Asia Pacific Educ. Rev. (2009) 10:495–503
DOI 10.1007/s12564-009-9044-x

The effects of worked examples in computer-based instruction: focus on the presentation format of worked examples and prior knowledge of learners

Sun A. Kyun · Hyunjeong Lee

Received: 22 May 2008 / Revised: 30 January 2009 / Accepted: 11 February 2009 / Published online: 18 June 2009

Abstract The aim of this study is to investigate the effects of presentation formats of worked examples and the interaction effects between the presentation formats of worked examples and the prior knowledge of learners. An investigation with 97 middle school students working in four conditions (CPWE, CWE, PWE, and the control group) was conducted. The results indicate that CPWE was the most effective condition in retention and transfer. In addition, a partial expertise reversal effect was revealed in the *element transfer test*. High prior knowledge learners in both CPWE and PWE were superior to those who were in CWE and the control group, while low prior knowledge learners in CPWE were superior to those who were in other conditions.

Keywords Worked examples · Problem solving · Cognitive load · Information presentation

Introduction

Over the last decades, a tremendous amount of successful results on worked examples in various fields (i.e., Mathematics, Physics, Computer Programming, etc.) have been reported. Worked examples are effective instructional methods that facilitate the schemata. The schema is made up of an individual's knowledge structure and is concerned with acquiring new knowledge and solving complicated problems. These methods are deeply associated with the processing of working memory which is very limited in capacity and duration when dealing with unfamiliar information (Kalyuga 2006). Accordingly, an enormous amount of previous research in relation to the processing of working memory was to demonstrate the effectiveness of worked examples or to find the maximum of efficiency in adding helpful information. However, the research results have not been analyzed significantly about worked examples themselves, how they impact the gaining of new knowledge and problem solving skills, and how the presentation formats of worked examples play a pivotal role in obtaining new knowledge and problem solving.

In this study, the presentation formats of worked examples that have not been attempted to be analyzed so far are investigated. This approach intends to consider the cognitive processes of working memory and prior knowledge of learners.

S. A. Kyun
University of New South Wales, Sydney, NSW 2052, Australia
e-mail: sunnoos@naver.com

H. Lee (✉)
Graduate School of Education, The University of Seoul, Jeonnong-dong (Siripdae-1 gil 12-1), Dongdaemun-gu, Seoul 130-743, Korea
e-mail: hyunjlee@uos.ac.kr

Worked examples and schema construction

Worked examples are example-based methods that can minimize students' use of cognitive resources in activities that are not relevant to schema acquisition or automation, rather maximize the use of cognitive resources in germane activities, which are associated in constructing schemata within the limits of a working memory capacity. According to Sweller (1994), learners have to acquire schemata to solve cognitive problems. The schemata can be acquired through well-designed instructions including worked example strategies. A number of researchers investigated the efficiency of using worked example instructions and provided evidences on the effectiveness (Carrol 1994; Cooper and Sweller 1987; Paas and van Merriënboer 1994; Sweller and Cooper 1985; Zhu and Simon 1987).

Worked examples and prior knowledge

Worked examples are one of the earliest instructional methods that can help learners construct schemata that could influence the acquisition of new knowledge and facilitate problem solving within the limitation of cognitive resources. However, worked examples do not work all the time. According to Kalyuga et al. (2001), worked examples were effective for low prior knowledge learners, but not for high prior knowledge learners. “Expertise reversal effects” take place (Kalyuga et al. 2003).

As indicated above, recent research has found that the effectiveness of instructional materials is dependent on the expertise of the learners. There is an interaction effect between prior knowledge levels of learners and the amount of information included in instruction. Ward and Sweller (1990) and Kalyuga et al. (2001) demonstrated that worked examples are not always beneficial for all students, and therefore, a learner’s cognitive load should be considered. Based on an experiment with elementary school students in the field of Mathematics, Kim (2005) also investigated that worked examples are not effective for learners who have already formed a partial schema of target cognitive knowledge.

In addition, there were a number of researchers who investigated how to increase the germane cognitive load (Gerjets et al. 2006; Nadolski et al. 2006; Paas and van Merriënboer 1994; van Gog et al. 2006). However, worked examples were not effective in all those cases. These strategies of increasing germane cognitive load were effective just for low prior knowledge learners because, in these studies, most of the treatments which were intended to facilitate construction of schemata were played as redundant information, especially for high prior knowledge learners.

