et al., 2009; Florax & Ploetzner, 2010) and worked example effects (Renkl & Atkinson, 2003; Renkl, 2005; Sweller, 2006) should be applied to design the instructional materials to avoid the effects of cognitive loads. However, few studies exist on these learning effects of programming language instruction using various teaching materials in the environments with single or dual screens.
Two learning environments have been designed in this study in a computer classroom for programming language instruction. The teacher instructs a programming language course in a single-screen learning environment (SSLE), and he/she must repeatedly swap the instructional view between learning content and operational procedures of programming development software in order to make a connection reference of them. That is, if the teacher is instructing on the view of the learning materials, the other view of operating programming development software for demonstration will be temporally unavailable, and vice versa. The other is a dual-screen learning environment, called DSLE. The DSLE is designed to show the two views of learning content and operating programming development software. That is, if the teacher is instructing one view of these two screens, he/she must stand in the front of that screen to attract the attention of the learners.

The main purpose of this study is to investigate the significant effects of learning programming language in a dual-screen environment. The question then arises about cognitive loads of learners and learning achievement: both might be affected by processing separate or integrated information on dual screens. From the perspective of the split-attention effect, the instructional slides with a series of popup objects and corresponding programming view are presented to highlight learning focal points and to attract learners’ attention. From the perspective of the worked examples effect, the experimental materials provide proper examples to learners. Specific research questions in this study are identified as follows. How will the learning materials be designed in split-attention and worked examples formats affect the learning in a programming language course between SSLE and DSLE? What are the differences among levels of learning achievement in a programming language course between SSLE and DSLE? To investigate the learning effects, levels of learning achievement, and their differences between SSLE and DSLE in an experimental course, Windows Programming in Microsoft Visual Studio .Net 2005, was used in this study.

**Literature review**

This literature review of this study focuses on the multi-image presentation of multiple-channel communication to explain the effects of information presented in separate and integrated formats to humans. The information processing approach to human cognition hypothesizes that several information storage areas are used to convert stimuli to information (Miller, 1956). The review of multi-image presentation addresses theoretical aspects and current findings of using multi-image presentations in multimedia learning. Moreover, the split-attention and worked examples effects based on cognitive load theory involve the evidence of eliminating the cognitive loads when designing multimedia materials. The cognitive load theory provides explanations toward understanding the multiple-channel processing on cognitive structures.

**Multi-image presentation of Multiple-channel communications**

The theories and effects related to multiple-channel communication addressed in the following previous studies involve the information processing view of the cognitive theory. Broadbent (1965) suggested that one reason for the reduction of learning in multiple-channel presentations is a result of the filtering process that occurs in individual information processing. Whatever the amount of information presented in visual or verbal modality from sensory channels, learners are able to accept only limited amounts using the information processing approach (Jacobson, 1951). Dwyer (1978) identified nineteen factors that complicate interpretation and cause contradictory results of the single-channel and multiple-channel communications research studies. To recognize information simultaneously, the different sensory channels must process a great variety of different cues. The cue summation of learning theory predicts that learning is increased as a number of available cues or stimuli are increased.

The research issue of multi-image presentation is relevant to the properties of cue summation research, which suggests using more cues within a single channel or using more cues across multiple channels. The multi-image presentations in the previous studies (Atherton, 1971; Bollman, 1970) have referred to the use of more than one image on single or multiple projection screens. Low (1968) stated that no single image can establish certain memory combinations, but a multi-image presentation with a group of images perceived simultaneously often recalls long forgotten memories. Perrin (1969) adopted a multi-image presentation to present multiple and relevant images simultaneously. He identified three major factors for multi-image presentation: larger screen, simultaneous images, and information density. A larger screen can display many various concepts and many complicated ideas simultaneously. Simultaneous images can increase the information density while presenting from a larger screen.
The effective information allows users to process the rich information in a very short time. A number of instances available to the learner to be associated by visual comparison with simultaneously presented images are greater than with images presented sequentially. Westwater (1973) also showed that presenting multiple images in wide-screen environments had some significant differences between linear and simultaneous formats. Therefore, the simultaneous materials should follow the cognitive theory to construct their presenting structures. The multi-image presentation developed according to a well-known phenomenon in multimedia learning which is learning from multiple sources of information simultaneously (Florax & Ploetzner, 2010). Ayres and Sweller (2005) explained that this type of presentation having split-attention effect followed the cognitive load theory. It means that learners obtain better learning performance by integrated information. Mayer (2005b) proposed similar design principle for multimedia learning theory called the temporal contiguity principle. It means that learners learn better when corresponding verbs and visual content are presented simultaneously rather than successively.

