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# 온라인 학습에서 비구조화된 문제에 대한 해결된 예제 효과*

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# The Worked Example Effect using Ill-defined Problems in On-line Learning : Focus on the Components of a Worked Example*

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■ Abstract ■

This study has two goals. The first goal is to investigate whether worked examples are effective in the ill-defined domain with on-line learning and the second goal is to find out which components (conceptual or procedural knowledge) of worked examples are effective factor at the given learning environment. We carried out three experiments in which Korean undergraduate or graduate students were working in three or four conditions of worked examples (CWE, PWE, CPWE, or the control group). While experiment 1 conducted in on-line learning environment did not find any effect and difference among groups and also any logical reason for those results, experiment 2 conducted in completely controlled laboratory setting with less knowledgeable students showed the clear difference among groups by the order CPWE, PWE, and CWE. Experiment 3 in which highly knowledgeable and motivated students were presented the same materials in more controlled on-line learning environment indicated the difference among groups by the order CWE, CPWE, and PWE. The results were discussed within the framework of cognitive load theory.

Keyword : Cognitive Load Theory, Worked Examples, Ill-Defined Problem, On-Line Learning

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# 1. Introduction

Over the last decades, there have been many studies indicating instruction using worked examples can be maximally effective in well-defined domains such as mathematics and science (see Sweller et al., 2011). Recently, it has been tested in ill-defined domains such as literature (e.g., Kyun et al., 2013), design history (e.g., Rourke and Sweller, 2009), and medical domains (e.g., Stark et al., 2011). While the huge success of worked examples in technical domains has been thoroughly approved, it has been still argued that the success of explicit instructional guidance approaches such as worked examples in well-defined domains cannot extend to ill-defined domains (see Spiro and DeSchryver, 2009). However, a successful demonstration of the worked example effect using ill-defined problems would suggest that human cognitive architecture does not distinguish between learning domains and that learning and problem solving do not differ depending on the nature of the learning domain (Kyun et al., 2013).

In the present study, the worked example using ill-defined problems in on-line learning environment was tested, which had not been demonstrated yet. While there was an attempt using ill-defined problems of literature in controlled classroom-based instruction (e.g., Kyun et al., 2013), which reported successful results, or using well-defined problems of chemistry in web-based instruction (e.g., Crippen and Earl, 2007), there had been no case using the both 'ill-defined problems' and 'on-line learning environment', which might highly bring about cognitive overload. We hypothesized that regardless of learning domains and environments, the worked example will be effective and also explored in terms of the components of a worked example.

# 2. Well-defined and Ill-defined Domains

The boundary between well-defined and ill-defined problem is vague, fluid, and not susceptible to formalization, partly because any problem solving process will appear ill-defined (Simon, 1973). Hence, according to the nature of problems and their representations (see Goel, 1992a, 1992b; Greeno, 1976), mathematics, science, and related technical domains are classified as well-defined, whereas literature, history, social studies, and related nontechnical domains are classified as ill-defined. While there is a difference between well-defined or ill-defined knowledge representations, there is no evidence that learning and problem solving differ substantially depending on the learning domains. That is, according to our current understanding of human cognitive architecture, the procedures by which we learn and solve problems are identical for both "well-defined" and "ill-defined" problems. In both cases, learning to solve problems is a domain specific activity in which students learn to recognize a problem state and learn appropriate moves for that state. The number of possible moves that may need to be learned may be greater in the case of ill-defined than well-defined problems (that is, the cognitive load when solving ill-defined problems might be higher than when solving well-defined problems), but the processes of learning are identical. We learn to solve problems by recognizing problem states and the appropriate moves associated with them. Unless this information is stored in long-term memory in all learning domains, problem solving skill does not develop. The clearest way to ensure that learners have acquired this information is to present them with explicit, direct guidance, i.e., worked examples. Accordingly, if worked examples are effective in well-defined domains, they should be just as effective in ill-defined domains (see Kyun et al., 2013). This study has been conducted to test this assumption.