Worked examples in the computer-based learning environments

Recently, there have been rapid developments in the use of computer-based learning environments related to worked examples (Gerjets et al. 2006; Gerjets et al. 2008; Jung and Kim 2006; Kalyuga et al. 2001; Kim 2005; Nadolski et al. 2006; Paas and van Merriënboer 1994; Schworm and Renkel 2006; van Gog et al. 2006, 2008). These computer-based studies which have been conducted in laboratory settings have reported the various effects of worked examples. Most of the research of worked examples on computer-based learning environment provided evidence that the instructional method of worked examples has efficiency in well-structure domain such as Mathematics and Science (Crippen and Earl 2007; Gerjets et al. 2008; Gerjets et al. 2006; Kim 2005; Paas and van Merriënboer 1994; Schworm and Renkel 2006). Moreover, Crippen and Earl (2007), Gerjets et al. (2006), and Schworm and Renkel (2006) explored whether the prompts of self-explanations or instructional explanations in the worked example instructions enhanced the performance. In addition, van Gog et al. (2006, 2008) divided worked examples into product- and process-oriented worked examples and compared the effectiveness of the process-oriented worked examples and the sequences of these two kinds of worked examples on the transfer. Besides, Jung and Kim (2006) showed the effects of worked examples on knowledge sharing process in computer supported collaborated learning. Most recently, Gerjets et al. (2008) examined the hyper-text environments as an interactive tool to maximize the worked example effects. In our study, we extended the above computer-based learning environments in laboratory settings to control extra elements beside worked examples.

Variation in worked examples

Among the studies of worked examples, recent research is associated with complex cognitive tasks (Hoogveld et al. 2005; Joung 2006). The acquisition of complex cognitive knowledge and skills is heavily constrained by the limited processing capacity of the human mind. “Cognitive load theory” provides guidelines to circumvent those limitations in training situations. They provide guidelines to decrease extraneous cognitive load, which is not relevant to learning, and increase, within the limits of total available cognitive capacity, germane cognitive load (van Gerven et al. 2002).

Joung (2006) tried to divide a worked example into parts as a strategy to resolve complex cognitive problems. She assumed that if parts of a worked example would be practiced first, a complex cognitive task such as computer programming could be solved better. Therefore, she divided a worked example into “the product-oriented whole task approach” and “the process-oriented part task approach.” The investigator expected that the latter approach would be more effective; however, the results showed that the former approach was superior to the latter.

In our view, the former approach in her study is analyzed as a classical configuration of worked examples and the latter approach is analyzed as just a partial collection of components, which consist of worked examples. Therefore, the results of Joung (2006) could be predictable because the latter worked example was an incomplete instruction compared to the former, which more completely helped in resolving the problems. Also in her study, the individual differences of learners were not considered. However, the research of Joung (2006) has contributed to such studies in that it presented worked examples that could be separated into components.

In this present study, we extend the conceptual framework of Joung (2006). We assume conceptual- and procedural-worked examples because worked examples consist of conceptual and procedural information. We also considered the prior knowledge of learners as an important factor in the cognitive process. Learning environment is a critical element that affects learning achievements. Many previous studies (Carrol 1994; Cooper and Sweller 1987; Sweller and Cooper 1985; Zhu and Simon 1987) demonstrated the positive results of worked examples in the traditional classroom environments. This study focused on the computer-based learning environments because we have interests in the effect of worked examples in self-regulated learning environments. Accordingly, the purpose of this research is to clearly identify which component is the most effective element of worked examples. Research questions are as follows: (1) How do different presentation formats of worked examples (control, conceptual-worked examples, procedural-worked examples, or conceptual- and procedural-worked examples group; see Learning materials section) affect retention, transfer, and cognitive load in computer-based instruction? (2) What is the interaction effect between worked example formats and a learner's prior knowledge on retention, transfer, and cognitive load in computer-based instruction?

Method

Participants and design

The participants were 112 students from the public middle school, Incheon, Korea. There were 51 male and 61 female and their ages ranged from 12 to 14. We used a 4×2 mixed design with presentation formats of worked examples (control, conceptual-worked examples, procedural-worked examples, or conceptual- and procedural-worked examples group) and prior knowledge (high vs. low). Concerning presentation formats of worked examples, 28 students served in the control group (in which they did not receive any treatment), 28 students served in the conceptual-worked examples group, 28 students served in the procedural-worked examples group, and 28 students served in the conceptual and procedural-worked examples group. Concerning prior knowledge, participants were divided into high-knowledge and low-knowledge group based on the most recent algebra standardized test scores. High-knowledge students ($n = 51$) were in the top 40%, low-knowledge students ($n = 46$) were in the bottom 40% of the 112 students, and the students in the middle 20% were excluded because we could not call the students in the 49% of 112 students as a high-knowledge student, and 51% of 112 students as a low-knowledge student; actually, the scores of these two students seemed very similar that was why we excluded 20% in the middle of 112 students. All participants had previously never studied the substantial knowledge of an algebraic manipulation in their regular algebra class. For each participant, cognitive measurements and retention test were taken after computer-based learning on worked examples; also, transfer test was taken on the next day.

