EMPHASIS MANIPULATION EFFECT IN TERMS OF THE LEAST-ABLED SETS ON COGNITIVE LOAD, TRANSFER, AND INSTRUCTIONAL EFFICIENCY

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Abstract

This research suggests emphasis manipulation on constituent skills of least-abled sets, improves coordination and integration of knowledge, skills, and attitudes on cognitive load, transfer, and instructional efficiency. The participants were divided into two groups. Competency levels for the designated skill sets were evaluated, and a pre-test was performed on both groups. The research applied an educational design based on individual learner's least-abled sets of constituent skills and identified the design's effectiveness on complex learning. One group was provided with the whole learning contents according to emphasis manipulation sequencing method, and the other group was provided personalized learning contents according to a method based on the least-abled sets of constituent skills emphasis manipulation. The group received materials constructed with emphasis manipulation, learned the whole constituent skills of learning contents and carried out conventional tasks. However, treatment group received materials constructed with the least-abled sets of constituent skills emphasis manipulation, learned only the least-abled constituent skills and carried out conventional tasks. This research suggests that teaching with the least-abled sets of constituent skills helps to reduce expertise-reversal effect and improve results of cognitive load, transfer and instructional efficiency.
Keywords: *cognitive load, complex tasks, emphasis manipulation, instructional efficiency, learning transfer.*

Introduction

The modern society presents numerous opportunities for learners to acquire knowledge. However, knowledge in the modern education is becoming more and more complex, causing difficulty for the learners to efficiently acquire knowledge. For these reasons, educational design should focus on individual learners' differences and be flexible in teaching learners with various expertise. Teachers should construct educational design while considering learners' prior knowledge into account (Gagné & Dick, 1983). Task sequencing, which takes individual learners' differences, can be effective on teaching (Shute & Towle, 2003), and it can lead to better transfer from educational environments to real-world situations (Van Merriënboer & Kirschner, 2001).

However, advocates of task sequencing that involves analysis of learning tasks with hierarchy, have argued that educational goals are achieved when respective subordinate objectives are achieved (Gagné & Merrill, 1990). As a result of putting such an emphasis on achieving educational goals, hierarchical task analysis and sequencing do not consider individual learner's prior knowledge, and have been providing unified, identical learning tasks

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to every learner in the order of task complexity. The methodology provided fragmented learning tasks to the learners according to the sub-goal of learning; while it is effective in achieving educational goals, traditional task sequencing cannot provide information on real-life tasks, and the acquired knowledge and principles could become a tacit knowledge (Renkl, 2011).

In addition, fragmented learning tasks are not able to address the whole task and results in educational objectives not interacting with one another, preventing coordination and integration of the fragmented learning elements (Clark & Estes, 1999; Perkins & Grotzer, 1997; Spector & Anderson, 2000). Therefore, the design of complex and real-life tasks has been the focus of much previous research over past decades, as practitioners and educational designers seek to adopt more meaningful learning approaches to their learning environments (Brickell & Herrington, 2006). However, the design of whole-task sequencing for more experienced learners has not been considered. Thus, whole task sequencing methods that are appropriate for more experienced learners and complex learning should be designed to integrate and coordinate knowledge, skills and attitudes.

Complex learning focuses on solving real-life tasks, not on fragmented elements of problem-solving skills (Van Merriënboer, Kirschner, & Kester, 2003). In other words, educational design for complex learning should be designed to acquire practical knowledge (Merrill, 2002; Reigeluth & Carr-Chellman, 1999; Van Merriënboer & Kirschner, 2001). Van Merriënboer (1997) proposed whole-task sequencing as a design for complex learning. Whole-task sequencing has a goal for learners to acquire schema which can help problem solving. General complex task sequencing starts from simple to complex (Van Merriënboer & Kirschner, 2007). However, complex learning process needs such characteristics, and this is the cause of higher cognitive load (Clark, Ayres, & Sweller, 2005; Plass, Moreno, & Brunken, 2010). Thus, complex task sequencing can be divided into part-task sequencing depending on the level of the tasks given, but part-task sequencing hinders the integration of knowledge, skills, and attitudes and the transfer to new problem situations. For this reason, part-task sequencing should be carefully designed (Van Merriënboer & Kirschner, 2007) as other studies which compared whole-task sequencing and part-task sequencing suggested (Lim, Reiser, & Olina, 2009; Salden, Paas, & Van Merriënboer, 2006).