# 3. Worked Example Effect

A worked example represents one of the major instructional methods based on cognitive load theory. It reduces unproductive extraneous cognitive load imposed by the use of weak problem solving strategies and foster learning by allowing learners to devote available capacity to studying the solution moves corresponding to the specific problem states (van Gog et al., 2010). So this mechanism helps reduce load in working memory and facilitate schema construction, which can influence the acquisition of new knowledge. Worked example effect occurs when learners who studied worked examples outperformed the learners who actively solved problems. While the bulk of research into the worked example effect has primarily been conducted in well-defined domains, recently the effectiveness of a worked example has begun to be tested in ill-defined domains and also in a variety of learning environments.

## 3.1 Worked Example Effect in Ill-defined Problems

In relatively discursive domains such as design history, literature, and ill-structured diagnostic tasks in medical subjects, a worked example has been provided as a form of explicit instruction. Rourke and Sweller (2009) compared worked examples with problem solving practice in ill-defined domain of design history and found a superiority of worked examples over conventional problem solving practice. In a classroom environment, students who received lectures were randomly assigned to worked examples or problem solving conditions and were asked to study the characteristics needed to identify designers' style in each condition. In the following test phase, novice learners who studied worked examples performed better than those who solved the equivalent problems.

Stark, Kopp, and Fischer (2011) investigated the effectiveness of worked example formats and feedback prompts. With diagnostic tasks in the domain of hypertension and hyperthyroidism, Stark et al. compared correct worked examples with incorrect worked examples and also elaborated feedback prompts with knowledge of results (KOR) feedback prompts. The elaborated feedback prompts provided learners with additional explanations and further consequence which elucidated the diagnostic process while the KOR feedback prompts only evaluated conclusions and procedures as wrong or right without further explanation. Stark et al. found that while diagnostic competence was not significantly influenced by worked examples and feedback formats, incorrect worked examples with elaborated feedback significantly improved learners' strategic and conditional knowledge.

Kyun, Kalyuga, and Sweller (2013) also demonstrated the worked example effect in ill-defined domain of English literature. In 3 experiments, more-and less-knowledgeable university students were randomly assigned to worked examples or problem solving conditions. During the learning phase, while students in the problem solving condition were presented essay questions that they were asked to answer, the students in the worked example condition were presented the same questions along with 'model answers' (i.e., worked examples) that they were asked to study. In the following test phase, for the retention test, the less-knowledgeable students in the worked example group performed significantly better than the problem-solving group.

### 3.2 Worked Example Effect in On-line Learning

Crippen and Earl (2007) investigated the effect of worked examples with self-explanation strategies in well-defined domain of chemistry using on-line environment. In their study, students were supposed to study via on-line access. 'On-line learning software' was designed for the purpose of helping students' self-regulated learning, and the 'weekly quiz' as the strategy to draw students into the learning environment. However, Crippen and Earl found no significant statistical differences between worked examples and conventional groups and concluded that there may be unexpected variables that must be controlled. If these variables were found and controlled appropriately, this flexible learning environment may be the most potential learning condition. For the same reason, the present study was designed and conducted.

## 4. Research Purpose and Questions

The purpose of this research is to investigate whether worked examples affect on-line learning using ill-defined problems as similar as a traditional classroom- or computer-based learning. Particularly, the current work intended to discover which component was the most effective component of worked examples to comprehend in on-line learning using ill-defined problems.

Basically, the current work has been extended from the previous research (Kyun a Lee, 2009). The big differences between the previous research and the current one are a learning domain and environment. While Kyun and Lee (2009) used well-defined problems in the controlled computer-based learning environment, the current work used ill-defined problems in on-line learning environment. Research questions were as follows.

1. What is the effect of worked examples on the comprehension in on-line learning using ill-defined problems?
2. What is the effect of different components of worked examples on the comprehension in on-line learning using ill-defined problems?
3. What is the effect of different components of worked examples on the cognitive load in on-line learning using ill-defined problems?

## 5. Experiment 1

The main goal of the experiment 1 was to investigate the worked example effect and which kind of component of a worked example (conceptual knowledge, procedural knowledge, or the both conceptual and procedural knowledge of worked example) help learners to comprehend in on-line learning using ill-defined problems. Additionally, this experiment intended to explain the effect of worked examples by way of measuring cognitive load.