Materials and apparatus

The computer-based materials consisted of four computer-based learning materials on Algebra manipulations and mental effort rating questionnaires. The paper-based materials consisted of eight retention problem sheets and eight transfer problem sheets.

Learning materials

The computer-based learning materials, developed by S. A. Kyun using ASP Program language and MS-SQL server, consisted of four formats of worked examples. The variants of conditions were developed based on the presentation formats of worked examples, including a control group. The control group was provided by a conventional approach format. In other words, it did not present any information of worked examples on the screen. The other three instructional formats presented different information of worked examples on a screen. To begin with, in the conceptual-worked example format, students received information on "Four Equation Rules" which are equivalence properties of equality (i.e., addition: if $a = b$ then $a + c = b + c$; subtraction: if $a =$ b then $a - c = b - c$; multiplication: if $a = b$ then $ac = bc$; division: if $a = b$ and $c \neq 0$ then $a/c = b/c$). These algebra rules for manipulating equations are considered as the conceptual information in our study. Next, in the procedural-worked example format, students received information on the process of developing the algebraic problems without any explanation about the basic concepts of elements—i.e., four algebra rules for manipulating equations. Finally, in the conceptual- and procedural-worked example formats, students received both information on "Four Equation Rules" and the process of developing the algebraic problems in a series. The subject of the computer-based learning materials was algebra composed of the original

Sweller's (Sweller and Cooper 1985) materials (see Appendix B). We selected the algebra problems because we thought the algebra task seemed to involve a large number of interacting elements.

Mental effort rating

This study used three measurement instruments. For obtaining the cognitive load of participants, subjective measurement modified by Bralfish et al. (1972) was used. Students were required to rate "What effort did you make to understand the instructions?" "How easy or difficult was it to understand the instructions?" and "How easy or difficult was it to understand the subject?" Options were provided with 5-point scale (see Appendix A). The subjective measurement of cognitive load in this study was developed as a computer-based instrument.

Retention test and transfer test

For a retention and transfer test, the paper-and-pencil materials made up of the original Sweller's (Sweller and Cooper 1985) materials was used (see Appendices B, C). Each test had eight test items in it and the maximum total score was 8 for each test. The retention test items were identical items which students had practiced in the computer-based learning materials. The transfer test items were divided into two kinds of test items: the "element transfer" items were to transfer the elements of the problems which students had studied in learning materials and the "structure transfer" items were to transfer the structure of the problems which students had studied in learning materials. The maximum total score was 4 for each transfer test.

Apparatus

The apparatus consisted of 28 personal computers with 17-inch monitor in the computer lab of the school.

Procedure

These experiments were conducted in the computer lab and classrooms for 2 days. The experiments of the first day were conducted in the computer lab, and the experiments of the second day were conducted in their own classroom.

First day

Experimental training session

Participants from the four student groups (i.e., one control group, three experimental groups) were required to come and stay at the designated computer lab during the experimental session. Four student groups which were approximately of the same mathematical ability were randomly allocated corresponding to four instructional conditions (28 students in the conventional approach format, 28 students in the conceptual-worked example format, 28 students in the procedural-worked example format, and 28 students in the conceptual- and procedural-worked example formats). When students were seated and ready to begin learning in their respective experimental conditions, the administrator gave brief instructions and asked the students to begin their participation by browsing to the experimental web site and following the instructions on the screen. Students studied first four items in each instruction and could have the opportunity to practice four more items which were similar to the problems they had studied, but the practicing was not required. They were instructed to manipulate algebraic problems and were given about 15 min to use the computer-based instruction.

Subjective ratings

After the instruction of the worked examples according to the presentation formats, the subjective ratings of mental effort and task difficulty were collected electronically on the computer from the students. The self-ratings of the mental effort and the task difficulty as the methods of measuring cognitive load have been used and the technique is highly appropriate in natural training procedures (Kalyuga et al. 2001); also, many previous researchers have used to measure cognitive load of human being (Lee et al. 2006; Paas and van Merriënboer 1994). In this study, subjective measurement modified by Bralfish et al. (1972), which is a 5-point scale, was used (see Appendix A). After completing their work with the subjective ratings, students were given 5 min break for refresh.

