Wong, L.-H. et al. (Eds.) (2013). Proceedings of the 21st International Conference on Computers in Education. Indonesia: Asia-Pacific Society for Computers in Education

Exploring the Effect of Worked Example Problem-based Learning on Learners' Web-technology Design Performance

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Abstract: The process of creating media products, maximizing the merits of advanced interactive technology is very complex. Media producers are highly demand of their cognitive abilities to integrate multiple domains of knowledge, which may include graphic design, technology skills, and problem-solving skills. The problem-based learning strategy (PBL), starting learning with a real-world problem, has been frequently adopted to develop the competency of learners with a major in technology or media production. Despite the fact that PBL effects have been reasonably argued and empirically tested, its associated learning tasks may overload the learners. This paper, grounded on the cognitive load theory, aimed to investigate the effects of worked examples on learners' web-technology design skills. The web-technology design problem was chosen as the main problem for participants to explore during the PBL activity. A series of problems and associated worked examples were developed. Furthermore, a web-based learning system was created to engage participants in observing the problems, watching the examples and practicing solving the given problems. A pre-and-post experimental design was adopted to test the effect of worked-examples. 80 university students, with a major in instructional technology programs, were invited to participate in the study and were randomly assigned to one of the intervention conditions. The finding supported the positive effect of the worked example on enhancing learners' web-technology design performance.

Keywords: Web-technology design performance, worked-out examples, problem-based learning

1. Introduction

Designing media products, using diverse features of advanced interactive technology is a very complex process, which demands media producers' cognitive abilities to integrate graphic design knowledge, web-technology design skills, problem-solving skills, and so on. They have to use the knowledge and skills to analyze the problems and devote cognitive capabilities to identify the differences between those problems and problems they have solved in the past, and come up a better solution. Once they successfully solve the problems, they also have to integrate the knowledge and experience learned during the problem-solving process into their existing schema, which may serve as their knowledge base for dealing with another problem in the future (Bransford and Schwartz, 1999; Chi and VanLehn, 2007; Jonassen, 1997). Therefore, training of media producers should move beyond focusing on the technology knowledge or techniques. Facilitating them in synthesizing diverse skills to solve given problems and re-constructing their scheme during problem-solving process should not be ignored.

Problem-based learning (PBL) engages learners in reasoning through real-world problems (Hmelo and Evensen, 2000), emphasizes the process of solving the process and encourages them to synthesize and construct their own knowledge base. This strategy helps them to associate the learned concepts or techniques with their application in the workplace, thus leading to enhancement of learning transfer (van Merriënboer, 2007; van Merriënboer and Kester, 2007; van Merriënboer, Kirschner and Kester, 2003). However, the learning tasks designed based on PBL might demand learners' intrinsic cognitive efforts to explore the knowledge elements associated with the given problem or task. Learners with less knowledge or lower cognitive capabilities might devote their attentions and efforts both to relevant and irrelevant information, which might exceed their limited cognitive capacity and thus, decreasing the positive learning effect of PBL (Sweller, 2010; Sweller, van Merriënboer and Paas, 1998).

Therefore, prior studies have suggested incorporation of worked examples as a scaffold into PBL to facilitate learners in managing their limited cognitive capacity to construct their schema (e.g. Ayres and Paas, 2009; Kirschner, Paas, Kirschner and Janssen, 2011; Renkl, 1997; Sweller et al., 1998). Despite the effects of worked-out examples have been evidenced in more well-structured learning tasks (e.g. Atkinson, Derry, Renkl and Wortham, 2000), few studies validated its effects in the ill-structured learning tasks, such as web-technology design. Therefore, the purpose of this study is to explore the influence of worked example problem-based learning, (WPBL) on university learners' web-technology design performance.

2. Literature Review

Problem-based learning (PBL) engages learners in problem representation, analysis, solutions creation and evaluation. In order to correctly interpret and process the PBL task, learners do not only need to understand the concepts represented in the problems, but also to think through the interrelationships among those elements. On one hand, this strategy, if adopted appropriately, could impose the germane cognitive load on learners, encouraging them to actively construct knowledge of their own. On the other hand, this strategy could impose heavy intrinsic and extraneous cognitive load on learners, which affects the learning effects (Sweller et al., 1998).

