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Effects of multimedia on cognitive load, self-efficacy, and multiple rule-based problem solving

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Abstract

This study investigates effects of multimedia on cognitive load, self-efficacy and learners' ability to solve multiple rule-based problems. Two hundred twenty-two college students were randomly assigned to interactive and non-interactive multimedia groups. Based on Engelkamp's multimodal theory, the present study investigates the role of multimedia in multiple rule-based problem solving. The findings indicate that providing learners with manipulative function in multimedia would facilitate their problem solving through reduced cognitive load and improved self-efficacy. The study identifies a significant mediator effect for self-efficacy that mediates between multimedia and learners' problem solving. Discussion focuses on the effects of multimedia and self-efficacy on learners' performance in multiple rule-based problem solving. Suggestions are made with regard to the design of problem solving in future studies.

Introduction

Recently, considerable attention has been given to using multimedia to facilitate learners' problem solving abilities (Lee, Plass & Homer, 2006; van Merrrienboer & Sweller, 2005). Research shows that problem solving can be very challenging to learners because of the high cognitive load induced by the problem solving process (Kester, Kirschner & van Merrienboer, 2005; Mayer & Sims, 1994; Sweller & Chandler, 1991, 1994). Research in the past has been primarily focused on applying non-interactive multimedia to solve linear causal relationship problems (Mayer & Sims, 1994). Few studies have examined the relationship between interactive multimedia and multiple rule-based problem solving. It is believed that providing manipulative function in multimedia can improve learners' problem solving skills by (1) promoting their self-efficacy and (2) reducing the cognitive load involved in problem solving process (Zheng & Zhou, 2006; Zheng, Miller, Snelbecker & Cohen, 2006). Therefore, the goal of the present study is to examine the role of interactive multimedia, along with other factors such as self-efficacy, in learners' ability to solve multiple rule-based problems.

Problem-solving and cognitive load

Problems may be categorised either as ill-structured or well-structured. The ill-structured problem emphasises an open-ended approach without specific solutions in mind. The purpose is to help learners develop the abilities to create and construct new knowledge through reasoning. It focuses on diverse relationships between elements and the changes over time in elements (Jonassen, 1997; van Merrienboer, 1997). The well-structured complex problem has a pre-defined solution and is characterised by a high level of element interactivity (Sweller, 2006; Sweller & Chandler, 1991). Thus, ill-structured problems are used to promote learners' constructive thinking in problem solving whereas well-structured problems are utilised in instruction to 'manifest reasoning and thinking processes' (Jonassen, 1997, p. 67). The present study used well-structured problems to investigate learners' reasoning and thinking processes in terms of cognitive load.

It is believed that the learner's ability to solve problems can be affected by the cognitive load which is in turn influenced by the level of complexity in the problem (Sweller & Chandler, 1991, 1994; van Merrrienboer & Sweller, 2005). For example, a single rule-based problem requires a straightforward deductive thinking such as applying the rule of card sorting to the action of sorting a deck of cards (Frye, Zelazo & Palfai, 1995; Johnson, Boyd & Magnani, 1994) and is, therefore, less memory intensive. In contrast, a multiple rule-based problem involves a complex, nonlinear thinking where the learner reaches a solution by engaging in a series of cognitive activities such as analysing, synthesising, and evaluating while holding several conditions and rules in mind within a short time framework (Zheng *et al*, 2006). VanLehn (1999) studied college students who applied multiple rules to solve physics problems in a college physics class. He observed that as students applied multiple rules to problem solving, an 'impasse' occurred which caused significant delays in problem solving as well as failure to apply correct rules to problem solving. He concluded that multiple rule-based problem solving requires high-level cognitive resources and may affect learners' ability to solve problems.

Obviously, multiple rule-based problem solving is likely to consume more cognitive resources in the limited working memory and therefore would induce a higher level of cognitive load in problem solving than does a single rule-based problem. Consider, eg, solving a multiple rule-based problem presented in Figure 1. The problem is a well-structured problem that includes several mutually restricting conditions that constrain the order and parking positions of airplanes. The learner has to consider these conditions simultaneously before a solution can be reached by deciding which airplane would park at which gate without violating the conditions. The information process involved