Retention test

A series of eight questions are followed after the measuring subjective ratings. The test questions (see Appendix B) were identical to the problems presented to students during the training and were given in paper-and-pencil materials. Students were given about 20 min to complete the retention test.

Second day

Transfer test

A transfer test (see Appendix C) took place a day after the retention test in the classroom. A series of eight questions are followed. Eight questions were made of two kinds of transfer problems, and four questions were "element transfer" problems, which were identical in the structures but different in the elements compared with the problems presented to students during the training. In contrast, the other four items of the eight questions were "structure transfer" problems, which were quite different in the structure and the elements compared with the problems presented to students during the training. Students were given about 20 min to complete the two kinds of transfer problems.

Results

Mean scores and standard deviation of the presentation format of worked examples in the retention test, transfer test, as well as the self rating cognitive load measures were recorded (see Tables 1, 2). These scores were analyzed using 4 × 2 analysis of variance with the presentation formats (a conventional approach format, conceptual-worked example format, procedural-worked example format, or conceptual- and procedural-worked example format) and the levels of prior knowledge (high and low) as independent variables. The dependent variables were both retention and transfer test and three kinds of cognitive load (i.e., germane cognitive load, extraneous cognitive load, and intrinsic cognitive load).

Retention

For the retention test scores, there were significant main effects from different presentation formats of worked examples: $F(3, 89) = 9.219$, MSE = 117.015, $p < 0.001$; and levels of prior knowledge, $F(1, 89) = 47.712$, MSE = 351.044, $p < 0.001$. Tukey tests revealed that the CPWE group scored significantly higher than the Control and PWE group, yielding an effect size of 0.237; and the high prior knowledge groups scored significantly higher than the low prior knowledge groups, yielding an effect size of 0.324. However, there was no interaction effect between presentation formats of worked examples and the levels of prior knowledge of learners.

Transfer

Element transfer test

For the element transfer test scores, there were significant main effects from the different presentation formats, $F(3, 89) = 22.409$, MSE = 30.794, $p < 0.001$; and the levels of prior knowledge: $F(1, 89) = 21.231$, MSE = 92.383, $p < 0.001$. Tukey tests revealed that the CPWE group scored significantly higher than the Control, CWE, and PWE group, yielding an effect size of 0.430; and the high prior knowledge groups scored significantly higher than the low prior knowledge groups, yielding an effect size of 0.193. Also, there were significant interaction effects between presentation formats and the levels of learners' prior knowledge on element transfer test: $F(3, 89) = 3.699$, MSE = 30.794, $p < 0.05$. The effect size was 0.111. In the high prior knowledge groups, the scores were higher for treatment conditions with CPWE-H ($M = 2.54$, SD = 1.561) than for those with PWE-H ($M = 2.40$, SD =

Table 1 Mean and standard deviations for NEW, CWE, PWE, and CPWE on the retention, transfer tests

Group	N	Type of tests					
		Retention		Element transfer		Structure transfer	
		M	SD	M	SD	M	SD
NWE							
H	15	2.40	2.558	0.47	0.915	0.40	0.738
L	10	0.00	0.000	0.00	0.000	0.00	0.000
Total	25	1.32	1.32	0.25	0.701	0.21	0.568
CWE							
H	13	2.23	1.878	1.00	1.225	0.77	1.235
L	11	0.27	0.467	0.00	0.000	0.00	0.000
Total	24	1.25	1.602	0.50	0.962	0.36	0.911
PWE							
H	10	5.10	1.912	2.40	1.075	1.20	1.229
L	13	0.77	1.691	0.31	0.751	0.15	0.555
Total	23	2.75	2.661	1.29	1.321	0.64	1.026
CPWE							
H	13	4.62	2.873	2.54	1.561	1.77	1.481
L	12	2.67	2.103	2.25	1.215	1.17	1.193
Total	25	3.82	2.722	2.29	1.487	1.36	1.339

NWE no worked examples (control group); *CWE* conceptual worked examples; *PWE* procedural worked examples; *CPWE* conceptual and procedural worked examples; *H* high prior knowledge (the top 40% of the students); *L* low prior knowledge (the bottom 40% of the students); *Total* the total number of the students regardless of prior knowledge