Two design issues need careful attention while designing and implementing PBL. First, as PBL encourages cooperative learning, perspectives of the cooperative learning theory as well as the cognitive load theory should be taken into consideration. The cooperative learning theorists proposed that the diversity among team members could help learners to approach the given tasks from multiple perspectives. Similarly, the cognitive load theorists argue that when working in a cooperative condition, the information necessary to carry out the task and its associated cognitive loads can be executed in the expanded working memory capacity constituted by that of all the team members (Kirschner, Paas and Kirschner, 2009). This expanded working memory capacity could imply the existence of less intrinsic cognitive load for each individual group member (Kirschner et al., 2009; 2010). At the same time, learners might need to devote more time and effort to communicating with their peers who have different cognitive abilities and schemata in order to reach a consensus on the shared workload, and thus co-construct group schema. This may then prevent groups from effectively carrying out the task, and even negatively affect learning, if it reaches a state of cognitive overload (Kirschner et al., 2009). Therefore, to reduce the extraneous cognitive load resulted from communicating with the peers, this study allowed the subjects to choice their partners to work with.

Second, the scaffolds, such as worked-out examples, designed to facilitate learners in effectively managing their cognitive capacity to construct their own schema of the learned content have gained increasing attention (e.g. Ayres and Paas, 2009; Kirschner et al., 2011; Renkl, 1997; Sweller et al., 1998). The worked-out examples guided leaners to focus on the critical information of the given problems, excluding the irrelevant information, which could effectively decrease the extraneous cognitive load (Hübner, Nückles and Renkl, 2010; Paas and van Gog, 2006; Stark, Kopp and Fischer, 2011; van Gog, 201l; Wittwer and Renkl, 2010). Furthermore, it helps them to concentrate on schema activation by observing the problem-solving strategies and process presented in the examples, and to re-construct their own schema for solving the similar problems (Atkinson et al., 2000; Renkl, 2005; van Gog, Paas and van Merriënboer, 2004). Its positive effects on learning have been evidenced in science and mathematics learning under the context of well-structured learning tasks (e.g. Atkinson et al., 2000; Paas and van Merriënboer, 1994; Sweller et al., 1998). Additionally, its positive effects were supported in the domain of instruction theories (e.g. Hoogveld, Paas and Jochems, 2005), argumentation development (e.g. Schworm and Renkl, 2006) and so on.

However, providing worked-out examples does not guarantee students' effective utilization of cognitive capacity to interpret the examples and construct schema (Gerjets, Scheiter and Catrambone, 2004; Renkl, 1997). While solving an ill-structured problem, such as a web-technology design problem, reading the worked-out examples could impose learners cognitive load. Worked-out examples, which simulate experts' reasoning process and solutions, might guide learners to observing the given problems from macro perspectives and focus on the highly relevant information. However, learners may not be able to identify the important information embedded in the examples or they may encounter the difficulty in understanding the contents or strategies presented in the examples (Catrambone and Holyoak, 1989). Instead, it might be easier for learners to imitate the worked-out examples that only present the experts' solution steps. Reading such an example might not demand too many cognitive efforts. However, the examples, which over-simplify experts' problems solving process, may not benefit learners in grasping the critical reasoning points, thus affecting their ability to transfer learned skills to solve more complex problems. Therefore, it brings the needs to test whether the positive effect of worked examples could be generated to the context of learning ill-structured web-technology design skills.

3. Research Method

This study compared the effect of worked example problem-based learning with traditional problem-based learning on learners' web technology design performance. 84 university students, who have a major in instructional technology and passed the basic course of web-design, were invited for this study. All the subjects were asked to form a group of 2 and each group were randomly assigned to one of the two intervention conditions. The interventions were implemented in a series of workshop with the same facilitator, learning topics, web-technology problems, learning system and supporting materials except the instructional strategies (PBL vs. WPBL). Four subjects dropped out of the workshop because the workshop schedule conflicted with their personal meetings; therefore, only data of 80 subjects were included for analysis.

3.1 Research Design

Eighty university students participated in the pre- and post-test experimental study. The web technology design problem was chosen as the main problems for participants to explore during the study. A series of problems and associated worked examples were embedded in the web-based learning system, named EPRARS. The system allowed subjects not only to interact with the given problems by watching the problem scenarios, typing and uploading solutions but also to watch the worked-out examples. Furthermore, subjects' paths of observing the worked-out examples were recorded.