Therefore, complex task sequencing differs from task sequencing, which analyzes tasks according to hierarchy in their methodology and emphasis. However, complex task sequencing can also provide redundant information to learners if the educational design does not consider knowledge level differences of individual learners. Task sequencing influences on learning achievement (Clarke, Ayres, & Sweller, 2005; Lim, Reiser, & Olina, 2009), and an instructional design created without consideration of learners' prior knowledge provide learning materials that do not help schema acquisition and automation of learning, and hinders cognitive learning process (Kalyuga & Sweller, 2014). Also, if the learners are provided with a task that is too easy for them from the beginning, learners cannot construct schema for the whole-task, and the increased difficulties in assimilation and subsumption result in decreased efficiency and effectiveness (Reigeluth & Stein, 1983). Thus, task sequencing should provide a personalized teaching tailored to each learner's learning level. However, providing redundant information in the learning contents regardless of learners' prior knowledge can create the expertise reversal effect for advanced learners (Kalyuga, Ayres, Chandler, & Sweller, 2003; Sweller, Ayres, & Kalyuga, 2011), causing difficulty in learning, and ultimately, the transfer of knowledge. Therefore, it is important to design an educational method that can be linked to learner's various learning experiences and can extend the prior knowledge of learners. Appropriate learning materials decrease the gap between what learners already know and what learners should know, letting the learners have a meaningful learning experience and enhance learning effects (Van Merriënboer & Kirschner, 2007). To achieve a successful and a meaningful learning process, the whole-task sequencing with consideration of prior learner knowledge would be necessary, as well as an optimization of the individual learner's cognitive load.

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For these reasons, this research provided learning contents according to the knowledge level differences in individual learners using emphasis manipulation (Gopher, Weil, & Siegel, 1989) of whole-task sequencing. Emphasis manipulation is one of the whole-task sequencing methods of complex tasks. Constituent sets of skills and general tasks would take turns repeatedly, and the sequencing provides a whole-task from the beginning, improving learners' performance through various experiences. In addition, emphasis manipulation helps the coordination and the integration of prior knowledge and new complex tasks, but since original emphasis manipulation did not consider prior learner knowledge, it resulted in extra cognitive load to the learners. Therefore, a new way of emphasis manipulation task sequencing is needed based on individual learner's sets of the least-abled skills.

Therefore, this research was aimed to compare the effects of cognitive load and knowledge transfer between emphasis manipulation and sets of the least-abled skills emphasis manipulation according to learners' prior knowledge, and ultimately to suggest an optimal design of complex learning considering the instructional efficiency.

Research Questions

The questions of this research were as follows.

1. What is the effect of emphasis manipulation and sets of the least-abled skills emphasis manipulation on cognitive load?
2. What is the effect of the emphasis manipulation and sets of the least-abled skills emphasis manipulation on the transfer?
3. What is the effect of emphasis manipulation and sets of the least-abled skills emphasis manipulation on instructional efficiency?

Theoretical Foundation

Emphasis Manipulation

Emphasis manipulation is one of the well-known whole-task sequencing methods (Gopher, Weil, & Siegel, 1989), and it emphasizes a specific set of constituent skills. It exposes learners to the whole learning process from the beginning, and helps learners to integrate, coordinate, and construct schema (Van Merriënboer & Kirschner, 2007) effectively. Since such complex tasks from the whole learning process actively interact with one another, emphasizing numerous learning elements at the same time may result in higher cognitive load, and thus could be detrimental to schema construction and transfer (Kester, Kirschner, & Van Merriënboer, 2005). Thus, a personalized and an optimized set of constituent skills that are appropriate to the individual learners' current level should be provided. Instructors should design an instructional method that excludes redundant information from learners. In addition, educational design should reduce extraneous cognitive load and help the transfer of knowledge.

Sets of the Least-Abled Skills Emphasis Manipulation

Sets of the least-abled skills emphasis manipulation is an individualized instructional design considering learners' prior knowledge, and it is an instructional method tailored to the individual learners. Sets of the least-abled skills can be identified as sets of constituent skills in complex tasks that cannot be performed because of lack of prior knowledge: the least-abled skills can be defined as conventional tasks subtracted by learner's current level.

According to information processing theory (Mayer, 2009), learners go through three cognitive processes of learning: selection, organization, and integration. The learners select relevant information, the selected information is organized, and finally, the organized information is integrated with prior knowledge (Mayer, 2008). Likewise, learners can generate schema through an elaboration between prior knowledge and new learning contents (Van Merriënboer, 2007).