Table 2 Mean and standard deviations for NEW, CWE, PWE, and CPWE on the cognitive loads

Group	N	Type of cognitive load					
		Germane		Extraneous		Intrinsic	
		M	SD	M	SD	M	SD
NWE							
H	15	3.20	1.475	4.08	0.561	4.00	1.363
L	10	2.80	1.476	4.10	1.514	4.20	1.135
Total	25	3.14	1.443	4.32	1.307	3.93	1.303
CWE							
H	13	3.00	1.354	3.38	1.193	2.69	1.377
L	11	2.55	1.214	3.73	1.348	3.45	1.695
Total	24	2.93	1.331	3.57	1.317	3.18	1.541
PWE							
H	10	3.70	1.059	2.10	0.738	2.30	1.160
L	13	3.46	1.050	2.77	0.927	3.00	1.291
Total	23	3.61	1.031	2.54	0.881	2.61	1.257
CPWE							
H	13	4.00	0.707	2.31	1.251	2.23	1.092
L	12	4.08	0.669	2.00	0.603	2.67	0.651
Total	25	3.96	0.074	2.25	1.005	2.54	0.922

NWE no worked examples (control group); *CWE* conceptual worked examples; *PWE* procedural worked examples; *CPWE* conceptual and procedural worked examples; *H* high prior knowledge (the top 40% of the students); *L* low prior knowledge (the bottom 40% of the students); *Total* the total number of the students regardless of prior knowledge

1.075), for those with CWE-H ($M = 1.00$, SD = 1.225), and for those with NWE-H ($M = 0.47$, SD = 0.915). In the low prior knowledge groups, the scores were higher for treatment conditions with CPWE-L ($M = 2.25$, SD = 1.215) than for those with PWE-L ($M = 0.31$, SD = 0.751), for those with CWE-L ($M = 0.00$, SD = 0.000), and for those with NWE-L ($M = 0.00$, SD = 0.000).

Structure transfer test

For the structure transfer test scores, there were significant main effects from the different presentation formats of worked examples: $F(3, 89) = 8.044$, MSE = 28.391, $p < 0.001$; and the levels of prior knowledge, $F(1, 89) = 12.353$, MSE = 85.174, $p < 0.01$. Tukey tests revealed that the CPWE group scored significantly higher than the Control, CWE, and PWE group, yielding an effect size of 0.213; the high prior knowledge groups scored significantly higher than the low prior knowledge groups, yielding an effect size of 0.122. However, there was no significant interaction effect between presentation formats and prior knowledge of learners on structure transfer test.

Cognitive load

Germane cognitive load

For the germane cognitive load scores, there was significant main effect from the presentation formats: $F(3, 89) = 5.892$, MSE = 40.325, $p < 0.001$. Tukey tests revealed that the CPWE group scored significantly higher than the Control and PWE group, yielding an effect size of 0.166. However, there was no significant main effect in the levels of prior knowledge. Also, there was no interaction effect between presentation formats of worked examples and levels of prior knowledge of learners on germane load.

Extraneous cognitive load

For the extraneous cognitive load scores, there were significant main effect from the presentation formats: $F(3, 89) = 5.892$, MSE = 32.845, $p < 0.001$. Tukey tests revealed that the Control group scored significantly higher than the CWE, PWE, and CPWE group, and PWE group scored significantly higher than the CWE and CPWE group, yielding an effect size of 0.451. However, there was no significant main effect in the levels of prior knowledge. Also, there was no interaction effect between presentation formats and the levels of prior knowledge of learners on extraneous load.

Intrinsic cognitive load

For the intrinsic cognitive load scores, there was significant main effect from the presentation formats: $F(3, 89) = 8.272$, MSE = 46.724, $p < 0.001$. Tukey tests revealed that the Control group scored significantly higher than the CWE, PWE, and CPWE group, yielding an effect size of 0.218. Also, there was significant main effect in the levels of prior knowledge: $F(1, 89) = 4.461$, $\mathrm{MSE} = 140.171$, $p < 0.001$. Tukey tests revealed that the low prior knowledge groups scored significantly higher than the high prior knowledge groups, yielding an effect size of 0.045. However, there was no significant interaction effect between presentation formats of worked example and the levels of prior knowledge of learners on intrinsic load.

Discussion

This study intends to investigate the effects of different presentation formats of worked examples in connection with the prior knowledge of learners. On the basic concepts of Sweller's learning materials (Sweller and Cooper 1985), learning mechanisms (1994), and the study by Joung (2006), we extended the conceptual framework and experiment designs. The first aim of this research was to examine how the presentation formats of worked examples affect the retention test, transfer test, and cognitive load. The second aim was to examine how the expertise levels of students affect their achievements in the same example-based learning conditions.