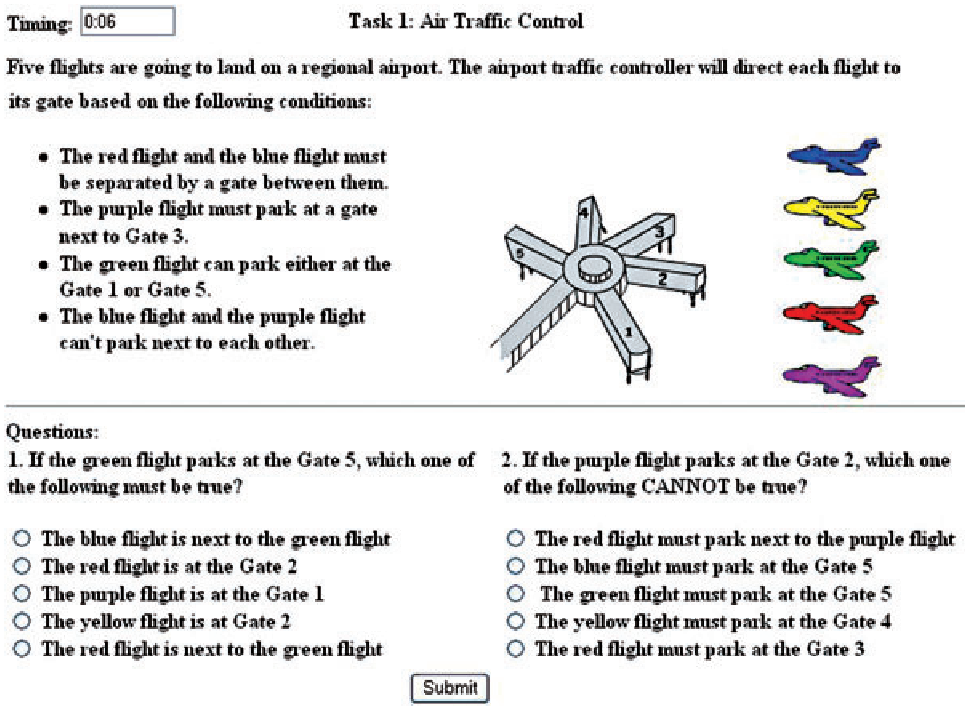

Figure 1: A sample of multiple rule-based problem solving task: Air traffic control

in this type of problem solving has a high level of element interactivity (ie, considering multiple conditions simultaneously) that can induce a high cognitive load in the memory workspace.

Two types of cognitive load may affect learning. They are intrinsic and extraneous cognitive load. According to Sweller and Chandler (1991), intrinsic cognitive load refers to cognitive load that is induced by the structure and complexity of the instructional material. Usually, teachers or instructional designers can do little to influence the intrinsic cognitive load. Extraneous cognitive load refers to the cognitive load caused by the format and manner in which information is presented. For example, teachers may unwittingly increase learners' extraneous cognitive load by presenting materials that 'require students to mentally integrate mutually referring, disparate sources of information' (Sweller & Chandler, 1991, p. 353). Over the last three decades, efforts have been made to explore ways to reduce cognitive load in problem solving through the introduction of multimedia learning.

Multimedia learning

Research on multimedia learning suggests that multimedia can foster cognitive change (Mariano, Doolittle & Hicks, in press; Mautone & Mayer, 2001) and facilitate information processing in learning (Mayer & Moreno, 2003; Rieber & Kini, 1991). According to Mayer's (2001) theory of multimedia learning, the learner's ability to generate mental representation of external information is enhanced when incoming information is presented through multiple sensory channels, an assumption that aligns well with Paivio's (1986) dual coding theory. However, this line of research in the past has been focused on the effects of non-interactive external stimuli such as text, pictures, narration, and so forth. Little research has been done to examine the effects of interactive or manipulative aspects in learning (Reed, 2006).

With an increasing presence of interactive multimedia (eg, simulations, gaming and virtual reality) in education, research on interactive multimedia begins to emerge. One of the major questions addressed by this emerging research is the cognitive benefit of having students interact with multimedia. In other words, why is manipulative learning effective for learners' learning? Engelkamp (1998) proposes a multimodal theory in which he contends that observed actions ought to be distinguished from performed actions due to the different encoding systems involved. Engelkamp conducted a series of studies by asking participants to act out or just read the action words. The results show that enactment is more effective than just reading the action words in recalling (Engelkamp, 1998). Engelkamp believes that haptic learning, like motor manipulation, is encoded differently than perceptual learning that involves primarily verbal and visual encoding. By extending the principle suggested in the findings of Engelkamp, it can be reasonably assumed that interactive multimedia would be more effective than non-interactive multimedia in facilitating the processing of information.