Cognitive load theory

Cognitive load refers to the resources used by working memory at a given point in time. Mayer’s (2005a) discussion of the limited capacity assumptions suggested that humans are limited in the amount of information that can be processed in each channel at one time. According to the limited capacity of the working memory, two types of cognitive load have been identified in particular: intrinsic cognitive load; and extraneous cognitive load (Sweller et al., 1998; Mayer, 2005b). Intrinsic cognitive load refers to the load placed on the working memory by the degree of difficulty of learning content. This load depends on the inherent difficulty of learning materials. Extraneous cognitive load is caused by the designed instructional learning materials, and depends on the presentation of instructional messages that are designed, organized, and presented. The third cognitive load, germane cognitive load, is associated with the processes and construction of presentation from learning material and environment (Sweller et al., 1998). Instructional designers are suggested to reduce the extraneous cognitive load and transfer learners’ attention to cognitive processes that should be considered with regard to the constructions of instructional learning materials. Schnotz and Kürschner (2007) also argued that intrinsic and germane loads should be related to a certain extent. Cognitive load theory explains that the split-attention and worked-examples effects in the information processing approach are to emphasize the limitations of working memory capacity (Ayres & Sweller, 2005; Renkl, 2005).

The empirical methods to measure the construct of cognitive load have been used in three mainly techniques: rating scale, psycho-physiological technique, and secondary task technique (Paas, et al., 2003). It is a common technique using the rating scale to gather subjective data of learners in cognitive load researches. Although someone argued that the measurement of self-rating was not exactly precise, it has been demonstrated that learners are quite capable of giving a numerical indication of their perceived mental effort (Gopher & Braune, 1984). Paas (1992) was the first to use this finding by using rating scale to determine the cognitive load. Cognitive load theory researchers have shown that this kind of technique could obtain the reliable measures (Paas, 1992; Pollock, et al., 2002).

Split-attention effect

Attention is speculated to be a very limited mental resource (Anderson, 1985). However, it is difficult for learners to concentrate learning attention on two simultaneous instructional presentations. Norman (1969) also stated that this type of recognition involves paying attention while receiving the relevant information. The split-attention effect may occur when instructional materials cause learners to split their attention among the integrated multiple sources of information in multiple channel communication (Smith, 2001). If the effective working memory can be increased by using dual-modality presentation techniques, it may be effective in facilitating learning as physically integrating two sources presenting visual information. Therefore, the two separated visual sources (screens) of information should be physically integrated to reduce the load for mental integration (Ayres & Sweller, 2005).

Tarmizi and Sweller (1988) were one of the first to use graphics that demonstrated comparison of different levels of learning performance with split and integrated forms. In their other two experiments, they argued that learners receiving worked examples designed in separate and integrated formats at the beginning of cognitive skill acquisition will gain a deep understanding of subject domain. Redesigning instructional materials with integrated information to highlight the teaching focal points can help the learners to eliminate the unnecessary information searches (Chandler & Sweller, 1996). It can also enhance their learning processes through gaining meaningful learning. Instructional
split-attention may be occurred when learners are required to split their attention among multiple integrated sources of physically or temporally disparate information, where each source of learning information is for understanding the learning content (Ayres & Sweller, 2005; Owens & Sweller, 2008). The split-attention effect happens when learners studying integrated information outperform learners studying the same information presented in the split-attention format. To avoid split-attention, researchers have successfully employed the strategy of physically integrating various sources of information (Cierniak et al., 2009; Clark & Mayer, 2008; Florax & Ploezer, 2010).