A training session was delivered at the beginning to ensure that the participants possessed the fundamental computer skills required for interacting with the given problems within the adopted learning system. After training, each participant accomplished the pre-test followed by one month workshop. During the workshop, subjects, working in a group, interacted with the system to solve a series of 8 web-technology design problems. Subjects in the worked-example PBL condition could watch the examples on their own pace before proceeding to practice applying the learned strategies to solve the similar problems. At the end, each participant accomplished the post-test.

3.2 Variables and Instruments

The intervention included two levels: the traditional PBL and WPBL. Both levels were structured into two stages: The first stage started with a real-world web-technology design problem. Subjects were asked to observe the problems, identify the web design techniques that are highly related to the problems and try to generate their solutions. Simultaneously an e-manual with several web technology skills listed was given to them as a learning resource. All the eight given problems were sequenced according to problem complexity and difficulty. The subjects were required to solve one before proceeding to the next one. At the second, stage, the subjects solved four more complex web design problems without the manual at hand. In regard with the WPBL intervention, each problem was presented with a worked-out example, which contained three components. The example started with presenting key points for problem interpretation. This component exemplified how web-technology experts would interpret the problem, what key information might be relevant to the problem and how such information might influence ways to approach the problem. The second component simulated experts' thinking and solutions. That is, subjects could manipulate the solution options in every decision nod and watch the demonstration of how the decision was turned into web design effects. The third component explained the impacts of each design decision. This component was designed to help subjects understand the rationale behind each decision taken during the design process.

The dependent variable, which refers to learners' web technology design performance, was assessed by the correctness of solving the given 5 web-design problems within 60 minutes. Additionally, the pretest, including 10 basic web-design skills, was administered to detect pre-existing differences between the two groups.

4. Results and Conclusions

4.1 Results

The descriptive statistics of the variables are listed in Table 1. It can be seen that the subjects in the worked-example PBL group performed better than those in the traditional PBL group. Also, it should be noted that the pre-test scores of the two intervention groups are different; therefore, to use the ANCOVA analysis technique to control the possible effect of the pre-test becomes necessary.

Table 1. Descriptive statistics of the web technology design performance

Variable	No.	Pre-test		Post-test	
		Mean	SD	Mean	SD
Traditional PBL	42	73.38	11.01	71.81	18.46
Worked example PBL	38	80.58	7.22	85.74	14.61
Total	80	76.80	10.18	78.42	18.05

ANCOVA analysis, using the pre-test scores as the covariate was conducted to examine whether the subjects engaged in the worked examples PBL condition performed significantly better than those in the PBL condition. The Levene's test was conducted to examine the homogeneity of the variances. The assumption of the ANCOVA was not violated ($F=.85$, $p=.35$). As can be seen in Table 2, the statistically significant difference in the post-test scores between the two intervention groups was supported by the ANCOVA result. ($F=8.27$, $p=.005$)

Table 2. ANCOVA results

Source	Sum of Squares	df	Mean Square	F	P-value	Partial Eta Squared	Observed Power[c]
Corrected model	4711.24[b]	2	2355.62	8.63	.000	.18	.96
Intercept	3086.77	1	3086.77	11.30	.001	.13	.91
Pre-test	841.53	1	841.53	3.08	.083	.04	.41
Intervention	2259.73	1	2259.73	8.27	.005	.10	.81
Error	21030.31	77	273.12				
Total	517780.00	80					
Corrected Total	25741.55	79					

a. The dependent variable is web-technology design performance
b. R squared = .183 (adjusted R Squared = .162)
c. $^{*} < .05$, $^{**} <.001$

4.2 Conclusions

This study evidenced the positive effects of the worked example PBL on enhancing learners' web-technology design performance. Specifically, the worked-out examples simulating experts' reasoning process with additional explanations on the rationale behind the decision helps learners not only to concentrate on the problem-solving process but also to transfer learned strategies to solve similar problems. Therefore, incorporation of well-designed worked examples into PBL is recommended. Furthermore, in the current study, the measurement of learners' web-technology design performance was limited to learners' abilities to solve a series of web design problems. Future research is suggested to explore whether the worked example PBL would help learners to transfer learned web-technology skills to develop a web-based product.

Acknowledgements

This paper was funded by the research grant from the National Science Council, Taiwan, ROC (NSC 100-2511-S-032-002). The author would like to thank research assistants, Chia-Lun Chang, Zi-Xuan Su, Pi-Han Lo, Li-Chun Huang, Kai-Feng Zheng for their assistance during the learning system design and data collection process.

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