This study found that there were better performances in all tests when both conceptual and procedural information were presented together regardless of the learners' expertise (see Table 1). That is, to acquire the schemata that enhance problem solving ability, both conceptual and procedural information of worked examples are required. One of the important findings of this research is the effect of the learners' mental effort for learning. Extraordinarily, in our data, the score of the control group (i.e., conventional approach group) was higher than the conceptual-worked example group in the retention test. However, we could observe the reason in the score from the germane cognitive load. The germane cognitive load score of the control group was higher than that of the conceptual-worked example group (see Fig. 1). Germane cognitive load is directly related to learning achievement because it is imposed by mental efforts. Although the intrinsic and extraneous loads in the conventional approach group were higher than in the conceptual-worked example group, we could conclude that the germane load was more affective than those two loads. These results imply that the level of retention test in this kind of experiment does not exceed the working memory capacity and, therefore, support the Sweller (1994)'s cognitive load theory.

Regarding the interaction effect of two independent variables, there were significant effects in the element transfer test (see Fig. 2). Our study reported the "expertise reversal effect" in the element transfer test. For our experiments, learners with the high prior knowledge in the treatment which was presented by the only procedural information of worked example achieved higher but non-significant scores than in the treatment which was presented by the sequential presentation of two kinds of information of worked examples. These results mean that two kinds of information were redundant and were not helpful for high prior knowledge learners. However, learners with low prior knowledge achieved significantly higher scores in the CPWE condition than in the PWE condition. The results showed that both conceptual and procedural information are necessary for low prior knowledge learners to solve the complex problems. We can

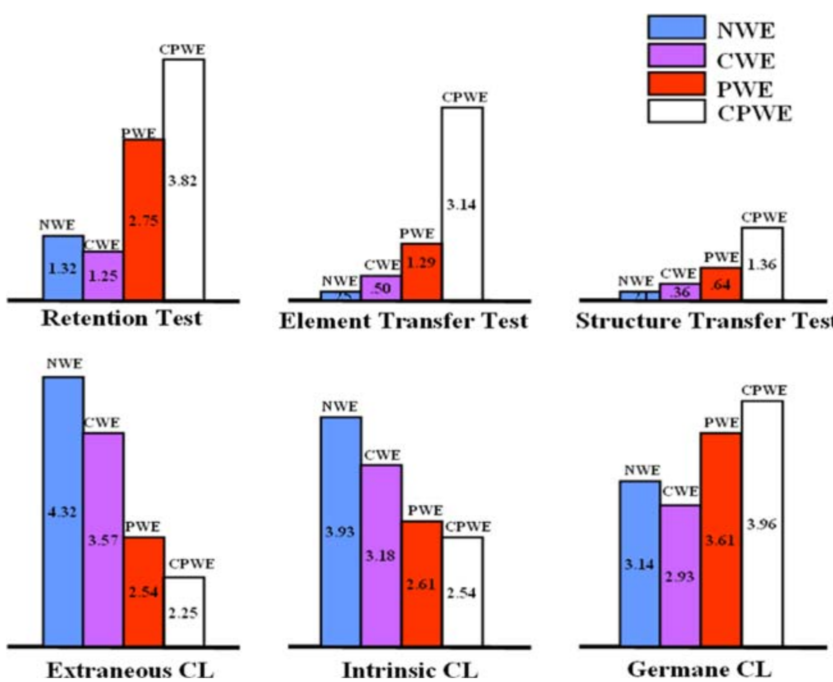

Fig. 1 Proportions by the presentation formats of worked examples on the retention, transfer, and cognitive loads. *Note*: *NWE* no worked examples (control group); *CWE* conceptual worked examples; *PWE* procedural worked examples; *CPWE* conceptual and procedural worked examples