**Worked examples effect**

Learning by doing and learning by solving complicated problems are frequently discussed in the literature on teaching and learning, particularly on multimedia learning. Demonstrating worked example is an effective method for teachers to instruct learners to obtain the skills of problem solving (Renkl & Atkinson, 2003). The principle of worked examples in multimedia learning declares that learners gain a deeper understanding of a skill domain when they receive worked examples in the beginning of cognitive skill acquisition (Sweller et al., 1990; Renkl, 2005). At the beginning of a learning process for low ability learners or novices, they cannot apply the problem-solving skills required to build meaningful relationships among received information (Moreno, 2004). A worked example consists of problem formulations, solution steps, and the final solutions. Worked examples can be expected to reduce the extraneous cognitive load by acting as an instructional central execution, therefore, reducing the load on working memory (Sweller et al., 1998; Sweller, 2006).

Lewis (2005) proposed an animated form to demonstrate the worked examples. The animated worked examples were primarily useful for training complicated cognitive skills of learners. When learners learn with this type of worked example, they could follow the animated explaining steps to get the right learning without unnecessary visual information search. In this study, the subject matter of using worked examples involved providing an executable program as a worked example to the learners. By teaching with the instructional slides and the executable programming instances, the learners expect to perform at a significantly higher level than when learning with the static structured worked examples for solving problems.

Although information processing in human cognition restricts the ability of processing multiple sources from learning environments with a larger screen regardless of single or dual screens, teachers can adopt split-attention and worked examples effects to provide effectively designed multimedia learning materials for learners.

**Environment Design**

In this study, the learning environment primarily involves two adjacent projection systems controlled by a digital table in a computer classroom. Such environment presents information through multiple-channel communication involving simultaneous presentations of stimuli through different sensory channels such as sight, sound, or touch (Moore et al., 2004). We also followed the multimedia principle of temporal contiguity to design instructional materials. This principle argued that it can improve the ability of users to make referential links between the text explanations and corresponding visual objects. Figure 1 shows two adjacent screens (left and right screens) displaying two different multimedia materials from the teacher’s PC and laptop to create a DSLE. With the aim of providing a bright and clear learning environment screens, the setting of projection system in a computer classroom comprises two projectors with 3000 lumens and two 90-inch projection. Alternatively, as shown in Figure 1, the teacher can also use one of these two screens to be an SSLE through the display controller of digital table. The setting of our learning environment allows teachers to display a worked example along with the teaching materials spatially on big screens, which may facilitate the understanding of content for learners.

For example, Figure 2 describes a teacher using one (left) screen to lecture about Windows Programming in instructional slides as text explanations while also using the other (right) screen to display the executed steps of programming development software as corresponding worked examples. In a traditional computer classroom with a single projector (SSLE), the teacher must switch the teaching views between the instructional slides and the programming development environment. In other words, learners only see a single view of the instructional material. Several worked examples of Windows Programming were designed to instruct in the SSLE and DSLE. From two teaching materials displayed on two side-by-side screens, learners can simultaneously see both views of instructional
slides and the programming development environment. Learning by solving complicated worked examples from the teacher is an effective method when the teacher demands learners to demonstrate the skill of problem solving. Through the computer classroom, learning by doing is also an effective way to follow the executed steps of programming development software from the teacher.

**Figure 1:** Dual-screen system in digital table within the computer classroom

Mayer (2005a) suggested that reading can preserve texts and images in the working memory simultaneously. Learners can easily make referential connections between two views of screens. Therefore, the concept of popup windows was attempted (Erhel & Jamet, 2006) to design popup objects of learning content in instructional slides for highlighting the focal points of learning. That is, popup objects can place the textual explanations as labels near the corresponding graphical object. These popup objects correspond with executed steps of programming development software displayed on the other screen. The limitation of popup objects is that they may obstruct the views of texts and images. Popup objects should be formatted as short texts and small images (Weinreich & Lamersdorf, 2000). This compares different information so that learners use the information to store and recall prior knowledge.