## 5.1 Method

### 5.1.1 Participants and Design

112 students were recruited from the Education department of Korea Digital University. There were 35 male and 77 female students, and their ages ranged from 18 to 50. Most of students have not taken the chance to learn the domain of 'Theory and Practice of Distance Education', one of the ill-defined areas of Education. Students were randomly assigned to the each of the four groups; 28 students were assigned to the conceptual knowledge of a worked example (CWE), 27 students to the procedural knowledge of a worked example (PWE), and 34 students to the conceptual and procedural knowledge of a worked example (CPWE), and 23 students to the control (NWE) groups.

### 5.1.2 Materials

The learning materials consisted of 'on-line lecture', and 'learning resources made by worked examples.' The measurements were a 'comprehension test' and a 'subjective rating scale' for cognitive load. The both learning and comprehension test materials were produced by the professor who taught this subject, and the subjective rating scale of Bralfish, Borg, and Dornic (1972) was modified by researchers of the present study.

***On-line lectures.*** On-line lecture composed of 'a video-recorded lecture' and a 'lecture note' were uploaded at the designated site of on-line learning system, and students were required to access those materials by themselves.

***Learning resources made by worked examples***. There were three different types of learning resources created based on learning topics: (1) CWE consisted of parts of the information related learning topics, and (2) PWE was the process information on how to solve the problems. (3) CPWE, in other words a *worked example*, included the both information ahead (Generally, a *worked example* includes the both of conceptual and procedural information). In this study, the components of a worked example were distinguished and explored regarding which components of them were effective to solve the problems.

***Comprehension test.*** Comprehension test was conducted after the instruction regarding the "instructional model of distance education." A comprehension problem was to suggest a desirable 'instructional model' of distance learning and also explain the rationale for the answer.

***Cognitive load measurement.*** We used the modified 5-point likert scale by Bralfish, Borg, and Dornic (1972) to measure the levels of cognitive load following the test phase. Students were required to rate the questions, (1) How easy or difficult was it to understand the subject? (intrinsic load). (2) How easy or difficult was it to understand the instructions? (extraneous load). (3) What effort did you make to understand the instructions? (germane load).

### 5.1.3 Procedure

The experiment composed with four phases was conducted for the first four weeks of a semester in teaching 'Theory and Practice of Distance Education' to university students. This course was the class operated by cyber university. Basically students were provided in the order of a 'video-recorded lecture', 'lecture note', 'learning resources made by worked examples', 'a comprehension problem', and 'a subjective rating scale' via electronic learning system by the week.

At the first week, students were randomly assigned into the four groups (i.e., CWE, PWE, CPWE and control group) based on the results of pretest. Pretest was composed of students' prior knowledge of the learning domain and none of students had previous experience in the area of 'Theory and Practice of Distance Education'. Then, students were provided the instruction on how to study using on-line learning system and spent two weeks making adjustments for the system. At fourth week, based on the randomly assigned groups, the main experiment included three phases (lecture, learning, and test phases) was conducted.

In lecture phase, four groups were provided the same lecture. Each student was individually required to access to a video-recorded lecture uploaded in on-line learning system. The lecture lasted for about two hours but it could be played several times depends on individual preference of students. Also, lecture note (summary of lecture) was provided as the form of word file. In learning phase, three groups were provided the three different types (CWE, PWE, and CPWE) of learning resources created based on learning topic and the control group was not provided any resource. All groups were required to study by themselves with learning materials. In test phase, all students were required to answer the subjective rating scale followed by the comprehension problem presented in on-line board. Then, the results of these two types of test were required to deliver to the instructor by email.

#### 5.1.4 Scoring procedure

The students answered to the comprehension problem during test phase and their answers were scored by the professor in the area of Education. Each answer was marked in terms of three perspectives, i.e., 'completeness', 'logicality', and 'creativity, and was differentiated into 5 levels (from 1 to 5) for each category. Therefore, the maximum score of a comprehension test was 15 points.

### 5.2 Results and Discussion

<Table 1> shows the mean scores and standard deviations of the four groups on the scores of comprehension and three kinds of cognitive load. We conducted a one-way analysis of variance, with a worked example as the between subjects factor.