Therefore, providing sets of the least-abled skills considering prior knowledge can help learners to go through cognitive process of selecting, organizing, and integrating information on the least-abled skills and prior knowledge. At the same time, using emphasis manipulation enhances transfer to conventional tasks through coordination and integration of complex tasks. Furthermore, since the sequencing process considering the prior knowledge of the learners can handle cognitive load from redundant information for advanced learners more effectively, the method may prevent the expertise reversal effect.

Emphasis Manipulation and Cognitive Load

Basic Assumptions of Cognitive Load Theory

According to cognitive load theory, learning is influenced by the degree of mental effort and cognitive load during the information processing in working memory (Paas, Renkl, & Sweller, 2004). Distinctive from long-term memory, working memory is limited in its total capacity (Sweller, 1988). Therefore, an instructional design that takes cognitive load imposed upon the working memory into account is needed.

Cognitive load is divided into intrinsic cognitive load, extraneous cognitive load, and germane cognitive load. Intrinsic cognitive load is a cognitive load that is determined by the difficulty of the learning tasks (Sweller, 2010). The level of difficulty signifies complexity of learning tasks that is defined with the number of elements and interactivity. Extraneous cognitive load occurs because of an inappropriate instructional design requiring unnecessary cognitive efforts of the learners. Finally, germane cognitive load means a mental effort to integrate the existing schema with new information (Sweller, 2010). Limited working memory capacity requires an instructional design method that can reduce extraneous cognitive load, manage intrinsic cognitive load, and increase germane load.

Emphasis Manipulation and Strategies for Cognitive Load

The emphasis manipulation is one of the whole task sequencing methods assuming a complex learning process (Gopher, Weil, & Siegel, 1989), and the whole task is performed based on the task class. As complex tasks essentially have a high interactivity among the task elements, the amount of information to be processed in working memory increases, and simultaneously, cognitive load increases (Sweller, 2010). In the study of Chandler and Sweller (1996), higher intrinsic and extraneous cognitive load resulted in learning difficulties. Fundamentally, complex learning with high intrinsic cognitive load requires an adjustment of extraneous cognitive load in order to manage the total amount of cognitive overload to secure working memory capacity and to ensure effective integration of the acquired knowledge with existing schema (Sweller & Chandler, 1994). Extraneous cognitive load can be reduced through appropriate instructional designs (Salden, Paas, & Van Merriënboer, 2006).

The traditional emphasis manipulation method provides identical learning tasks to the learners. Therefore, if learners are provided with unnecessary information, the extraneous cognitive load would increase; the increased extraneous cognitive load would result in expertise reversal effect if the learner has acquired expertise through the learning process (Kalyuga, 2007). Expertise reversal effect can be solved by designing an instructional design that considers learners' prior knowledge (Kalyuga, 2007) and by providing information excluding what the learners already know (Kalyuga, 2007). Therefore, task classes in emphasis manipulation should be divided and designed according to the learners' least-abled skills.

Transfer of Complex Learning

According to Holton, Bates, Seyler, and Carvalho (1997), transfer is defined as applying acquired knowledge, skills and attitudes to the real world, and Ford and Weissbein (1997) suggested that transfer is the application, generalization and maintenance of new knowledge. In addition, Noe (2013) argued that transfer is the ability to apply knowledge, skills, attitudes, and cognitive strategies effectively and consistently to a real situation.

In complex tasks, performance of complex tasks can be regarded as transfer because transfer means application of learning tasks in to real-life tasks (Gulikers, Bastiaens, & Kirschner, 2006). Therefore, applying emphasis manipulation should aid in successful task performances and transfer, decrease extraneous cognitive load, and provide information that is appropriate for individual learner.

Instructional Efficiency

Instructional efficiency is suitable for measuring the effectiveness of a particular instructional condition, considering the measured value of learners' performance and cognitive load (Paas & Van Merriënboer, 1993; Tuovinen & Paas, 2004; Van Gog, & Paas, 2008). If a particular instruction condition shows high efficiency, it would have high achievement scores with low mental effort and vice versa (Paas & Van Merriënboer, 1993). Paas and Van Merriënboer (1993) suggested instructional efficiency that focuses on learning outcomes, and Tuovinen and Paas (2004) suggested the modified instructional efficiency that focuses on learning process.

