The Effectiveness of Worked Examples in a Game-Based Learning Environment

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Abstract

Researches indicate that worked examples could effectively facilitate problem solving by reducing cognitive load during learning. However, there is no study using worked examples in a game-based environment. The purpose of this study was to examine the effectiveness of worked examples on problem solving in a game-based environment. In this study, 72 adults were randomly assigned into the treatment group (i.e., worked examples) or control group and asked to play a computer puzzle game. Participants were asked to complete a content understanding knowledge map and answer retention and transfer problem-solving strategy questions. Results show that the treatment group improved significantly more than the control group on all measures. In conclusion, this study indicates that worked examples had significant effects on problem solving in a game-based task. However, the improvement was small compared to experts' performance. In order to obtain greater improvement, the worked example instruction could add: (a) practice problems, (b) fading procedure, (c) self-explanations, (d) verbal instruction, and (e) subgoals.

Keywords: Worked Examples, Computer Games, Problem Solving, Cognitive Load Theory, Scaffolding

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Many researches indicate that worked examples could effectively facilitate problem solving by reducing cognitive load during learning. On other hand, many researches show that computer games are widely accepted as an alternative to traditional ways of teaching and learning. However, there is no study using worked examples in a game-based environment.

Purpose of the Study

The main purpose of this study was to examine the effectiveness of worked examples on problem solving in a game-based environment. The researcher used the problem-solving assessment model developed by the National Center for Research on Evaluation, Standards, and Student Testing (CRESST) to measure the three components of problem solving: content understanding, problem-solving strategy, and self-regulation (Baker & Mayer, 1999; Mayer, 2002).

Theoretical Framework

Computer games have been used for learning and training in many different fields, such as academic (Adams, 1998), business (Faria, 1998; Lane, 1995; Washbush & Gosen, 2001), military (Chambers, Sherlock, & Kucik, 2002), and medical (Ruben, 1999). Researchers (e.g., Mayer, Moutone, & Prothero, 2002; Rosenorn & Kofoed, 1998; Schank, 1997) pointed out that games are widely accepted as an alternative to traditional ways of teaching and learning, with the merits of facilitating learning by doing.

The effects of instructional games can be generally divided into four categories: (a) promotion of motivation, (b) enhancement of thinking skills and metacognition, (c) improvement of knowledge, and (d) improvement of attitude. There is some evidence that playing computer games can enhance motivation (e.g. Amory, Niacker, Vincent, & Adams, 1999; Dawes & Dumbleton, 2001; Westrom and Shaban, 1992), thinking skills and metacognition (e.g. Bruning et al., 1999; Henderson, Klemes, & Eshet, 2000; Pillay, Browlee, & Wilss, 1999; Taylor, Renshaw, & Jensen, 1997), knowledge (e.g. Adams, 1998; Fery & Ponserre, 2001; Ricci et al., 1996; Santos, 2002; Westbrook & Braithwaite, 2001), and attitudes (e.g. Amory et al., 1999; Wellington & Faria, 1996; Westbrook & Braithwaite, 2001). In addition, problem solving may be effectively improved by computer games (Mayer et al., 2002).

Many researchers agree that problem solving is defined as cognitive processing directed at achieving a goal when no solution method is obvious to the problem solver (Mayer & Wittrock, 1996). There are many studies showing the problem solving is one of the most important abilities in workplaces and schools (Bassi et al., 1996; Mayer et al., 2002).

The National Center for Research on Evaluation, Standards, and Student Testing (CRESST) developed a problem-solving model. The CRESST model of problem solving consists of three components: (a) content understanding, (b) problem-solving strategies, and (c) self-regulation (Baker & Mayer, 1999). In addition, problem-solving strategies could be divided into two categories, which are domain-independent and domain-specific problem-solving strategies. Furthermore, self-regulation consists of two subcategories, metacognition and motivation. The former is composed of self-monitor and planning, and the latter is composed of effort and self-efficacy (Baker & Mayer, 1999). This study used the CRESST model of problem solving as its theoretical frame.

A number of researchers investigated the efficacy of using worked examples in classroom instruction and provided evidence in the effectiveness of worked examples instruction (Carroll, 1994; Cooper & Sweller, 1987; Ward & Sweller, 1990; Zhu & Simon, 1987). According to Sweller (1998), a worked example is a procedure that focuses on problem states and associated operators (i.e. solution steps), enabling students to induce generalized solutions or schemas. The authors used worked examples as the instructional intervention in this study.

Based on the results of the studies conducted by Sweller (1994) and Sweller and Chandler (1994), they developed cognitive load theory to explain the limitation of cognitive resources during problem solving. Sweller (1990) also used schema theory to explain worked example effect and defined schema as a cognitive construct that allows problem solvers to recognize problems and problem states as belonging to a particular category requiring particular moves for solution. Vygotsky (1989) viewed scaffolding as personal aid provided by a teacher or peer to help with the learning process. Recently, the concept of scaffolding has been broadened to include a multitude of different tools and resources that can be used by students to assist them with instructional activities (Brush & Saye, 2001). According to Rosenshine and Meister (1992) and Woolfolk (2001), worked example instruction is one kind of scaffolding.