***Comprehension test.*** There were no significant differences between groups on the comprehension, $F$ (3,109) = .172, MSE = .014, $p$ = .915.

***Cognitive loads.*** There were no significant differences on the three kinds of cognitive load. On the intrinsic load, there were no significant differences, $F$ (3,109) = 1.854, MSE = 1.007, $p$ = .142. In addition, significant differences were not found among groups on the extraneous load, $F$ (3,109) = .1.214, MSE = .780, $p$ = .308. Finally, there were no significant differences on germane load, $F$ (3,109) = .494, MSE = .318, $p$ = .687.

In experiment 1, the students' level of knowledge of Education subjects, including 'Theory and Practice of Distance Education' were low, which may have rendered the problems too difficult for most of students. According to cognitive load theory, optimizing cognitive load

〈Table 1〉 Mean Scores on Comprehension Test and Cognitive Loads and Corresponding Standard Deviations for Four Groups in Experiment 1

| | | Type of Measure | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Comprehension test | | Intrinsic load | | Extraneous load | | Germane load | |
| Group | N | M | SD | M | SD | M | SD | M | SD |
| NWE | 23 | 4.52 | 4.803 | 3.35 | .714 | 2.16 | .810 | 3.70 | .765 |
| CWE | 28 | 4.71 | 5.208 | 3.71 | .976 | 2.14 | .705 | 3.82 | .905 |
| PWE | 27 | 5.07 | 5.513 | 3.44 | .641 | 2.30 | .724 | 3.63 | .792 |
| CPWE | 34 | 4.71 | 4.965 | 3.29 | .579 | 1.94 | .919 | 3.85 | .744 |

Note) *NWE* = no worked examples (control group); *CWE* = conceptual knowledge of a worked example; *PWE* = procedural knowledge of a worked example; *CPWE* = conceptual and procedural knowledge of a worked example. Total possible scores are as follow: Comprehension test, 15; Intrinsic load, 5; Extraneous load, 5; Germane load, 5.

of working memory is the most important to solve problems (Sweller, 1994). Not only high knowledgeable students for the learning domain but also low knowledgeable students can make working memory overloaded, which results in failure to solve problems (see Kyun et al., 2013).

Besides, experiment 1 was conducted in a realistic on-line learning environment using ill-defined problems, which might highly be a condition of working memory overload (see Kyun et al., 2013). We already predicted and so tried to cope with these conditions, but failed to control them. The results of experiment 1 were different from the results of previous studies (Carrol, 1994; Cooper and Sweller, 1987; Kyun and Lee, 2009; Sweller and Cooper, 1985; Ward and Sweller, 1990), although we expected that at least a worked example (i.e., CPWE) would be helpful for learning comprehension. Contrary to our expectation, there were no significant differences on the comprehension test and cognitive loads in experiment 1. Therefore, experiment 2 was conducted in order to find out the reason why the results of experiment 1were different from previous studies.

# 6. Experiment 2

Experiment 2 used the same research design and an ill-defined problem used in the experiment 1, and also used less knowledgeable students in the same way as experiment 1, but used different learning environment. That is, we changed the only learning environment from ‘a realistic on-line learning’ to ‘a controlled computer-based setting.’ The purpose of this experiment was to investigate whether a controlled learning environment using ill-defined problems would yield worked example effect. Experiment 2 was designed as a small study to compare with the results of experiment 1.

## 6.1 Method

### 6.1.1 Participants and Design

The participants were 11 undergraduate university students who lacked experience in the domain of ‘Theory and Practice of Distance Education’ recruited from the School of Engineering at the University of Seoul. There were 7 male and 4 female students, and their ages ranged from 19 to 23. The experimental design was identical to the experiment 1except there was no control group in experiment 2. Students were randomly assigned to the each of the three groups : 4 students were assigned to the CWE, 3 students to the PWE, and 4 students to the CPWE groups.

#### 6.1.2 Materials and Apparatus

***Learning and measurement materials.*** Learning and measurement materials were identical to those used in the experiment 1. The comprehension test and a subjective rating scale were implemented by paper and pencil-based materials.

***Apparatus.*** The apparatus consisted of 11 personal computers with 17-inch monitor and headset. Students were required to use individual headset during the lecture phase in a computer lab.