Instructional efficiency is measured as a degree of reduced extraneous cognitive load to invest less mental effort for learners who have a similar prior knowledge level (Van Gog & Paas, 2008). Modified instructional efficiency shows relationship between achievement and cognitive load during the learning process. It can be used to identify whether the integration and coordination of complex learning is well achieved in given instructional conditions or not. Instructional efficiency can be evaluated by comparing groups under different instructional design conditions.

$$E = \frac{Z_p - Z_{lme}}{\sqrt{2}}$$

Figure 1. Instructional efficiency formula (Tuovinen & Paas, 2004).

Research Methodology

General Background

This research employed a quasi-experimental study method. Learners were randomly divided into control group and treatment group. Learner prior knowledge about learning domain was evaluated in advance through a pre-test. Learning phase was conducted for 3 weeks. During the learning phase, Learners were again evaluated for their prior knowledge in the first week, and then the students carried out learning tasks in the second week. Finally, the participants performed conventional tasks which require participants to make PowerPoint slides while using whole constituent skills. The whole research process took 6 weeks including pre-test, learning phase, and post-test. Learning transfer was measured after 2 weeks from the learning phase.

Participants

The participants in this research were 56 students in their first and second year of high school, which is located in Chuncheon, Republic of Korea. The age of students ranged from 17 to 18 years old (*M* = 17.52, *SD* = .5). Learners were applicants who wanted to learn PowerPoint and improve their PowerPoint skills. The participants were divided into two groups of 28 participants recruited from the first and second grade student population. The prior experiences about learning domain were varied among the participants. However, students in the first grade had over 50 hours of computer education. In addition, students in the second grade had over 70 hours computer instruction. Thus, it would be appropriate to assume that the participants had enough prior knowledge about the learning domain. The data obtained from all 56 students were prepared for a statistical analysis.

Ethical Considerations

Ethics approval for this experiment was obtained from the participating school principals and teachers. Additionally, informed consent from students and their parents was obtained before the research. Participation of the research was voluntary, and participants were informed about the purpose, contents of the research in advance. Participants were also informed that their personal information would be confidential and treated anonymously.

Instrument and Procedures

Conventional Tasks Setting

This research included training on how to learn the basic features of Microsoft PowerPoint 2010. The purpose of this training was making a PowerPoint presentation using three constituent skills of PowerPoint. Three constituent skills consisted of texts, graphics, and animations (See Figure 4). PowerPoint was chosen as the experiment program since most people are somewhat familiar with PowerPoint and its function, the program was deemed to be an appropriate choice considering the purpose of the study because the students are likely to have experience of using the tool, but everyone has various strengths and weaknesses in using the program due to their difference in prior knowledge. Conventional tasks were given after learning from an online course on each task class. The conventional task for this experiment is applying PowerPoint skills to make PowerPoint presentation slides. As the task should include the whole-task while focusing on different task classes, learning tasks were created in three versions with different task class focuses. Control group was to learn the whole learning materials and perform conventional tasks, but treatment group was to only learn the materials that they do not know and perform conventional tasks. Treatment group participants were given their student number as a personal ID. Participants logged into the designated webpage and created their own personal page. Personal pages of individual learners included learning contents according to least-abled constituent (See Figure 2).

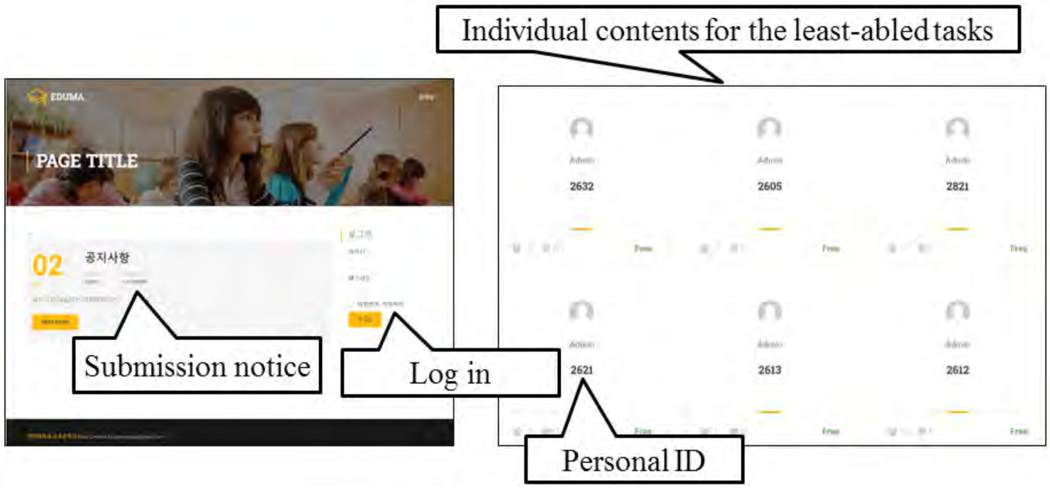

Figure 2. Page title for submission notice of conventional tasks and log-in (left) and learners' personal ID page to access individual learning contents (right).