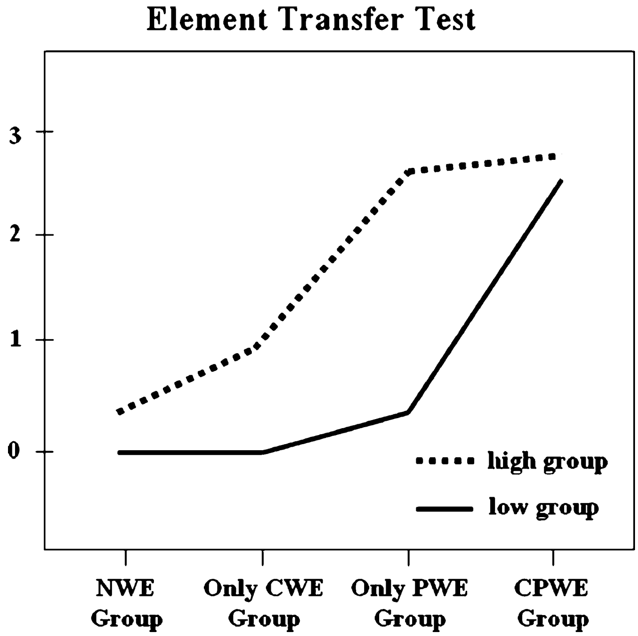

Fig. 2 Interaction effect presentation formats of worked example and prior knowledge of learner in the Element Transfer Test. *Note*: *NWE* no worked examples (control group); *CWE* conceptual worked examples; *PWE* procedural worked examples; *CPWE* conceptual and procedural worked examples

conclude that conceptual- and procedural-worked examples are essential components for learners who lack of pre-requisite knowledge and prior experience.

This expertise reversal effect happens not in the retention test and structure transfer test but in the element transfer test. Retention is to memorize new knowledge or information. Therefore, the more amount of information such as both kinds (conceptual and procedural) of worked examples are provided, the better learners can retain the information. Whereas, element transfer test is not too difficult as the structure transfer test, learners experience similar format questions in the retention test. Accordingly, we interpret both conceptual and procedural information of worked examples as redundant for high prior knowledge learners in the element transfer test, because the element transfer test is a kind of test which is slightly applied and transformed. We can conclude that worked example needs to be classified and be differently provided to learners dependent on their own prior knowledge level. This study has the significance to support cognitive load theory and expertise reversal effect on the theoretical side, and the implication to suggest instructional strategies according to the level of learners' prior knowledge and problems on the practical side.

This study is significant in that the components of worked examples were categorized and their main effects and the interaction effects were examined. We investigated the effect of worked example components only in well-structured computer-based learning environments and the subject of Mathematics. It is necessary to develop the results of this present study in various subjects, with different learners and in ill-structured learning environments.

Acknowledgment This work was supported by the University of Seoul 2007 Research Fund.

Appendix A

Cognitive load subjective experience questionnaire

1. What effort did you make to understand the instructions?

   ① I just skipped the instructions.
   ② I roughly read the instructions.
   ③ I earnestly read the instructions.
   ④ I read the instructions trying to understand well.
   ⑤ I completely concentrated on reading instructions.

2. How easy or difficult was it to understand the instructions?

   ① The instructions were very easy to understand.
   ② The instructions were a little bit easy to understand.
   ③ The instructions were neither easy nor difficult to understand.
   ④ The instructions were a little bit difficult to understand.
   ⑤ The instructions were extremely difficult to understand.

3. How easy or difficult was it to understand the subject?

   ① Subject was very easy to understand.
   ② Subject was a little bit easy to understand.
   ③ Subject was neither easy nor difficult to understand.
   ④ Subject was a little bit difficult to understand.
   ⑤ Subject was extremely difficult to understand.

   (I didn't understand any of the problems)

Appendix B

Sheet used in retention test
   * You will be solving algebra problems as follows

1. $c\,(a + d)/f = g$ express a in terms of other variations.
2. $a = d + ac$ express a in terms of other variations.
3. $c\,(a + d) = a/af$ express a in terms of other variations.
4. $(af + e)/b = c$ express a in terms of other variations.

5. $d\,(b - a)/g = f$ express b in terms of other variations.
6. $b = f - bg$ express b in terms of other variations.
7. $c\,(a + b) = bf/b$ express b in terms of other variations.
8. $bf + e/d = c$ express b in terms of other variations.

Appendix C

Sheet used in transfer test

* You will be solving algebra problems as follows.

<Element Transfer Test>

1. $d\,(a - b)/e = f$ express a in terms of other variations.
2. $b = e + bc$ express b in terms of other variations.
3. $c\,(b + a) = af/f$ express a in terms of other variations.
4. $bf + e/d = c$ express b in terms of other variations.