#### 6.1.3 Procedure

The experiment was conducted in the computer lab. During the lecture phase, students who lacked in the learning domain of 'Theory and Practice of Distance Education' were randomly assigned to the three conditions, CWE, PWE, and CPWE. Then, they were provided a video-recorded lecture, a lecture note, and each learning resource made by a worked example, and required to study by themselves using personal monitor and headset in each computer station. All materials were identical to those used in the experiment 1. After this computer-based instruction, students were required complete the paper and pencil-based subjective rating scale followed by the comprehension test.

#### 6.1.4 Scoring procedure

The data analyses were identical to those used in experiment 1.

### 6.2 Results and Discussion

<Table 2> shows the mean scores and standard deviations of the three groups on the comprehension test and the three kinds of cognitive load. In this case, we did not conduct an analysis of variance because the small sample size would not provide adequate statistical power for meaningful significance.

***Comprehension test.*** As can be seen in the <Table 2>, there were mean score differences among groups CWE, PWE, and CPWE. The CPWE group scored higher than the PWE, and the CWE groups.

〈Table 2〉 Mean Scores on Comprehension Test and Cognitive Loads and Corresponding Standard Deviations for Three Groups in Experiment 2

| | | Type of Measure | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Comprehension test | | Intrinsic load | | Extraneous load | | Germane load | |
| Group | N | M | SD | M | SD | M | SD | M | SD |
| CWE | 4 | 5.75 | 2.500 | 3.75 | .500 | 2.25 | .500 | 3.25 | .957 |
| PWE | 3 | 6.67 | 3.055 | 3.33 | .577 | 2.00 | 1.000 | 3.00 | .000 |
| CPWE | 4 | 8.50 | 1.291 | 4.00 | .816 | 1.00 | .000 | 4.00 | .816 |

Note) *CWE* = conceptual knowledge of a worked example; *PWE* = procedural knowledge of a worked example; *CPWE* = conceptual and procedural knowledge of a worked example. Total possible scores are as follow : Comprehension test, 15; Intrinsic load, 5; Extraneous load, 5; Germane load, 5.

***Cognitive loads.*** As can be observed in the <Table 2>, there were mean score differences among groups CWE, PWE, and CPWE on the cognitive loads. For the intrinsic load, the CPWE group scored higher than the CWE, and PWE groups. For the extraneous load, the CPWE group scored lower than the PWE and CWE groups. For the germane load, the CPWE group scored higher than the CWE, and PWE groups.

Experiment 2 showed extremely different results from experiment 1, but exactly the same pattern of the results as previous studies (Carrol, 1994; Cooper and Sweller, 1987; Kyun and Lee, 2009; Sweller and Cooper, 1985; Ward and Sweller, 1990), although it could not use statistical analysis. In experiment 2 using relatively low knowledgeable students in the domain of Education, significant differences were found between the groups on the comprehension test and cognitive loads. That is, students received 'a worked example' (i.e., CPWE) reported the lowest extraneous cognitive load and performed better on the comprehension test. From the results of comparing experiment 1 with 2, we estimated that the failure of worked example effect of experiment 1 would be provoked by uncontrolled learning environments.

# 7. Experiment 3

Experiment 2 found that the 'a worked example (i.e., CPWE)' condition was beneficial on the comprehension test, but it was only on the problem in the experiment designed as a small study. Since we confirmed worked example effect using ill-defined problems in controlled learning environment, in experiment 3, we tried again to investigate the possibility of worked example effect in on-line learning. Experiment 3 used more knowledgeable students for the purpose of adjusting students' working memory overload when learning of ill-defined domains in on-line environment. We re-conducted an experiment, using the same research design, learning domain as experiment 1 or 2, but different target audience. The purpose of experiment 3 was to investigate (1) whether relatively high knowledgeable students are beneficial in problem solving under the circumstance of high possibility of cognitive overload (that is, in on-line learning using ill-defined problems) and also (2) if there was worked example effect, which component (i.e., conceptual or procedural knowledge) of a worked example was effective to solve problems.