**Figure 2:** Programming language instruction on DSLE

Mayer (2005a) suggested that reading can preserve texts and images in the working memory simultaneously. Learners can easily make referential connections between two views of screens. Therefore, the concept of popup windows was attempted (Erhel & Jamet, 2006) to design popup objects of learning content in instructional slides for highlighting the focal points of learning. That is, popup objects can place the textual explanations as labels near the corresponding graphical object. These popup objects correspond with executed steps of programming development software displayed on the other screen. The limitation of popup objects is that they may obstruct the views of texts and images. Popup objects should be formatted as short texts and small images (Weinreich & Lamersdorf, 2000). This compares different information so that learners use the information to store and recall prior knowledge.
Our previous study (Chen et al., 2008) indicated that learning achievement could be improved in a statistic course through teaching with the dual-slide mode of DSLE. Regarding the dual-slide mode in a DSLE (shown in Figure 3), the teacher simultaneously uses the left screen to display prepared instructional materials designed in instructional slides and writes additional instructional contents, for example, hand-written statistical formulas, on the blank slides displayed on the right screen to illustrate the steps involved in solving statistical questions and other explanation points that the teacher wants to show learners. Learners can learn from the teacher’s written steps on the right screen while viewing the problem on the left screen without simultaneous hindrance. In this mode, the DSLE also allows materials to be presented side by side; therefore, learners could make the knowledge references among slide by slide materials without going back and forth between particular single slides. The DSLE applies the effect of the temporal contiguity principle (Mayer, 2005b) and split-attention effect (Ayres & Sweller, 2005), as well. Additionally, this mode in the DSLE was also able to present worked examples (Renkl, 2005) and learning content simultaneously, which might facilitate comprehensive learning materials for learners.

Research Design

This study designed to find the significant effects of learning programming language between the single- and dual-screen environments. The learners taking the Windows programming course were invited to participate in this experiment. The cognitive loads and learning achievement of participants were collected after learning with the particular subjects of Windows programming. The research design of this study was described as follows in detail.

Participants

Forty participants majoring in computer science and enrolled in the Windows Programming using Microsoft Visual Studio course were invited to participate in the experiment. This course was an undergraduate level course and participants were randomly assigned into two experimental conditions. The twenty-one participants (six females and fifteen males) involved in the Single-Screen (SS) group were taught in the SSLE. The nineteen participants (five females and fourteen males) assigned to the Dual-Screen (DS) group were assigned to learn in the DSLE. Their ages ranged from twenty to twenty-two years. All participants only had the basic programming ability of C/C++ programming language. That is, they were novice learners in Windows programming. This course focused on the advanced skills of C/C++ and visualized Windows programming languages. After finishing the course, the
participants could understand complicated designing flows of object-based programming language and data structure of Windows programming, and implement a complete Windows application by themselves.

Data collection instruments

The instruments in this study were used to address the cognitive load measurement and learning achievement. In terms of measuring cognitive load, the degrees of clarity and difficulty investigated learners’ intrinsic and extraneous cognitive loads. This study adopts the experimental measurement modified for previous studies (Paas, 1992; Pollock et al., 2002). The rating scale technique is adopted in this study since it has been widely used to measure the working memory load and mental effort in the literature (Gopher & Braune, 1984; Paas et al., 2003). That is, the rating scale has been proven that it is a very reliable measurement in cognitive load researches according to the analysis of its reliability and validity. The modified measurement in this study consists of four questions on a 7-point Likert-type scale in two domains, 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. Each degree was divided into two items listed in Table 1: learning content and learning with worked examples. The internal consistency reliabilities assessed by Cronbach’s alpha for rating scales of degrees of clarity and difficulty were .92 and .90 respectively. The item of learning content meant that the materials followed the design principles of the split-attention effect. The item of learning with worked examples presented in an executable programming instance as a worked example according to the suggestions of the worked examples effect.

