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The Effect of the Types of Learning Material and Epistemological Beliefs in an Ill-structured Problem Solving*

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This study investigated the effect of learning achievements and cognitive load according to different types of presenting learning materials and epistemological beliefs (EB). Learning achievements in this study were composed by retention and transfer of ill-structured problem. A total of 80 college students participated in the study. Prior to the learning, students were guided to fill out a questionnaire regarding epistemological beliefs and a prior knowledge test. The students of each group studied with a different type of reading material: full text (FT), full text including key questions (KeyFT) and full text including a concept map (CmFT). After a session of study was finished, they were asked to complete the posttest: retention and transfer. The results showed that there was a significant difference in transfer achievements. CmFT outperformed higher scores than the other types. There was no significant difference in retention among the groups. It is strongly believed that the types of presenting learning materials may have affected the understanding of ill-structured problem solving skills. Students with sophisticated EB showed higher achievements on retention and transfer than naïve-EB and mixed-EB. Even though the data showed decrease of the cognitive load on the type of materials and EB, there were no significant differences on the cognitive load. We should consider a positive effect of types of presenting learning materials and EB enhancing capabilities of solving ill-structured problems in real life.

Keywords : Learning material types, Epistemological beliefs, Retention, Transfer, Ill-structured problem

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Introduction

One of the most important purposes of college education is to enhance problem solving skills to adapt to the complicated modern society. Almost all problems experienced in ordinary life are ill-structured problems. Jonassen(1997) classified problems according to the degree of structuredness as the problem situation, solutions and processes: well-structured and ill-structured. We meet the well-structured problems at the end of college textbook chapters. These problems have a finite number of concepts, rules and correct answers. On the other hand, ill-structured problems are kinds of problems that are encountered in life. The solutions require many alternatives and complicated processes that they need multiple solutions and approaches, and there is no a single solution. Therefore, when students faced to solve ill-structured problems, they should search more knowledge and construct theoretical background justifying their beliefs. (Valanides & Angeli, 2005).

Previous study showed that the process of the problem solving between well-structured and ill-structured problem was basically different (Shin, Jonassen & MaGee, 2003). Different epistemological beliefs and justification are developed by the characteristics of task (Hofer, 2004; Jonassen, 2000; Muis, 2007). Therefore, solving ill-structured problems are more related to the epistemological beliefs than the well-structured knowledge. Students might experience more cognitive load with ill-structured problems than that of well-structured situations due to the task they need to define what the problem is and draw a set of a hypothesis and determination leading to a solution.

This study was to examine ill-structured problem solving achievement and the cognitive load through the types of learning materials and epistemological beliefs. Although there were a lot of previous studies on the presentation types and cognitive load, only few studies considered epistemological beliefs, presentation type and cognitive load. This study investigated the effect of ill-structured problem

solving according to the different types of presenting learning materials and epistemological beliefs.

It is believed that there have been numerous cases of researches performed on the design of the learning materials to enhance the learning achievement and decrease the cognitive load (Mayer & Anderson, 1991; Mayer & Gallini, 1990; Mayer & Moreno, 1998). Mayer & Gallini (1990) studied how to design the scientific text such as the types of illustrations. Mayer & Anderson (1991) reported the words-with- picture group outperformed the words-before-pictures group on tests of creative problem solving that involved reasoning about how the pump works. In a follow-up experiment, students in the words-with-pictures group performed better on the problem-solving test than the students who saw the animation without words, heard the words without the animation, or received no training. Methods of instruction which are intended to facilitate understanding tend to incorporate all the information elements required for understanding the instructions. However, to decrease the cognitive load and help in understanding, in the first phase, the element of complicated information was artificially divided by presenting the material as isolated elements of information. In the second phase, all the information for understanding is presented (Kester, Kirschner & Morrënboer, 2005; Leahy, Hanham & Sweller, 2015; Pollock, Chandler & Sweller, 2002). Some studies used advanced organizer in the learning materials to reduce the mental effort and solve the complicated problem solving (Oh & Kim, 2006, Oh, Kim, Jung & Kim, 2009).

