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Application of Completion Problem Effect in Teaching – Learning by Teaching

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ABSTRACT

When preparing PowerPoint (PPT) slides, instructors often revise existing slides provided by textbook authors based on teaching needs. During this process, we think very carefully and deepen our understanding of the course contents. This is an excellent learning opportunity. Similarly, students can also learn well if they develop and make a presentation for each chapter. They can prepare slides by including their own elaborations and explanations just like instructors do. As an application of the completion problem effect from cognitive load theory, this method can reduce students' cognitive load in understanding new theories and motivate them to learn course contents actively.

KEYWORDS: Cognitive load theory, Completion problem effect

INTRODUCTION

Throughout history, people have accumulated wisdom regarding teaching and learning. Roman philosopher Seneca said, "While we teach, we learn." That is, the best way to learn new knowledge is to teach others (ideas.time.com/2011/11/30/the-protege-effect/). This is an innate experience of the human being. In many other cultures, we can also find similar statements regarding teaching and learning, although the sources are less clear.

Today, university professors have the same experience: we are learning while we teach our students. As a faculty member, preparing chapter slides is the most common activity in our teaching practice. This is also a learning process of ours. However, before the advancement of productivity tools like MS Office, it was a very time-consuming task for instructors to prepare course lectures. Professors had to summarize key teaching points and develop slides manually. Finally, they had to print slides on transparency films for overhead projection.

Now we have many electronic supplemental teaching materials from publishers, which provide significant support to our teaching. In addition to test banks, case studies, and video clips, PowerPoint slides of chapter contents are also prepared by authors. These slides include key points of each chapter and provide a logical framework of chapter contents, but many of them are not perfect for us to use directly. Instructors often revise and customize these slides based on their teaching needs. During this process, we review the contents of each chapter, check reference books for details and more elaboration, prepare for possible questions from our students, and practice our lectures before class to ensure that we speak appropriately. This is truly a great learning process that includes thinking and designing.

As an effective learning method, reader-generated elaborations have been studied and applied for many years (Reder, Charney, & Morgan, 1986; Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Chi, de Leeuw, Chiu, & Lavancher, 1994; Renkl, Stark, Gruber, & Mandl, 1998). When making the presentation, people also elaborate each point by giving more details of the presented concepts. That is, the presenters generate elaborations based their understanding and prior knowledge. The readers' elaborating process can not only help their learning, but also help the retention of the learned contents (Reder, Charney, & Morgan, 1986). As many instructors have been experiencing, assigning students to read textbooks out of class is a challenging task. Alternatively, reading summary and major points is often more effective in learning than reading hundreds of textbook pages (Reder & Anderson, 1980, 1985). Likewise, PowerPoint slides consist of the summarized points of each chapter. Therefore, students can also learn effectively if they can develop their own chapter slides and present the contents. However, reading notes and summaries is still dependent on the self-motivation of students, and instructors have a little control of the completion of such assignments. This is similar to many innovative learning theories which only support students who want to learn, but not those who do not want to learn (Keller, 2006). If students do not read summaries and fail to elaborate the contents using their own words, they are still not able to learn. Therefore, we require a method to ensure students follow the designed procedure in learning. The development of information technology opens a new door for the application of this approach much more widely and which benefits more students. In our method, students are required to record their presentation using a software tool (i.e., CaptureSpace) to ensure students practice in our expected way.

As an application of the completion problem effect of cognitive load theory, students are learning when they follow the framework of PowerPoint slides during a presentation. This method can reduce students' cognitive load in understanding new theories and encourage them to actively learn subject contents at their own pace outside the classroom. The paper is structured as follows. First, we review the completion problem effect and problem-based learning; second, we describe our research methodology; third, we analyze the collected data regarding students' perceptions; finally, we discuss future research.