In terms of the learning achievement, this experiment evaluated learners in scorings of pre-test and post-test as transfer assessments designed by the teacher in this experimental course. Transfer assessment was measured by asking students to solve problems using information presented in the instruction. The pre-test consisted of sixteen choice questions regarding the based knowledge about the rules, logic, and problem skills of the C/C++ programming languages. The post-test consisted of the programming questions asking participants to write answers by filling in the correct programming codes. The purpose of the post-test was to evaluate the participants in Windows programming skills. The Windows programming skills referred to the usage of visual components and the ability of debug the Windows programs. The analysis results between the pre-test and post-test of learners involved determining the germane cognitive load between SS and DS groups. The total scores of the pre-test and the post-test were 16 and 100 respectively.

Procedures

The data collection sessions were conducted at roughly four-week intervals. The participants in each group were administered the pre-test at the beginning of this experiment. At the four-week intervals, the participants were taught the usage of Windows components classes to learn how to use the basic controls in Windows programming through effectively designed worked examples. Each group took four classes of teaching in the four-week intervals, and the time for teaching in each class was approximately 50 minutes. After four-week intervals, they filled out the measurement for cognitive load effects and the post-test for evaluating their learning achievement in Windows programming.

Instructional Materials

Participants of both groups were taught programming skills using basic controls in Windows programming, including eight classes, CView, CDocument, CList, CMap, CButton, CEdit, CListBox, CComboBox, CStatic, and CTime, which are the basic data and user-interface classes of Microsoft Foundation Classes (MFCs) developed by Microsoft. The instructional material displayed in the instructional slides with a series of popup objects was used to illustrate the worked example, which was an executable programming instance to design a basic calculator (as shown in Figure 4). Learners would pay their attention to understand the programming concepts and skills through the animation effects of popup objects.
In the SSLE, the teacher switches instructional screen views and uses programming language software to demonstrate the corresponding programming instances. Learners can see only one instructional view of these two views without information searching, and the teacher must switch the view to a single projection screen. In Figure 5, it assumes that the teacher currently explains the instructional contents at instructional slide. If the teacher wants to demonstrate the corresponding programming sample code, he must swap the teaching screen while using a single projection screen. On the other hand, the teacher can make use of two adjacent screens to simultaneously present the instructional slides and demonstrate a worked example using programming language software without interleaving.
these two instructional contents in the DSLE. Therefore, learners can simultaneously see both screen views as the multi-image presentation, and the teacher can change both screens to instruct immediately. As shown in Figure 6, when the teacher lectures from a page of formed instructional slides, he can also use the nearby projection screen to display the usage of programming language software while demonstrating the worked example simultaneously.

Figure 6: The teaching flow of DSLE

Results

To investigate intrinsic and extraneous cognitive loads of learners, four questionnaire items for learning content and learning with worked examples were designed to find the degrees of clarity and difficulty of understanding multiple materials during their learning processes in this experimental measurement. The degree of clarity referred to the extraneous cognitive load regarding the clarity of multiple information displayed on the screen. The degree of difficulty referred to the intrinsic cognitive load regarding the difficulty of multimedia learning materials learned by the learners. Because the samples of SS and DS group were both less than 30 samples, The Kolmogorov-Smirnov test was used to test the normal distribution between SS and DS groups. The p-values of each item in these two groups were all higher than 0.05. That is, these items in SS and DS groups were all normally distributed and the T-test analysis can be used to test the differences between these groups. The t-test and effect size (Cohen’s d) analyses of degrees of clarity and difficulty show in Table 1.