## 7.1 Method

***Participants and Design.*** The participants were 38 graduate school students recruited from the Education department at the Korea University. There were 24 male and 14 female students, and their ages ranged from 30 to 45. More than 95% of students were involved in business and industrial training areas, having much experiences and skills in education. The research design was identical to the experiment 2. Students were randomly assigned to the each of the three groups : 13 students were assigned to the CWE, 12 students to the PWE, and 13 students to the CPWE groups.

***Materials and Procedure.*** The materials, experimental procedure, and also scoring procedure were identical to those used in experiment 1.

### 7.2 Results and Discussion

<Table 3> shows the mean scores and standard deviations of the three groups on the comprehension test and the three kinds of cognitive load. We conducted an one-way analysis of variance, with a worked example as the between subjects factor. Tukey tests were followed for the case where the ANOVA yielded significant effect (with alpha less than .05).

***Comprehension test.*** There was a significant difference between groups on the comprehension, $F$ (2, 36) = 3.677, MSE = 10.262, $p$ = .036. Tukey tests revealed that the CWE group scored significantly higher than the PWE group, yielding an effect size of 0.17. However, the CPWE group did not differ significantly from either of the other two groups.

***Cognitive loads.*** There were no significant differences on the three kinds of cognitive load. On the intrinsic load, the one-way ANOVA test failed to reveal effect, $F$ (2, 36) = 1.856, MSE = .945, $p$ = .171. Also, the ANOVA test failed to reveal effect on both cognitive loads, $F$ (2, 36) = .027 and 1.262, MSE = .025 and 1.331, $p$ = .973 and .296, for extraneous and germane load, respectively.

In experiment 3, a significant difference was found between the groups on the comprehension test. The students in the CWE group performed significantly better than other two groups. This result indicates that studying a worked example reduced cognitive load, but procedural knowledge of a worked example was redundant for these students who has high level of domain-specific knowledge. Students' prior knowledge which had previously been obtained regarding how to approach educational subjects may be transferrable when learning and solving problems of new subject, 'Theory and Practice of Distance Learning.' For this reason, the method how to approach educational subject (i.e., procedural knowledge of a worked example to use our terms) were redundant to students and those who received only new conceptual knowledge (i.e., conceptual knowledge of a worked example to use our terms) regarding a new subject performed better than other groups. It can be explained as the expertise reversal effect that the worked example effect maybe unobtainable using high knowledge learners (Kalyuga et al., 2001). Therefore, in this experiment, students received the 'only conceptual knowledge of a worked example' performed significantly better on the comprehension test than those who received the 'a worke example.'

〈Table 3〉 Mean Scores on Comprehension Test and Cognitive Loads and Corresponding Standard Deviations for Three Groups in Experiment 3

| | | Type of Measure | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Comprehension test | | Intrinsic load | | Extraneous load | | Germane load | |
| Group | N | M | SD | M | SD | M | SD | M | SD |
| CWE | 13 | 6.31 | 1.843 | 3.46 | .877 | 2.08 | .954 | 4.23 | .599 |
| PWE | 12 | 4.58 | 1.165 | 3.17 | .389 | 2.00 | .853 | 3.58 | 1.165 |
| CPWE | 15 | 5.00 | 1.871 | 2.92 | .760 | 2.00 | 1.080 | 3.85 | 1.214 |

Note) *CWE* = conceptual knowledge of a worked example; *PWE* = procedural knowledge of a worked example; *CPWE* = conceptual and procedural knowledge of a worked example. Total possible scores are as follow : Comprehension test, 15; Intrinsic load, 5; Extraneous load, 5; Germane load, 5.

# 8. General Discussion

The first purpose of the present study was to investigate the worked example effect using ill-defined problems in on-line learning. This study further extended the effects of worked examples from well-defined domains to an ill-defined domain, and also from controlled learning settings to a realistic on-line learning environment. The second purpose was to find out which component of a worked example is effective factor in the ill-defined problem solving in on-line environment.

The first experiment found no evidence of worked example effect. There was no difference between groups on the comprehension test, and also no logical results in cognitive load. From the results, we analyzed that the participants' domain specific knowledge was very low and also the learning domain and environment was extremely difficult for these less knowledgeable students. This is why it was difficult to detect the logical reason of the different results from the prior research (e.g., Kyun and Lee, 2009).