The design or structure of worked examples plays an important role in their effectiveness (Catrambone, 1994; Catrambone & Holyoak, 1990; Mwangi & Sweller, 1998; Ward & Sweller, 1990; Zhu & Simon, 1987). There are six instructional principles of worked examples: before vs. after (Reiser, 1993), complete vs. incomplete (Renkl, Atkinson, Maier, & Staley, 2002), backward fading vs. forward fading (Atkinson, Renkl, & Merrill, 2003; Renkl, Atkinson, Maier, and Staley, 2002), text vs. diagrams (Sweller, 2004; Sweller, Chandler, Tierney, & Cooper, 1990; Tarmizi & Sweller, 1988; Ward & Sweller, 1990), visual vs. verbal (Mayer & Moreno, 2003;

Mousavi, Low, & Sweller, 1995), and steps vs. subgoals (Catrambone & Holyoak,1990). In summary, the worked examples in this study had the following design characteristics: (a) being given before the problem, (b) being complete, (c) not including fading procedure, (d) using integrated text and diagrams, (e) using visual-visual instruction, and (f) using steps.

Methods/Data Sources

The procedures in this study were adapted from Chen's (2005) study. The present study consisted of a pilot and a main study. The purpose of the pilot study was to investigate the feasibility of procedures and measurements, the format of worked examples and the assessment tools for problem solving. The purposes were successful. The purpose of the main study was to evaluate the effectiveness of worked examples in a game-based problem-solving task. The research question in this study is: Will participants in the worked example group increase their problem solving in a game-based task (i.e. SafeCracker) after studying worked examples compared to the control group?

In the main study, 72 undergraduate or graduate students were randomly assigned into two groups, which were the worked example and the control group. Each group was asked to play the computer puzzle game, i.e., SafeCracker. SafeCracker is a computer puzzle game that requires the players to find the clues, apply the tools and knowledge, and solve the puzzles in order to open the safes in a mansion. In the procedure, the participants were asked to fill out self-regulation questionnaires first. Then, they were asked to complete the knowledge maps and problem-solving strategy questions after the first game playing as the pretests. Next, the worked example group studied the worked examples, and the control group did not. Then, they were asked to complete the knowledge maps and problem solving strategy questions after the second

game playing as the posttests. Finally, the debriefing completed the main study.

Results and Conclusions

The results obtained in this study provided the evidence that worked examples could enhance problem solving in a game-based environment. First, the participants who received worked examples improved significantly more than those who did not receive worked examples on the knowledge map. The average improvement in knowledge map score of the worked example group was more than that of the control group, i.e., 2.21 (SD = 2.56) vs. 0.62 (SD = 2.45).

Second, the participants who received worked examples improved significantly more than those who did not on the problem solving retention question. The adjusted mean of the posttest of retention score of the worked example group was more than that of the control group, i.e., 4.18 (SD = .15) vs.3.54 (SD = .15). Third, the worked example group improved significantly more than the control group on the problem solving transfer question. The adjusted mean of the posttest of transfer score of the worked example group was more than that of the control group, i.e., 2.37 (SD = .14) vs. 1.97 (SD = .14).

With respect to self-regulation, significant relationships were found only between the scores of trait self regulation questionnaire and knowledge map scores for the total sample. For the total sample, the participants with higher planning performed better in knowledge map pretest and posttest; the participants with higher self-monitoring got higher scores on knowledge map posttest and improvement; the participants with higher effort performed better on knowledge map improvement; and the participants with higher self-efficacy got higher scores on knowledge

map pretest, posttest, and improvement.

In conclusion, this study indicated that worked examples had significant effects on problem solving in a game-based task. After studying the worked examples, the participants improved more than those who did not receive worked examples in content understanding and problem-solving strategies. However, the improvement was small compared to expert performance. The worked example group learned only 2.7% of the experts' knowledge reflected in their knowledge maps.

Scientific and Educational Implications of this Study

There are many worked example studies in the field of mathematics, computer programming, and physics (Tarmizi & Sweller, 1988; Sweller, Chandler, Tierney, & Cooper, 1990; Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Ward & Sweller, 1990), but there is no study investigating the effectiveness of worked examples in game-based problem-solving tasks. To our knowledge, this study is the first experimental study with adults using worked examples to improve learning in a game-based environment. Such study would improve the knowledge base, and for practicability it would provide design principles to promote learning from commercial off-the-shelf games.

There are several implications resulting from this study in the fields of worked example instruction, problem solving, and game-based learning environments. The present study confirmed that worked example is effective in a game-based problem-solving task. In this study, worked example instruction produced a significant increase in content understanding and problem-solving strategies compared to the control group. The utility of a knowledge mapping system to assess content understanding was also indicated. The results also show that providing

effective instructional strategies, i.e., worked examples, could enhance the training effectiveness with commercial off-the-shelf computer games. However, the validity of this new system needs to be evaluated in future studies.

Although the results suggested that worked example is superior to problem solving on enhancement of problem solving in a game-based environment, the improvement was small. In order to obtain greater improvement, the worked example instruction could add: (a) practice problems (Pass, 1992; van Merrienboer, 1990), (b) fading procedure (Renkl, Atkinson, Maier, & Staley, 2002), (c) self-explanations (Atkinson, Renkl, & Merrill, 2003; Renkl, Atkinson, & Grobe, 2004), (d) verbal instruction (Mayer, Moreno, & Boire, 1999), and (e) subgoals (Catrambone, 1994; Catrambone & Holyoak, 1990) in future study.

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