Regarding the degree of clarity of learning content and learning with worked examples, learners in the DS group answered both clearer than those in the SS group. The t-test of degree of clarity showed that learning content ($t(38)=3.347^{**}, p<0.005, d=1.06$) and learning with worked examples ($t(38)=3.798^{**}, p<0.005, d=1.21$) both had significant differences between the SS and DS groups. Cohen (1988, p25) defined effect size as “small, $d=0.2$”, “medium, $d=0.5$”, and “large, $d=0.8$”. The effect sizes of degree of clarity in both items referred to large sizes between these two groups. Regarding the degree of difficulty of learning content and learning with worked examples, learners in the DS group answered both easier than those in the SS group. The t-test of degree of difficulty showed that learning content was significantly different and its effect size was medium within these groups ($t(38)=2.093^*, p<0.05, d=0.70$), but there was no significant difference for the degree of difficulty of teaching with worked examples ($t(38)=.946, p>0.05$).
Table 1. T-test and effect size of degrees of clarity and difficulty

<table>
<thead>
<tr>
<th>The Degrees of Clarity and Difficulty</th>
<th>Group(N)</th>
<th>Mean</th>
<th>SD</th>
<th>T-value</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
<td>Cohen’s d</td>
</tr>
<tr>
<td>The degree of clarity of learning content in single/dual-screen learning environment.</td>
<td>SS (21)</td>
<td>3.81</td>
<td>.980</td>
<td>3.347**</td>
<td>1.06L</td>
</tr>
<tr>
<td></td>
<td>DS (19)</td>
<td>2.74</td>
<td>1.046</td>
<td>3.798**</td>
<td>1.21L</td>
</tr>
<tr>
<td>The degree of clarity of learning with worked examples in sequential/simultaneous time of single/dual-screen learning environment.</td>
<td>SS (21)</td>
<td>3.67</td>
<td>.966</td>
<td>2.093*</td>
<td>0.70M</td>
</tr>
<tr>
<td></td>
<td>DS (19)</td>
<td>2.47</td>
<td>1.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The degree of difficulty of learning content in single/dual-screen learning environment</td>
<td>SS (21)</td>
<td>4.24</td>
<td>.889</td>
<td>2.093*</td>
<td>0.70M</td>
</tr>
<tr>
<td></td>
<td>DS (19)</td>
<td>3.47</td>
<td>1.389</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The degree of difficulty of learning with worked examples in sequential/simultaneous time of single/dual-screen learning environment.</td>
<td>SS (21)</td>
<td>4.05</td>
<td>1.177</td>
<td>.946**</td>
<td>0.64M</td>
</tr>
<tr>
<td></td>
<td>DS (19)</td>
<td>3.63</td>
<td>1.640</td>
<td></td>
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</tbody>
</table>

* p<0.05; ** p<0.005; ns = no significant; L: large effect size; M: medium effect size

The Kolmogorov-Smirnov test showed that the pre-test and post-test were both normally distributed within each group. For examining the effect on learning achievement of participants in DSLE, the t-test and effect size analyses were used to access the achievement of learners in learning Windows programming between these two groups. Table 2 shows no difference in pre-test of learners (t(38)=1.064, p>0.05). It meant that the basic knowledge of the learners was no difference between these groups before learning Windows programming in this experimental course. On the learning achievement, there was a main significant effect in post-test of learners (t(38)=-3.395, p<0.005, d=1.08). The effect size of post-test presented a large size between these groups. Learners in the DS group (Mean=88.84, SD=1.83) gained higher scores than those in the SS group (Mean=86.93, SD=1.72). This result reflected that the dual-screen environment was a helpful option to instruct the programming language when teaching instructional slides with worked programming examples.