Therefore, we studied the second experiment employing the same research design with experiment 1 except learning environment. We considered that it was difficult to control extra effects in on-line learning environment as the same as in the laboratory settings. Therefore, we conducted the experiment 2 with undergraduate students who still had less domain-specific knowledge, using the same research design and the same learning domain which had been used in experiment 1. The experiment was completely controlled in the experimental environment of laboratory settings. The results showed the clear differences among the groups by the order CPWE, PWE, and CWE. In addition, the scores of cognitive load showed the theoretical relationship with the comprehension test. In the CPWE group, extraneous load showed the lowest and germane load showed the highest score. This means the both components of a worked example (i.e., conceptual knowledge of a worked example and procedural knowledge of worked example to use our terms) decreased the extraneous load which is imposed by the instructional design and allowed learners to use more cognitive capacity for their germane load. This learning process could affect learners' comprehension. According to the experiment 2, we may estimate the both components of a worked example (i.e., a worked example) was the most effective in ill-defined domain learning, specifically for the less knowledgeable students, as the previous research.

To achieve the purposes of the study, worked example effect using ill-defined problems in on-line learning, experiment 3 was conducted regulating experimental variables. In experiment 3, we used relatively more knowledgeable students for the purpose of adjusting students' working memory overload. The participants were graduate school students most of whom were working at education and training areas. They already possessed the education-related knowledge and experience. Consequently, the results of experiment 3 demonstrated the significant difference among groups of CWE, CPWE, and PWE. The Post-hoc test revealed that the conceptual knowledge of a worked example was effective than the procedural knowledge of a worked example by the effect size 0.17. However, there were no significant differences on the three types of cognitive loads. We may interpret that conceptual information is more beneficial to the experienced learners than beginners because the experienced learners already possess the procedural knowledge to approach the problem solving. That is, the experiment 1 and 3 were conducted in the same on-line learning environment using ill-defined problems. While there were no effects of a worked example in experiment 1, there was the pattern of expertise reversal effect as well as redundancy effect in experiment 3, even though it did not show statistical significance: i.e., the students who received the only conceptual knowledge of a worked example performed better on the comprehension test than those who received the both conceptual and procedural knowledge of a worked example (i.e., a worked example). We explain the reasons as follows. The participants from experiment 3 were more knowledgeable students to deal with cognitive overload derived from ill-defined problems and also uncontrolled on-line learning environment.

The present study offers important theoretical and practical implications. On the theoretical side, our findings support the cognitive load theory by demonstrating 'worked example effect', 'redundancy effect', and 'expertise reversal effect.' While experiment 2 demonstrated that CPWE (i.e., a worked example) is the most effective component of worked example for beginners (worked example effect), experiment 3 showed that CWE (i.e., conceptual knowledge of a worked example) is the most effective for the experienced learners (expertise reversal effect). That is, the PWE (i.e., procedural knowledge of a worked example) was redundant for the experienced learners (redundancy effect). Furthermore, while research on worked examples so far has typically compared conventional worked examples and additional explanation to the worked examples (Gerjets et al., 2006; Große and Renkel, 2007; Nadolski et al., 2006; Schworm and Renkel, 2006; van Gog et al., 2006), the present study expanded those previous worked example studies in that not adding the extra information, but dividing the conventional worked example into conceptual and procedural information.

On the practical side, our findings emphasize the need to consider research environments and participants. Many previous studies dealing with on-line learning environments did not inform how they control many extra variables and their effects in the research. The results of comparing the controlled and uncontrolled learning environments suggest that future research of on-line learning extraordinarily consider and control the factors of learning environments affecting the results.

There are limitations to the present study that need to be addressed in subsequent work. First, the control group was not used in the experiment 2 and 3 under the assumption deduced from the previous work that a worked example is beneficial than conventional problem solving. In future research, the more rigorous experimental design to test worked example effect will need to be carry out in this challenging learning environment, on-line learning environment. Second, experiment 2 was conducted to investigate the effect of learning environment. However, the sample size was too low to use statistical analysis. In future study, enough students should be included to study the interaction effect of learning environments and worked examples.

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