PROBLEM BASED LEARNING AND COGNITIVE LOAD THEORY

Currently, there are two major streams of learning theory. The first is based on the philosophy of constructivism. Constructivism means that learners acquire knowledge by incorporating new concepts or ideas into their prior framework (Piaget, 1973). With this philosophy, people develop a series of specific learning methods, such as active learning, experiential learning, discovery learning, exploratory learning, and problem-based learning (PBL). Of many learning approaches rooted in constructivism, problem-based learning is a widely applied method in education since its inception in mid-1960s' (Loyens, Rikers, & Schmidt, 2006), and has several variations such as project-based learning, case-based learning, and inquiry-based learning (Loyens, Kirschner, & Paas, 2011). Although the PBL process is very organized and has a clear procedure, the fundamental principles are as follows: students are supplied several questions and study by themselves in a facilitated study group (Loyens, Kirschner, & Paas, 2011).

With the wide applications of problem-based learning in the past decades, instructors have gradually realized certain shortcomings of this method. Teachers found that many students become confused in their learning. The major problem stems from cognitive load consideration. Constructivism assumes that learners incorporate new concepts or ideas into their prior knowledge framework when learning. However, in many fields like technology application, new learners do not have any prior framework in mind about a new theory or concept. For example, people have few chances to develop experience about Java programming in their daily lives. In practice, one very difficult task is for students to build a framework and then continue into further and deeper learning. Pure problem-based learning causes a significant cognitive load to learners and so the learning is far less effective. That is, many students may feel overloaded and confused when they study subject knowledge by exploring assigned problems. Of course, this can be alleviated by well-trained facilitators. However, the demand on facilitators is very high, regardless of the time and skills. There is a high burden for facilitators in preparing materials, questions, and support.

The second stream of learning theory is based on cognitive load theory. Cognitive load theory indicates that learning is most effective when the germane cognitive load for real learning is high, and the total cognitive load is within the limit (Sweller, 1994). Cognitive load theory provides a guideline for instructors to design courses. Under the guidance of cognitive load theory, instructors ensure students learn effectively by providing instructions under the cognitive load limit of students. Based on the cognitive load theory, there are several effects regarding the human learning process, including the goal-free effect, worked example effect, completion problem effect, split-attention effect, modality effect, redundancy effect, and variability effect (Sweller, van Merrienboer, & Paas, 1998). These effects have wide applications in the design of learning approaches. As an effective way in learning design-oriented skills, "Completion problems are problems for which a given state, a goal state, and a partial solution are provided to learners who must complete the partial solution." (Sweller, van Merrienboer, & Paas, 1998, p. 275). The preparation of lecture slides is a design process. With PPT slides provided by authors, we have a basic framework of chapter contents and we need to fill in the details and make changes based on our needs. As an instructor, we prepare slides for each chapter and teach students step by step. During the preparation process, we check for difficult points and find more details to enhance our teaching. This is a completion problem process. From another prospective, this is also a guided problem based learning process since we can explore each difficult point and search for answers from the textbook or other sources such as the internet. Integrating the completion problem effect of cognitive load theory and some key components of problem-based learning will provide us the strengths of both learning strategies and avoid their weaknesses. Preparing slides from scratch is a challenging task and requires substantial mental effort. This is not a simple review process of existing materials. It involves significant amounts of critical thinking and learning activities. The completion problem effect can reduce learners' cognitive load by providing a learning framework. With PPT slides from the author, students have a basic framework in understanding the major points of each chapter. This framework significantly reduces students' cognitive load when constructing knowledge in their mind. On the other hand, PBL has many advantages in fostering active learning with very effective components. For example, at the student level, student directed learning encourage students to learn actively with better self-control, and the learning results will last longer than regular lecture-based learning (Loyens, Kirschner, & Paas, 2011). Integrating effective components of PBL into the cognitive load theory based learning approach enables students to learn actively within a well prepared subject framework. As one self-directed learning format, students can actively explore various problems when they review and prepare the presentation slides. During this designing process, students fill in the details of concepts by studying materials from textbooks and other resources. The recorded presentation ensures students go through the whole chapter without missing important points.