Researchers (eg, Mayer, 2001; Mayer & Moreno, 2003) argue that facilitating effective information process and reducing cognitive load in learning require more than just providing single-modal or multimodal delivery procedures, and that the design of multimedia is more important in helping learners learn content efficiently and effectively. In his theory of multimedia learning, Mayer (2001) identifies principles for designing effective multimedia for optimal learning. One of these principles concerns the effects of juxtaposing the text and the graphics simultaneously on one display. Mayer argues that if the text and the graphics are displayed on one screen, there would be less distraction and easier mental coordination between verbal and visual information (spacial contiguity; Mayer, 2001). However, if the text and the graphics are displayed on separate screens, additional cognitive resources are needed to mentally integrate the information that would induce high cognitive load.

Self-efficacy

Studies have shown that learners' ability to solve problems can be affected by their self-efficacy (Lodewyk & Winne, 2005). Self-efficacy is defined as a belief that an individual has about his or her capabilities to execute the courses of actions required to manage prospective situations. Unlike efficacy, or to state it another way, competence, which is the power to produce an effect, self-efficacy is the individual's self-perception of his or her power to produce that effect (Bleicher & Lindgren, 2005; Lodewyk & Winne, 2005). Bandura (1993) believes that self-efficacy is the most central or pervasive variable that influences learners' achievement. Bleicher and Lindgren (2005) discovered a significant impact of self-efficacy on learners' hands-on and minds-on learning in science. Research in the past has been primarily focused on the effects of self-efficacy on achievement. Little attention has been given to the effects of multimedia on learners' self-efficacy. A recent study by Isiksal and Askar (2005) indicates that technology may influence students' self-efficacy in learning. Cauble and Thurston's (2000) study on the effects of technology on self-efficacy finds that technology provides multiple benefits to students by allowing 'students to control the pace of the program ... explore content and create their own routes through the material' (p. 436). They conclude that technologies 'influence their [students] confidence level with the material ... [and] develop a sense of competence in the student area' (p. 436). Obviously, previous research has treated self-efficacy either as an independent variable that influences learning achievement (eg, Bleicher & Lindgren, 2005), or looked at it as a dependent variable that is influenced by technology (eg, Cauble & Thurston, 2000; Isiksal & Askar, 2005). Yet, a holistic approach to self-efficacy is lacking that examines self-efficacy as being influenced by and influencing other variables involved in learning. In other words, there is a need to explore the role of self-efficacy as a mediator that mediates between independent and dependent variables. Therefore, the present study examines the effects of multimedia on learners' changes in self-efficacy and whether the changes in self-efficacy would in turn influence performance.

Research questions

Based on the discussion above, the following research questions are proposed as the basis for the study:

1. Does multimedia influence learners' self-efficacy, cognitive load and performance in solving well-structured complex problems?
2. Is there a change in self-efficacy due to a multimedia effect?
3. Is there a mediator effect for self-efficacy that mediates between multimedia and achievement?

Method

Participants

Participants ($n = 222$) were recruited from three universities that included a large urban university, a private university in the north-east of the United States, and a mid-size teaching university in the south. Of 222 participants, 32% ($n = 72$) were males and 68% ($n = 150$) were females. Approximately 87% ($n = 194$) were Caucasian and 13% ($n = 28$) were non-white. Participants varied in age from 19 to 57 years old ($M = 24$, $SD = 7.33$). None of the participants reported any familiarity with the content and problem types, thus eliminating the concern for prior knowledge as a covariance for affecting learners' performance in problem solving.

Instrumentation

The instruments used in this study consist of self- and task-perception questionnaire (STPQ) scales, cognitive load questionnaire and multimedia problem-solving tasks (MPSTs).

STPQ scales

The STPQ scales were originally developed by Lodewyk and Winne (2005) who reported an internal consistency reliability coefficients before and after each task ranging from 0.72 to 0.92. The instrument is adapted for the study with the permission of the original authors. Changes are made to better fit the purpose of this study. For example, the statement 'Knowing the difficulty of this project, the teacher, and my skills, I think I will do well on this project' was changed to 'Knowing my skills and abilities, I think I will do well on problem solving.' The instrument consists of seven statements with a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The total possible score one could obtain on the test is 35 points.