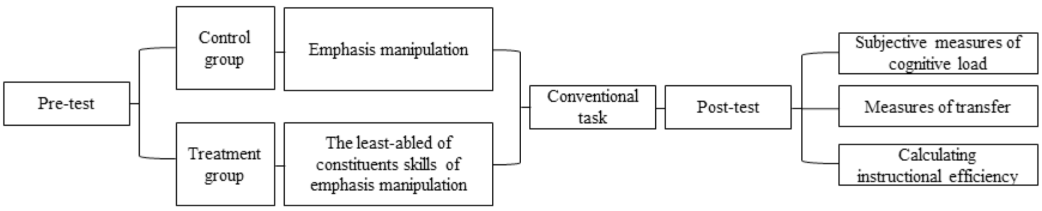

Figure 3. Teaching process of control group and treatment group.

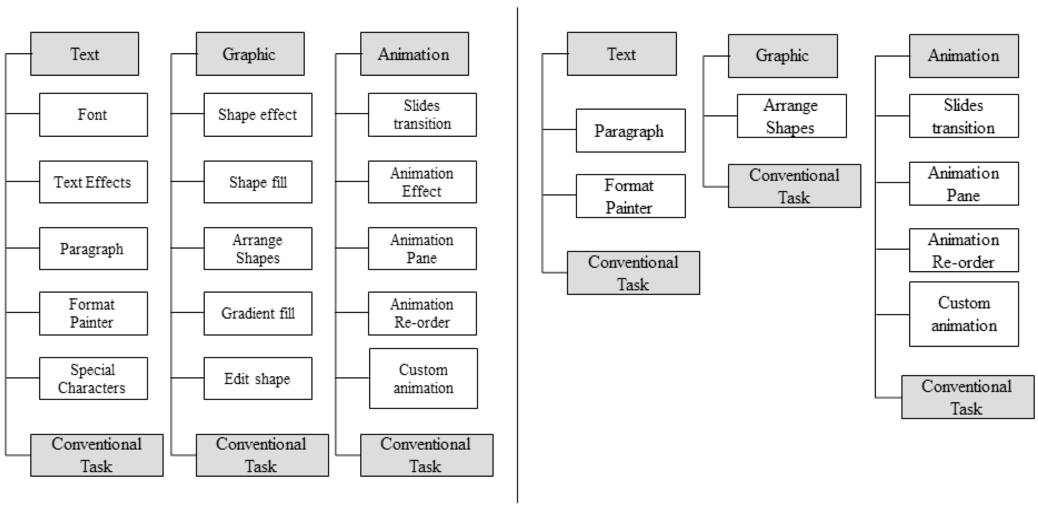

Figure 4. Whole learning contents structure of control group (left) and sample learning contents structure of treatment group (right).

Composition of the Online Course

Learning contents of an online course were composed of three functions of PowerPoint: texts, graphics, and animations. The three constituent skills included five sub-tasks and all units provided a 5-min video lecture per unit. After learning the five sub-tasks of each set of constituent skills, a conventional task was given, and the participants were to perform this task after the online learning. Participants in the control group had to learn all 15 online courses and carry out conventional tasks. Participants in the treatment group were given only the contents of the weaker part of the constituent skills according to the results of the pre-test. The treatment group only had to learn what they did not know, and then performed conventional tasks (See Figure 4).

Pre-Test

Pre-test was done to obtain a result of a homogeneity test of competency level as well as to identify the least-abled set of skills. Participants were asked to design and submit two slides of PowerPoint as similar as possible to the sample slides using the text, shape, and animation functions. Sample slides were provided with videos that correspond to each sample (See Figure 5). Validity of learning contents was identified by an educational expert and competency level and the least-abled sets of skills were identified by three researchers (See Table 1). All of the production process was recorded with a video recording application.