It's very important to reduce the unnecessary cognitive load to design the learning materials (Kalyuga, Chandler & Sweller, 2000; Mayer & Moreno, 2003). This study applied the strategies of designing learning materials to decrease the cognitive load and enhance learning. Each of college students in the groups was provided with the reading materials. The content of the materials was the same but the type of presenting information was different. The types of reading materials given to the groups are as follows: FT-type which was very similar to ordinary

college text written as whole texts. It was a four-paged with 2000 words. KeyFT-type was written in full-texts including questions which are added below the passages of 2-3. CmFT was full text which included a concept map. After reading materials, students had to solve the ill-structured problems. The concept map plays a role of a schematic device representing a set of concept meaning embedded in a framework of propositions (Novak & Gowin, 1984). Previous studies showed concept map facilitated the understanding and decreasing the cognitive load (Amadieu, Van Gog, Pass & Tricot, 2009; Chang, Sung & Chen, 2002; O'donnell, Dansereau & Hall, 2002; Oh et al., 2009; Paas, Tricot & Mariné, 2009; Van Gog, Kester, Nievelstein, Giesbers & Paas, 2009; Verhoeven, Schnotz & Paas, 2009). When college students read a text book, concept map and an appropriate summary question could decrease the memory load to understand the content. It was hypothesized that the CmFT and KeyFT might have advantages to decrease the cognitive load and understand learning material with higher efficiency. FT group would experience higher cognitive load than the other groups.

Epistemological Beliefs is a fundamental assumption about the nature of knowledge and learning, the certainty of knowing, and the criterion of knowing. Epistemological beliefs contain an individual's beliefs about the source, certainty, and organization of knowledge along with the control and learning speed of that knowledge (Schommer, 1990). Previous studies have examined the effects of epistemological beliefs on learning; for example, on reading comprehension (Schommer, 1990), text processing (Kardash & Howel, 200l), and conceptual change (Ding & Mollohan, 2015; Hatlevik & Smeby, 2015; Mason & Boscolo, 2004). Epistemological beliefs also affect problem solving skills (Mehdinezhad & Bamari, 2015) and strategies in ill-structured environments (Jehng, Johnson & Anderson, 1993; Schommer, 1993; Weinberg, 2015). Epistemological beliefs influence achievement, learning strategies and comprehension criteria. Students who have more simplified thoughts about knowledge structure showed higher simplified diagnosis than those with more complicated thoughts. They also ignored

various and idiosyncratic patient situations in the decision making process (Spiro et al., 1988). It was predicted that students who have more advanced and sophisticated beliefs would perform higher achievement on the retention and ill-structured transfer problem solving.

Cognitive load theory can provide guidelines to assist in the presentation of information in a manner that encourages learner activities that optimize intellectual performance (Merriënboer et al., 2002; Kirschner, 2002; Sweller, 1988). Cognitive load theory which assumes a limited working memory is connected to an unlimited long-term memory (Baddeley, 1986). As a result of this limitation, instructions should be designed in a way that the working memory is capable of processing in the instructions. Cognitive load theory, thus, is concerned with the limitations of working-memory capacity. Therefore, this study assumed that the group of only full-text-provided without learning aids would deeply feel certainly learning difficulty. The learning aids such as key-questions and concept maps could decrease the cognitive load and increase the level of comprehension. This study had predicted that the KeyFT and CmFT would affect not to exceed the working memory capacity. On the contrary, FT could impose the higher memory load to integrate the contents than the other groups.

Relatively few studies have examined certain types of learning materials and epistemological beliefs on achievement and cognitive load. The purpose of this study was to investigate the effect of learning material design and epistemological beliefs on the complicated problem solving and cognitive load. In order to meet these purposes, we have drawn the research problems as follows:

First, could the types of learning material affect on the ill-structured problem solving and cognitive load ?