METHOLOGY

The method was first implemented in an in person, face-to-face class, which is a management information systems course about decision support systems. This is a very comprehensive course, including almost all kinds of current analytics topics. The contents are very diverse. One challenging issue is to ensure our students have a good and comprehensive understanding of these many topics. In order to help students' learning, we developed this assignment to allow students to customize lecture slides for each chapter and make their presentations at home. Each class participant is expected to develop one presentation for each chapter by customizing/tailoring the PowerPoint slides accompanied with the textbook. The presentation is recorded using a software tool, CaptureSpace Lite. By making this presentation, students can go through all important contents without missing key points, and they are encouraged to think actively and carefully. With this presentation, students can also practice the important skill of presentation making. The presentation should include at least 30 slides. Students are required to share their chapter presentations on Blackboard, as well as provide feedback (rating and comments) for the presentations of their classmates.

To evaluate the impact of the overall approach, we investigate the cognitive impact to students. The results tell us if students can handle this approach with high satisfaction and motivation. Considering the characteristics of a pilot study, this is a bonus assignment in our first trial. Students choose to do it on a voluntary basis. We first investigate the cognitive load imposed on students in the learning process. From this, we will investigate how much germane cognitive load was carried out during learning. In addition, we also study users' interest, motivation, pressure, and satisfaction about using this learning method. The survey questions are adapted from other existing studies about cognitive load theory and applications. Please check appendix for the questionnaire.

STUDENTS' PERCEPTION

There are six responses from the class. Three are from male students, and three are from female students. The average age is 23.67. Table 1 indicates the students' perception (Mean and Std. Dev.) of different cognitive loads, mental effort, and perceived performance.

Table 1: Cognitive Load Measurement

	Intrinsic Load			Extraneous Load			Germane Load				Mental Effort	Perceived Performance
	IL1	IL2	IL3	EL1	EL2	EL3	GL1	GL2	GL3	GL4	ME	PER
MEAN	3.50	3.17	3.50	1.67	1.50	1.50	6.67	6.67	6.67	6.67	4.67	6.00
STD.	1.22	0.75	1.38	1.21	0.84	0.84	0.52	0.52	0.52	0.52	0.82	1.26

The sample is very small, but the descriptive data analysis still shows very promising findings. From the above table, we can see that the intrinsic load is medium, but the extraneous load is quite low, and the germane load is high. This clearly indicates the effective use of cognition effort using this methodology. Based on cognitive load theory, the goal of good instructional design is to minimize the extraneous load and have higher germane load in learning (Kirschner, Ayres, & Chandler, 2011). Therefore, this is a very effective learning method. Also, the invested mental effort is appropriate, but the perceived performance is high.

The students' intrinsic motivation is very important to the learning performance (Bradford, 2011). Many kinds of tactics and strategies have been developed to increase learning motivation from students (Keller, 2016). Here, we also look at the students' perceptions (Mean and Std. Dev.) about motivation, satisfaction, interest and pressure (See Table 2). The learning interest, motivation, and satisfaction are all high with this method. The students feel a low pressure at the same time.

Table 2: Intrinstic Motivation and Performance

	Interest		**Motivation**	**Pressure**	**Perceived Satisfaction**			
	INT1	INT2	MOT1	PRE1	PS1	PS2	PS3	PS4
MEAN	6.17	6.17	6.17	3.00	6.00	6.33	6.33	6.33
STD.	1.33	1.60	1.33	1.55	1.10	0.82	1.03	1.03

DISCUSSION AND FUTURE RESEARCH

The advantage of this method is substantial. Students can enhance their learning under the guidance of the instructor by following the PPT slides, and develop critical thinking skill by including their understanding and elaborations in the presentation. Students can also practice presentation skill frequently, which is impractical in the traditional classroom setting. With the replying function and peer rating function offered by course management systems (e.g., Blackboard), students receive feedback about their presentations from other students. To guide students in their presentation, the instructors also provide feedback about the quantity and quality of their presentations.