Table 2. T-test and effect size for pre-test and post-test

<table>
<thead>
<tr>
<th>Test</th>
<th>Group(N)</th>
<th>Mean</th>
<th>SD</th>
<th>T-value</th>
<th>Effect size</th>
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<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Cohen’s d</td>
</tr>
<tr>
<td>Pre-test</td>
<td>SS (21)</td>
<td>9.10</td>
<td>2.427</td>
<td>1.064**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DS (19)</td>
<td>8.37</td>
<td>1.862</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-test</td>
<td>SS (21)</td>
<td>86.93</td>
<td>1.725</td>
<td>-3.395**</td>
<td>1.08L</td>
</tr>
<tr>
<td></td>
<td>DS (19)</td>
<td>88.84</td>
<td>1.840</td>
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</tbody>
</table>

** p<0.005; ns = no significant; L: large effect size

Discussions and Conclusions

This study presented the results of measuring learners’ cognitive loads and learning achievement in learning programming language between SSLE and DSLE. The cognitive load measurement was designed to investigate the degrees of clarity and difficulty of learning content and learning with worked examples. Learning content referred to the presentation of instructional slides based on the design principles of split-attention effects. The degrees of clarity and difficulty of learning content showed significant differences and larger effect sizes between the SSLE and DSLE, meaning that learning content presented in the DSLE has fewer intrinsic and extraneous cognitive loads for learners than that presented in the SSLE. It could be concluded that the learning of programming language in the DSLE could be more effective in avoiding the split-attention effect than in the SSLE. Learning with worked examples referred to the demonstration of the corresponding programming instance as a worked example. A significant difference and larger effect size were found between these two environments on the degree of clarity of learning with worked examples, meaning that learning content presented in the DSLE has fewer extraneous cognitive loads for learners than that presented in the SSLE. This finding is in accord with the results of the previous studies (Renkl & Atkinson, 2003; Renkl, 2005). Renkl and his colleague found that the integration of text and diagrams within worked examples would reduce the extraneous cognitive load effectively. In other words, while instructing with multiple sources of information that includes instructional slides and executable examples in a programming language course, the DSLE will provide a clear and easy-to-understand learning environment for learners.
Cierniak et al. (2009) also reported that the germane load plays a critical role in mediating the split-attention effect. The analyses of comparing the pre-test and post-test also showed that the germane cognitive load causes significant difference in learning achievement of the learners between the two environments. This finding suggests that the germane cognitive load of DSLE may affect learners in gaining better learning achievement than SSLE. In a brief interview, the instructor of this course mentioned that the DSLE could provide him a clear and useful display space to present the whole materials of this course. Although teaching with two screens made him busy with controlling the classroom, he also suggested that an efficient assisting tool to control dual screens and to design layouts for these screens should be designed. It can therefore be concluded from the above findings that the DSLE can provide the teachers with a larger teaching view to instruct and the learners with an effective learning environment to learn through simultaneously displaying learning content and executable examples in a programming language course. This finding supports the findings of previous studies of multi-image presentation (Perrin, 1969; Atherton, 1971; Bollman, 1970) that a larger screen (as two adjacent screens presented in this study) provides higher quality approximations of real environments by addressing physical and psychological factors necessary for learning and teaching.

The results of this study could be useful to the teachers responsible for instructing programming language courses in multimedia learning environments in classrooms with either single or dual screens. Despite some significant differences of learning effects and levels of learning achievement between the SS and DS groups, the research of the present study is not without limitations. The first limitation concerns the pre-test and post-test used in the current study. These two tests were aimed to identify learners’ basic knowledge and problem solving ability of programming language at the beginning of learning Windows programming and the learning outcomes after the experiment respectively. However, learning achievement of learners in programming language instruction could not be evaluated after only four-week intervals of the experiment. The second limitation is rooted in the small group of participants who were investigated in this experiment. Since the study involved only two small groups, the results could not be generalized as a representative of the population. Thus, generalization of the results to other populations with different 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 aiming to experiment with a multiple-screen environment in a similar context. The DSLE is not only suitable to visualize Windows programming courses but also other types of programming languages. For example, when instructing networking programming language courses, one screen can present the view of the learning materials for instructing the programming illustrations. The other screen can display the demonstrated executable examples simultaneously in the web browser. Multiple-screen environments can be designed to extend the windows view of a big map without segmenting displays to introduce the geographic distribution of the whole map. Multiple-screen environments 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 of the conference, such as the slides for translation. In conclusion, the use of multiple-screen environments might provide an efficient and usable environment for teaching and learning.

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**References**