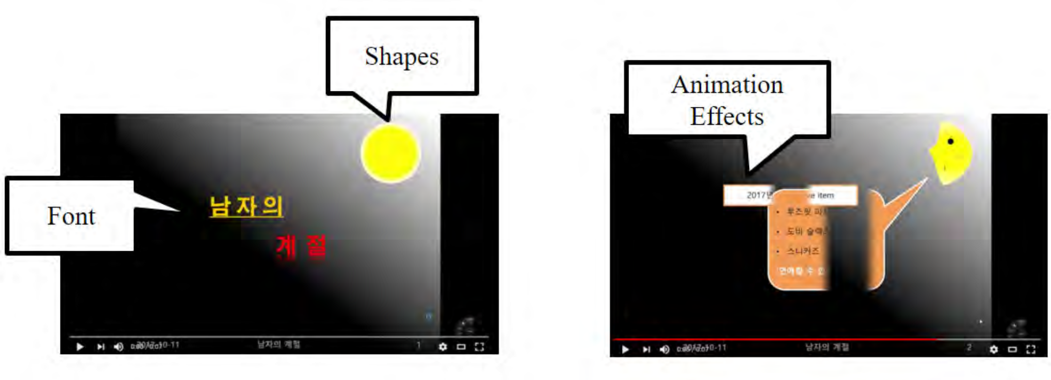

Figure 5. Sample slides that were given.

Table 1. Sample pre-test items to check list of the least-abled constituents of skills

Item #	The least-abled sets of constituent skills	Yes	No
1	Students can make PowerPoint slides using font functions.	□	□
2	Students can make PowerPoint slides using shape functions.	□	□
3	Students can make PowerPoint slides using animation effects.	□	□

Table 2 shows learners' competency level based on the results of learners' performance and video recording. Levene's test showed that equal variances could be assumed (F = 3.07, p = .085). Homogeneity test was not significant between control group (M = 6.14, SD = 2.82) and treatment group (M = 7.07, SD = 1.9): t(56) = -1.44, p = .15. Therefore, results identified that there was m=no significant difference in competency between the two groups.

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Table 2. Homogeneity test of competency level between control group and treatment group.

Competency test	*M*	*SD*	*p*
Homogeneity test			
control	6.14	2.82	.15
treatment	7.07	1.9	

Post-Test

The goal of the Post test is to see the participants' understanding of learning contents. The topic of assignment is about participants' future aspirations, and the students were asked to create 3 to5 pages of PowerPoint slide presentations. Similar to the pre-test, all participants recorded production process and submitted their PowerPoint slides.

Data Analysis

Subjective measures of cognitive load. The cognitive load questionnaire was based on the test developed by Cierniak, Scheiter and Gerjets (2009). The cognitive load questionnaire (negative sentence 10 items) is divided into three categories; intrinsic (3 items), extraneous (3 items), and germane cognitive load (4 items) (See Table 3). The questionnaire consisted of a 5-point Likert-scale questions that asked the participant to indicate the degree of difficulty and effort involved in their experience with the presentation: The labels indicate 1 = Strongly disagree, 2 = Disagree, 3 = Uncertain, 4 = Agree, 5 = Strongly agree. Cronbach's alpha of this research was .854.

Table 3. Sample questions for mental-effort rating.

Type of load	Item
Intrinsic load	I found the learning contents unnecessarily complex.
Extraneous load	I think the material presented did not help me to understand learning contents.
Germane load	I don't think I understood learning materials.

Measures of transfer. Evaluation on the degree of transfer consisted of 15 items about PowerPoint functions, and each item was worth one point. As transfer is applying what learners learned in problem solving (Johnson & Mayer, 2009), learners made 3 to5 PowerPoint slides about their future aspirations using all functions in task classes after learning each PowerPoint function and recorded the whole production process. Transfer test was self-reported (see Table 4), three researchers and one school teacher evaluated and reviewed the recordings and conventional tasks. In addition, transfer test was reviewed by two experts in PowerPoint education to ensure the validity of the study content. Reliability of Cronbach's alpha showed .777.

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Table 4. Sample transfer-test items

Item #	Constituent sets of skills	Yes	No
1	Students made PowerPoint slides using font functions.	□	□
2	Students made PowerPoint slides using shape functions.	□	□
3	Students made PowerPoint slides using animation effects.	□	□

Calculating instructional efficiency. Instructional efficiency was calculated with the formula of Tuovinen & Paas (2004) using the standardized mental effort scores of learning process and transfer in the conventional test scores. For this purpose, z-scores were produced and used for the instructional efficiency formula in Figure 1.