Second, could epistemological beliefs affect on the ill-structured problem solving and cognitive load?

Methods

Subjects and groups

A total of 80 college students who are involved in the area of education participated in the study. Five students were excluded from data due to their incomplete and missing information. The female students were 53(70.7%) out of 75. The age groups were as follows: 34(45.3%) belonged to the 20 and below age group, 34(45.3%) belonged to the 21 to 25 age group, lastly, 7 (9.3%) belonged in the above 26 group. In responses as to what the preferred learning method were as follows: 42(56%) preferred lecture, 17(22.7%) chose cooperative learning, reported discussion 11(14.7%) and 5(6.7%) indicated individualized learning. Moreover, the responses of the students about their most interesting theme were social issues with 20(28.6%), natural science with 6(8.6%), politics and economics with 4(5.3%), and culture and arts with 40(57.1). 5(6.6%) students did not answer. It was also noted that participants in their 20s were interested in lecture-type learning and culture and arts.

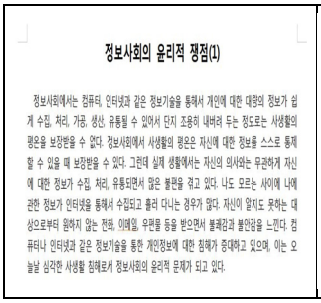
Learning material and measurement instruments

The students' epistemological beliefs were assessed using the Korean version of Epistemological Beliefs Questionnaire (Park & Jung, 2012). Park & Jung (2012) adapted and validated the EBQ using Schommer's (1990) and Hofer's (2004) scales. The EBQ is comprised of 46 items rated on a five-point likert scale (5 = strongly agree, 1 = strongly disagree) to reflect 12 belief systems. Table 1 is an epistemological beliefs 2 x 6 factorial structure. The reliability of the sophisticated EB was $\alpha = 0.78$, the reliability of naïve EB's one was $\alpha = 0.76$.

To identify the types of epistemological beliefs, we divided epistemological groups into sophisticated-EB, naïve-EB and mixed-EB. The standard was the mean scores the sophisticated-EB, and naïve-EB. The group of the sophisticated-EB was

high sophisticated-EB and low naïve-EB scores. The group of the naïve-EB was low sophisticated-EB and high naïve-EB scores. The mixed-EB was an uncertain EB disposition. This group did not have any coherence to make a classification. These students have both high sophisticated-EB and naïve-EB and vice versa.

Each of the groups was given a reading material: full-text- type (FT) which was very similar to ordinary college text, written in whole texts. It was about 4 pages with 2000 words. KeyFT-type was composed by full-text including 2-3 questions written below the passages of 2-3 in 6 pages. CmFT was full text including a concept map in 5 pages. The contents of learning materials were about the information society and ethical dilemma. The retention test merely assessed the recall of factual knowledge. The transfer test measured beyond the just-memorized factual knowledge, problem solving skills. These items required the interpretation of knowledge and inference of an unknown fact from a known fact. By doing this, students were able to solve the ill-structured problems. Retention test consisted of 9 items of multiple choices, and the reliability of retention items was $\alpha = 0.61$. The transfer test was composed by the ill-structured problems. Students were provided the transfer items with story-telling about the infringement of copyright. To solve the transfer items, students had to undergo several procedures such as: identifying problems, finding solutions as many as they can, then make the best decision as reconsidering other possible alternative solutions. The transfer items were assessed by two-raters. The inter-rater agreement (Cohen's kappa) was .92.