Most students in this class chose to complete this optional assignment, but only part of the participants completed the research survey voluntarily. In the survey, respondents gave very positive comments about this proposed method. In their comments, students clearly mentioned that this assignment can help them better prepare for class learning. Students think this innovative method can help them understand covered concepts. Different from many other research studies regarding teaching and learning, which usually evaluate effectiveness by comparing test scores before and after using a proposed method, we evaluated our proposed approach by measuring the perceived cognitive load and satisfaction of students. From the perspective of cognitive load theory, students invest their major cognitive effort on real learning activity and low effort on extraneous cognitive load when delivering presentations. Furthermore, students show a very high motivation and satisfaction about using this method, and they feel very low pressure to learn. The findings clearly indicate that students can easily accept this method and benefit from it.

Although the qualities of slides provided by textbook authors vary case by case, these slides do describe a logical framework for students to think and learn. Students can achieve high perceived satisfaction with appropriate mental efforts. If students do this assignment before the class, they can have an overview of the contents and are more prepared for the class meeting. If students do this assignment after a class meeting, they can review the chapter contents with better understanding. Very importantly, with the support of modern information technology, this method is easy to implement in online, hybrid, and face-to-face classes. Most of the work in this assignment is controlled by students. Instructors do not need to invest too much extra effort. Therefore, it can be easily accepted by both students and instructors.

As an exploratory study, the collected sample is very small, so we only have a descriptive data analysis in this paper to demonstrate the effectiveness. However, the findings are very encouraging. In the future, more rigorous empirical investigations about the students' short-term and long-term performance need to be conducted. We can compare the relative teaching efficiency with other learning methods in different courses. Empirical studies can provide us further information about its effectiveness and compatibilities with different subjects.

APPENDIX: SURVEY QUESTIONNAIRE

Part A: Demographic Information

Age (subjects must be at least 18 years old): _____________
Gender: Male Female

Times of making chapter presentations: _____________

Part B: Cognitive Efforts and Learning Achievements

Cognitive Load
(Adapted from Leppink, Paas, Van der Vleuten, et al. (2013))

Measured using a 7-point, Likert-type scale, ranging from 1 (strongly disagree) to 7 (strongly agree).

Intrinsic Load
IL1: The topic/topics covered in the activity was/were very complex.
IL2: The activity covered contents that I perceived as very complex.
IL3: The activity covered concepts and definitions that I perceived as very complex.

Extraneous Load
EL1: The instructions and/or explanations during the activity were very unclear.
EL2: The instructions and/or explanations were, in terms of learning, very ineffective.
EL3: The instructions and/or explanations were full of unclear language.

Germane Load
GL1: The activity really enhanced my understanding of the topic(s) covered.
GL2: The activity really enhanced my knowledge and understanding of contents.
GL3: The activity really enhanced my understanding of the contents covered.
GL4: The activity really enhanced my understanding of concepts and definitions.

Mental Effort
(Meissner & Bogner, 2012; Paas & van Merrie¨nboer, 1993**)**

How would you rate the mental effort you invested in doing presentations?

1: very, very low mental effort .. 4: medium mental effort .. 7: very, very high mental effort

Perceived Performance
(Adapted from Hart (2006))

How successful do you think you were in understanding the chapter contents?
1: very, very little successful 4: medium successful 7: very, very successful

Intrinstic Motivation and Performance Subjective Rating
(Adapted from Molina, Redondo, Lacave, and Ortega (2014)**)**

Measured using a 7-point, Likert-type scale, ranging from 1 (strongly disagree) to 7 (strongly agree).

Interest:
INT1: This method was fun to do.
INT2: I thought it was an interesting activity

Motivation:
MOT1: I felt motivated during the activity.

Pressure:
PRE1: I felt nervous while doing the activity.

Perceived Satisfaction:
PS1: I am satisfied with accessing learning contents using this method.
PS2: I am satisfied with the interaction with this method for studying.
PS3: I think that using this method for learning could be motivating.
PS4: I like using this method for studying.

Comments about Using the Proposed Method in Learning:

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