Research Results

Average scores on conventional tasks and cognitive load were calculated and recorded. As for the independent variables, both of the experimental group was analyzed with a t-test. Dependent variables were cognitive load, transfer, and instructional efficiency. Table 5 shows the results of cognitive load, transfer, and instructional efficiency.

Cognitive load scores. An independent-samples t-test was conducted to compare cognitive load in the controlled and the treatment conditions. Levene's test showed that equal variances could be assumed (F = 0.72, p = 0.4). Treatment (M = 16.15, SD = 4.66) condition showed higher cognitive load than control (M = 22.97, SD = 5.45) condition; t(56) = 5.01, p < .001, d = 1.34. Specifically, Levene's test of intrinsic cognitive load items showed that equal variances could be assumed (F = 1.41, p = 0.24), and controlled (M = 8.03, SD = 2.8) condition showed higher cognitive load than treatment (M = 5.7, SD = 2.28) condition; t(56) = 3.4, p < .001, d = .91. Levene's test of extrinsic cognitive load items showed that equal variances could be assumed (F = 0.19, p = 0.66), and controlled (M = 7.17, SD = 1.73) condition showed higher cognitive load than treatment (M = 5.85, SD = 1.99) condition; t(56) = 2.65, p = .011, d = .71. Finally, Levene's test of germane cognitive load items showed that equal variances could be assumed (F = 2.96, p = .91), and control (M = 7.76, SD = 2.57) condition showed higher cognitive load than treatment (M = 4.59, SD = 1.47) condition; t(56) = 5.59, p < .001, d = 1.5.

Transfer scores. An independent-samples t-test was conducted to compare transfer in control and treatment groups. Levene's test showed that equal variances could be assumed (F = 0.78, p = 0.38). There was a significant difference in the scores for control (M = 10.24, SD = 3.37) and treatment (M = 12.26, SD = 2.38) conditions; t (56) = -2.57, p = .013, d = 1.29.

Instructional efficiency. An independent-samples t-test was conducted to compare instructional efficiency in control and treatment groups. Levene's test showed that equal variances could be assumed (F = 0.47, p = .5). There was a significant difference in the scores for control (M = -0.6, SD = 1.08) and treatment (M = 0.65, SD = 0.84) conditions; t (56) = -4.807, p < .001, d = .69.

Table 5. Mean Cognitive load (Intrinsic cognitive load, Extraneous cognitive load, Germane cognitive load), Transfer and Instructional efficiency for Six.

Score type and group	*M*	*SD*	*p*	*d*
Cognitive load				
Control	22.97	5.45	<.001	1.34
Treatment	16.15	4.66		
Intrinsic cognitive load				
Control	8.03	2.8	<.001	.91
Treatment	5.7	2.28		
Extrinsic cognitive load				
Control	7.17	1.73	.011	.71
Treatment	5.85	1.99		
Germane cognitive load				
Control	7.76	2.57	<.001	1.5
Treatment	4.59	1.47		
Transfer				
Control	10.24	3.37	.013	.69
Treatment	12.26	2.38		
Instructional efficiency				
Control	-.6	1.08	<.001	1.29
Treatment	.65	.84		

The main research question tested in this research was supported: Students with sets of least-abled skills emphasis manipulation showed lower intrinsic and extrinsic cognitive load, and higher germane cognitive load than the students with emphasis manipulation regardless of their prior knowledge. Both measures of performance on the conventional task and the subjective measures of cognitive load supported this interpretation.

The first question, whether students experienced sets of least-abled skills emphasis manipulation would perform better on a conventional task or not (See Table 5), was also supported by the study results on cognitive load. The least-abled constituent set of skills emphasis manipulation that minimized redundant information to reduce extraneous cognitive load showed lower cognitive load in treatment group than control group. Specifically, treatment group showed lower extraneous and intrinsic cognitive load and higher germane load (see Table 5). The second question was also supported from the results on transfer (see Table 5). Both sets of results suggest that learners with sets of least-abled skills emphasis manipulation benefit from an improved instructional efficiency (see Table 5).

These results suggested that sets of least-abled skills emphasis manipulation showed benefits on cognitive load, transfer, and instructional efficiency. Besides, learning task sequencing regardless of learners' prior knowledge hindered learning of control and caused expertise reversal effect.