정보사회의 윤리적 쟁점(1)

정보사회에서는 컴퓨터, 인터넷과 같은 정보기술을 통해서 개인에 대한 대량의 정보가 쉽게 수집, 처리, 가공, 생산, 유통될 수 있어서 단지 조용히 내버려 두는 정도로는 사생활의 평온을 보장받을 수 없다. 정보사회에서 사생활의 평온은 자신에 대한 정보를 스스로 통제할 수 있을 때 보장받을 수 있다. 그런데 실제 생활에서는 자신의 의사와는 무관하게 자신에 대한 정보가 수집, 처리, 유통되면서 많은 불편을 겪고 있다. 나도 모르는 사이에 나에 관한 정보가 인터넷을 통해서 수집되고 흘러 다니는 경우가 많다. 자신이 알지도 못하는 대상으로부터 원하지 않는 전화, 이메일, 우편물 등을 받으면서 불쾌감과 불안감을 느낀다. 컴퓨터나 인터넷과 같은 정보기술을 통한 개인정보에 대한 침해가 증대하고 있으며, 이는 오늘날 심각한 사생활 침해로서 정보사회의 윤리적 문제가 되고 있다.

Figure 1.
Example of FT.


정보사회의 윤리적 쟁점(2)

정보사회는 만주주의 실현 가능성, 지식정보가치에 대한 새로운 인식, 여가와 생활의 관의성, 다양한 문화의 공존, 평생학습의 용이, 수평적인 의사소통의 활성화 등과 같은 긍정적인 면을 가지고 있다. 하지만 정보사회는 이런 밝은 면만 가지고 있는 것이 아니라 어두운 면도 동시에 가지고 있다. 정보사회의 어두운 면이 가지고 있는 파괴력은 매우 크다. 이는 정보매체에 매우 쉽게 악영향으로 접근할 수 있고, 악용의 결과물이 순식간에 전 세계적으로 복제되고 확산될 뿐만 아니라 원상회복이 거의 불가능하기 때문이다. 이런 점에서 정보사회에서 정보매체에 및 기술과 관련된 인간행위에 대한 세심한 윤리적 성찰과 고려가 요구된다.

1. 정보사회의 사생활 침해의 문제는 무엇인가?
2. 나도 모르게 나의 정보가 활용되어 불편을 겪었던 경험이 있는가?

Figure 2.
Example of KeyFT.


정보사회의 윤리적 쟁점(3)

정보사회의 윤리적 쟁점

Figure 3.
Example of CmFT.

Table 1. Epistemological Beliefs Questionnaires(EBQ) structure

EB structures	Epistemological beliefs levels	
	Naïve-level EB	Sophisticated-level EB
Certainty of knowledge	Certain knowledge	Tentative knowledge
Structure of knowledge	Simple knowledge	Integrated knowledge
Source of knowledge	External authorities	Individual meaning construction
Justification of knowing	Reception of the authority	Personal critical judgment
Ability to learn	Fixed ability	Gradually improved ability
Learning process	Quick learning	Progressive learning

The cognitive load was measured by one-item and 7- point likert scale (7 = highly difficult, 1 = very easy). The tool of cognitive load measurement employed in this study was developed by Pass (1992). The item is 'how difficult and how did you attend to understand reading materials?' It uses post-treatment questionnaires in which students are asked to report the amount of mental effort invested in understanding the learning materials. Through this indirect and subjective measure, we could easily find the general outline of the respondents' mental effort. Although this technique is frequently used in cognitive load research, it remains unclear how this mental effort is related to actual cognitive load (Brunken, Plass & Leutner, 2002). To enhance the reliability and validity of cognitive load measures, the dual-task-methodology which is direct and objective measurement was used (Baddley, 1986; Bruken et al., 2002; Oh & Kim, 2006; Oh et al., 2009; Pass, van Merrienboer & Adam, 1994; Schmeck, Opfermann, van Gog, Paas & Leutner, 2015). On account of many limitations and difficulties using the dual-task-methodology in the authentic learning environment, this study used indirect and subjective self-reported questionnaires.

Procedures

This study was implemented in the first semester of 2014. A week earlier of

the experiment, students were guided to complete a questionnaire regarding epistemological beliefs and a prior knowledge test. There was no significant difference in prior knowledge among the groups (F=.064, p=.938).