<Structure transfer test>

1. $2(y + 3)/x = 2$ express y in terms of other variations.
2. $y = 2 + xy$ express y in terms of other variations.
3. $3(2 + x) = xy/x$ express x in terms of other variations.
4. $3x + 2/y = 3$ express x in terms of other variations

References

Bralfish, O., Borg, G., & Dornic, S. (1972). Perceived item-difficulty in three tests of intellectual performance capacity, Report No. 29. Institute of Applied Psychology, Stockholm, Sweden.

Carrol, W. M. (1994). Using worked examples an instructional support in the algebra classroom. *Journal of Educational Psychology, 86*(3), 360–367.

Cooper, G., & Sweller, J. (1987). Effect of schema acquisition and rule automation on mathematical problem-solving transfer. *Journal of Educational Psychology, 79*(4), 347–362.

Crippen, K. J., & Earl, B. L. (2007). The impact of web-based worked examples and self-explanation on performance, problem solving, and self efficacy. *Computers & Education, 49*, 809–821.

Gerjets, P., Scheiter, K., & Catrambone, R. (2006). Can learning molar and modular worked examples be enhanced by instructional explanations and prompting self-explanations? *Learning and Instruction, 16*, 104–121.

Gerjets, P., Scheiter, K., & Schuh, J. (2008). Information comparisons in example-based hypermedia environments: Supporting learners with processing prompts and interactive comparison tool. *Educational Technology Research and Development, 56*, 73–92.

Hoogveld, A., Paas, F., & Jochems, W. (2005). Training higher education teachers for instructional design competency-base education: Product-oriented versus worked examples. *Teaching and Teacher Education, 21*(3), 287–297.

Joung, S. (2006). The effects of product-oriented whole-task approach on problem solving, cognitive load, and satisfaction. *Journal of Educational Technology in Korea, 22*(1), 35–55.

Jung, H., & Kim, D. (2006). The effect of the worked-out example types on knowledge sharing process in computer supported collaborative learning. *Journal of Educational Technology in Korea, 22*(3), 23–56.

Kalyuga, S. (2006). Rapid cognitive assessment of learners' knowledge structures. *Learning and Instruction, 16*, 1–11.

Kalyuga, S., Ayres, P., Chandler, P., & Sweller, J. (2003). The expertise reversal effect. *Educational Psychologist, 38*(1), 23–31.

Kalyuga, S., Chandler, P., Tuovinen, J., & Sweller, J. (2001). When problem solving is superior to studying worked examples. *Journal of Educational Psychology, 93*(3), 579–588.

Kim, K. (2005). Effect of practice problem on cognitive skill acquisition in multimedia-based instruction. *The Journal of Educational Information and Media, 21*(3), 33–62.

Lee, H., Plass, J. L., & Hormer, B. D. (2006). Optimizing cognitive load for learning from computer-based science simulations. *Journal of Educational Psychology, 98*(4), 902–913.

Nadolski, R. J., Kirschner, P. A., & van Merriënboer, J. J. G. (2006). Process support in learning tasks for acquiring complex cognitive skills in the domain of law. *Learning and Instruction, 16*, 266–278.

Paas, F., & van Merriënboer, J. J. G. (1994). Variability of worked examples and transfer of geometrical problem solving skill a cognitive load approach. *Journal of Educational Psychology, 86*(1), 122–133.

Schworm, S., & Renkel, A. (2006). Computer-supported example-based learning: When instructional explanations reduce self-explanations. *Computers & Education, 46*, 426–445.

Sweller, J. (1994). Cognitive load theory, learning difficulty and instructional design. *Learning and Instruction, 4*, 295–312.

Sweller, J., & Cooper, G. (1985). The use of example as a substitute for problem solving in learning algebra. *Cognition and Instruction, 2*(1), 59–89.

van Gerven, P., Paas, F., van Merriënboer, J. J. G., & Schmidt, H. G. (2002). Cognitive load theory and aging: Effect of worked examples on training efficiency. *Learning and Instruction, 12*, 87–105.

van Gog, T., Paas, F., & van Merriënboer, J. J. G. (2006). Effect of process-oriented worked examples on troubleshooting transfer performance. *Learning and Instruction, 16*, 154–164.

van Gog, T., Paas, F., & van Merriënboer, J. J. G. (2008). Effect of studying sequences of process oriented and product-oriented worked examples on troubleshooting transfer efficacy. *Learning and Instruction, 18*, 211–222.

Ward, M., & Sweller, J. (1990). Structuring effective worked example. *Cognition and Instruction, 7*(1), 1–39.

Zhu, X., & Simon, H. A. (1987). Learning mathematics from examples and by doing. *Cognition and Instruction, 4*(3), 137–166.