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Discussion

This research was aimed to compare the effects of sets of the least-abled skills emphasis manipulation and originally suggested emphasis manipulation based on computer-supported learning environments. This research identified effects of both of the task sequencing methods on cognitive load, transfer, and instructional efficiency. To exclude redundant information for learners with prior knowledge, the newly suggested sets of the least-abled skills emphasis manipulation task sequencing was utilized, providing learning contents without redundant information on the learning materials. Therefore, using the least-abled skills emphasis manipulation would optimize cognitive load, lead to a better transfer, and enhance learning efficiency. Within this context, the specific research results are as the following.

First of all, sets of the least-abled skills emphasis manipulation has a positive effect on cognitive load than a traditional emphasis manipulation method. Specifically, intrinsic and extraneous cognitive load of treatment group decreased, and germane cognitive load increased. These results showed that learners with sets of the least-abled skills emphasis manipulation integrated and coordinated their prior knowledge and new learning information. In addition, learners with least-abled sets of skills emphasis manipulation did not seem to have expertise reversal effect. Therefore, in computer-based learning environments, learners who have experienced the domains can have successful learning experience when they are provided with the sets of least-abled skills since it can help learners to exclude repetitive learning tasks.

For the second, emphasis manipulation with sets of the least-abled skills lead to better transfer than original emphasis manipulation. With regard to research question 1, it emphasized constituents skills excluding redundant learning materials, thus learners could concentrate on their least-abled skills and it led better transfer. Therefore, learning constituents and tasks which are organized with tasks that individual learners need, should be provided in emphasis manipulation sequencing of complex tasks while minimizing cognitive burden of learners.

For the last, sets of the least-abled skills emphasis manipulation has a positive effect on learning efficiency while showing significant differences in cognitive load and transfer than emphasis manipulation method. Emphasis manipulation sequencing based on computer-supported learning environments to carry out complex tasks can be modified according to learners' sets of least-abled skills. This sequencing helps learners to have a lower cognitive effort and lead to high task performance.

These results support previous research which claimed that educational methods that help novice learners can hamper learners with subject area expertise (Kalyuga & Renkl, 2010; Van Merriënboer & Sweller, 2010). As identified in the research of Kalyuga, Chandler and Sweller (1998), Yeung, Jin, and Sweller (1998), this research also identified that learners provided with only necessary information resulted in lower cognitive load than learners provided with whole information about learning domain. The reason for these results is that redundant information burdens learners with unnecessary cognitive processing for reconstruction of schema (Sweller et al., 2011).

Conclusions

Sets of the least-abled constituent skills emphasis manipulation was identified to be more effective on optimizing cognitive load, transfer, and instructional efficiency than originally suggested emphasis manipulation. Current research showed that task sequencing focused on the learners' sets of least-abled constituent skills can lead learners to a better learning achievement with a more optimized cognitive load. Emphasis manipulation with sets of the least-abled skills was suggested as a theoretical foundation for learners' personalized learning in a complex learning process. This task sequencing can be applied as a designing principle to support individual learners in various contexts. It is needed to identify whether this sequencing method can be effective and efficient for practitioners within diverse work environments to gain empirical evidences.

Implications of research are as following. When performing complex tasks, this research suggested learning sequencing which can lead to higher transfer of experienced learners. In the viewpoint of cognitive load, complex learning tasks basically have high intrinsic cognitive load. Therefore, it is needed to decrease extrinsic cognitive load in order to increase germane cognitive load. At this time, learners with learning experiences should be provided with learning materials while excluding unnecessary learning information, and then it can lead to better integration and coordination of knowledge.

The research about sets of least-abled skills emphasis manipulation provided theoretical implication on the whole-task sequencing for complex tasks. In computer-based learning environments, emphasis manipulation with least-abled skills can provide individual learners with appropriate whole-tasks sequencing. At the same time, this sequencing helps learners to prospect whole learning tasks but offer learning information based on individual learners' least-abled skills. It can help learners to follow effective cognitive process and simultaneously help instructors to operate effective instructional design and program.

Open resources and contents access from different channels can facilitate learners' various learning experiences and this can increase individual differences. More specifically, Push environments can increase learners' cognitive load, thus Pull learning environments which provide identified and categorized learning materials prior to learning process according to least-abled skills of learners. Consequently, effectiveness and efficiency of sets of least-abled skills emphasis manipulation can offer implication for optimized instructional design for individual learners.

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