After the EBQ and a prior knowledge test, each of the three groups of the students studied with a different type of reading materials: full text (FT), full text including the key questions (KeyFT) and full text including a concept map (CmFT). It took 30-35 minutes to read learning materials. After a session of study was finished, they were asked to complete the posttest of retention and transfer. The posttest of achievement took 35-40 minutes. Moreover, students had to check the difficulties of understanding the reading materials to measure cognitive load.

Results

Retention and transfer achievements according to the types of learning materials

The achievement of CmFT outperformed the other groups. There was no significant difference in retention among the groups (F=.664, p=.518). There was a significant difference in transfer achievements among the groups (F=3.385, p=.039). These differences were FT and CmFT. It is believed that the types learning material may have affected the understanding of complicated problem solving skills.

Retention and transfer achievements according to the EB

Students with sophisticated EB showed higher achievements than naïve and mixed EB on the retention. These differences were a statistically significance (F=3.864, p=.025), the difference between sophisticated EB and naïve-EB. There

Table 2. Mean and SD on achievement according to the type of learning materials and EB level

		N	retention (Max. 8)		transfer (Max. 20)	
			M	SD	M	SD
Types of learning material	FT	24	4.67	1.14	13.54	3.59
	KeyFT	25	4.88	1.24	14.36	4.68
	CmFT	26	5.12	1.37	16.38	3.61
Level of EB	Naïve-EB	25	4.48	1.33	14.92	4.33
	Sophisticated-EB	26	5.46	1.36	16.58	4.44
	Mixed-EB	24	4.71	1.26	12.75	2.42

was also a significant difference on transfer (F=6.141, p=.003): the difference between sophisticated EB and naïve-EB, between sophisticated EB and mixed-EB. Sophisticated EB might be more related than naïve and mixed-EB to solve the retention and transfer achievements.

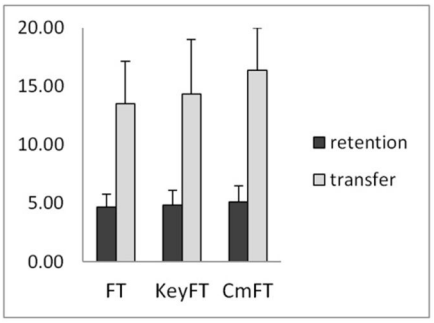


Figure 3. Mean and SD on achievement according to the type of learning materials

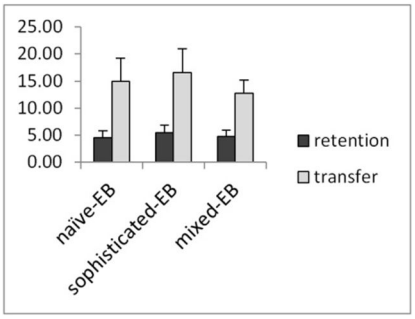


Figure 4. Mean and SD on achievement according to the type of EB

Cognitive load according to the type of learning materials and EB

Students with FT (M=4.77, SD=1.28) reported the higher cognitive load than KeyFT group (M=4.04, SD=1.39) during reading the learning materials. Also, CmFT group (M=3.88, SD=1.72) presented the least cognitive load. The mean

difference of the groups was not statistically significant (F=2.485, p=.090).

Students reported the degree of cognitive load on the EB levels as follows: naïve-EB (M=4.56, SD=1.00), Sophisticated-EB (M=4.00, SD=1.79), mixed- EB (M=4.10, SD=1.64). Even though the naïve-EB group reported the highest load, there was no significant difference (F=.969, p=.384).

Table 4. Mean and SD on cognitive load by the type of learning materials and EB

		N	M	SD
Types of learning material	FT	24	4.77	1.28
	KeyFT	25	4.04	1.39
	CmFT	26	3.88	1.72
Level of EB	Naïve-EB	25	4.56	1.00
	Sophisticated-EB	26	4.00	1.79
	Mixed-EB	24	4.10	1.64

Discussion

The purpose of this study was to investigate the effect of presentation types of learning materials and EB on the learning achievement and cognitive load. Firstly, the presentation of learning materials could not affect the retention. However, they affected the ill-structured transfer problem achievement. These results confirmed our prediction because retention tasks were simple and did not ask for the cognitive resource. Therefore, it can be inferred that learners were not in the need of specific learning strategies and not influenced by cognitive overload in the retention task. However, learners might have needed some aids to facilitate understanding of the contents and organization of the information in ill-structured transfer problems. Students who were provided with the FT material achieved the highest cognitive load among groups. Students of the CmFT group acquired the highest scores on the retention and transfer achievements. These results verified the prediction that

the concept map was possibly able to facilitate students' understanding (Amadieu et al., 2009; Chang et al., 2002; O'donnell et al., 2002; Oh et al., 2009; Van Gog et al., 2009; Verhoeven et al., 2009).

Secondly, the types of epistemological beliefs could affect the retention and the ill-structured transfer problem achievement. The students who have sophisticated-EB showed the higher achievement than naïve-EB and mixed-EB group. Previous studies showed the relevance of sophisticated-EB and learning achievement, especially, problem-solving skills and strategies (Jehng et al., 1993; Mason & Boscolo, 2004; Schommer, 1993).

These results were consistent that different epistemological beliefs had resulted in different problem solving process and achievement (Cho, Lee, & Jonassen, 2011; Hatlevik & Smeby, 2015; Jonassen, 2000; Kim, 2008; Mehdinezhad & Bamari, 2015; Oh & Lee, 2011; Oh & Lee, 2013). In other words, naïve-EB students preferred simple and certain knowledge to complicated and uncertain knowledge. Therefore, sophisticated-EB learners try to use elaborative learning strategies with multiple perspectives. Kienhues, Stadtler & Bromme (2011) investigated how ordinary people deal with conflicting or consistent medicine-related information on the Web. Students having conflicting medicine-related information showed more advanced treatments than when consistent information was provided. Therefore experiencing different ways of thinking can influence development of epistemological beliefs and its changes. These results indicate a need for educational programs encouraging learners to understand their EB in college education. To develop problem-solving skills of college students in the ill-structured real world, we should consider various types of presenting learning materials and level of the epistemological beliefs

Thirdly, CmFT group reported less difficulty in reading materials than FT and KeyFT group EB. But, this mean difference was not a statistically significant. In addition, there was no significant differences among EB levels, although, naïve-EB showed the higher difficulty than the others. As a matter of fact, we predicted CmFT and sophisticated-EB groups would take less cognitive load. These groups

might utilize concept maps and problem solving skills with multiple perspectives and strategies. However, these results did not demonstrate our prediction about the material types and EB levels on cognitive load due to the time interval between reading and testing.

There are a few limitations and suggestions as followings to interpret and apply the result of this study. Firstly, this study used CmFT to decrease the cognitive load in the ill-structured problem solving learning. But presenting the concept map and constructing the concept map by students might be different in the ill-structured reading material task. In the further study, it should be implemented.

Secondly, cognitive load instrument which was used in this study was indirect and subjective self-reported questionnaires. Students had to check the difficulty of reading materials after reading and solving the achievement test. Therefore, the interpretation of these results should have more careful approaches. Educators should consider more reliable and valid tools to check the cognitive load in the further study.

In conclusion, this study showed that the types of presenting learning materials and epistemological beliefs would be able to decrease the cognitive load. Available cognitive resource could help solve the retention and ill-structured transfer problems. To develop the college textbook and present the learning materials, teachers consider the design of presenting types and control of managing students' cognitive load. They also need to consider how to change the student's epistemological beliefs in college education to nurture competent individual learners who have the problem solving skills in the real world.

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