Cognitive load questionnaire (CLQ)

The CLQ is a three-item questionnaire developed by Paas (1992). Changes are made to better fit the purpose of the study. The first item probes into learners' mental effort involved in problem solving. The second item asks learners' experience in problem solving. The third item investigates learners' perception of the difficulty of the problems. A 9-point Likert scale is used with the first two items and the last item uses a 7-point scale. The total possible score one can obtain on the test is 25 points. An alpha reliability analysis was performed to determine the internal consistency of items. The result indicated a high reliability with Cronbach Alpha = 0.905.

Despite its subjectivity, the CLQ has been widely used to measure cognitive load in learning. In a review of 27 studies related to cognitive load measures, Paas, Tuovinen, Tabbers and van Gerven (2003) found that 21 out of 27 studies used CLQ to measure cognitive load. Windell and Wieber (2007) compared the NASA-Task Load IndeX (NASA-TLX) Mental Demands subscales with an adapted version of CLQ by assessing levels of cognitive load across a variety of load situations where intrinsic and extraneous loads were manipulated. They found a medium to high correlation between the two measures from 0.72 to 0.98. Given the fact that the CLQ has been widely adopted by researchers for measuring cognitive load in learning, the instrument was used in the current study for load measurement.

MPSTs

The problem solving tasks were developed by the first author (Zheng *et al*, 2006). Using Mayer's principle of spacial continuity multimedia design, a single display design approach was adopted with both text and picture on the same screen (Figure 1). The problem solving tasks include: air traffic control, tower of Hanoi, sailing boat, seating arrangement, taking pictures, and office inspection. Each task consists of two parts: (1) a problem presented with text format along with a visual presentation and (2) multiple choice questions. The problem includes a description of a problem situation and several mutually restricting conditions. The participant had to consider these conditions simultaneously before a solution could be reached. The inter-item reliability was run which showed a medium-high reliability with Cronbach Alpha = 0.881.

Participants were randomly assigned to one of two conditions: interactive and non-interactive. In the non-interactive multimedia condition, participants were given a static visual representation along with the text. In the interactive multimedia condition, participants were able to manipulate and move important components of the image (eg, airplanes) by referring back and forth to the text. Figure 1 shows the interface for both interactive and non-interactive multimedia conditions. In interactive multimedia condition learners were able to move the airplanes to simulate different situations whereas in non-interactive multimedia condition learners had the picture but were not able to simulate the situations via manipulation. Thus, the learners in non-interactive multimedia condition had to rely on mental operation to find the solution. For each problem, participants were asked to answer two questions that measured their problem solving skills. After completing the two questions, the participant clicked the submit button to complete the task. A timer was created to record the start and end time during the test. The total possible score one could obtain on the whole test was 12 points.

Procedures

A randomisation procedure was used to randomly assign the participant into one of the multimedia conditions: interactive and non-interactive. The participants were first given the URL and told to logon to the problem solving website. They were asked to complete a self-efficacy pre-test, fill out a demographic information sheet and then work on the MPSTs. The order of the problem solving tasks was randomised to minimise the test item effect. The participants in the interactive multimedia condition were able to move the figures to solve the problems whereas the participants in the non-interactive multimedia condition were provided with the same graphic presentation, but they were not able to move the figures.

Since one of the purposes of the study was to examine the effects of multimedia (interactive vs. non-interactive) on learner's problem solving, to record such effects in terms of interaction required the elimination of other forms of interaction such as using paper and pencil to simulate the problem situation, which would confound the results. Thus, none of the groups were allowed to use paper and pencil during their problem-solving test. After finishing the MPSTs test, they were asked to fill out a cognitive load questionnaire and take the self-efficacy post-test. It took about an hour and half for the participant to complete the entire experiment. Each participant was given a consent form to sign before she or he participated in the study.

Results

The descriptive data for cognitive load, test score, total time in seconds and self-efficacy pre- or post-tests between interactive and non-interactive multimedia groups are presented in Table 1.

Table 1: Mean and standard deviation for test score, total time in seconds, cognitive load, pre self-efficacy test, and post self-efficacy test between interactive and non-interactive multimedia groups

	Interactive multimedia (n = 110)		*Non-interactive multimedia (n = 112)*		*Total (n = 222)*	
	M	*SD*	*M*	*SD*	*M*	*SD*
Test score	8.60	1.59	4.10	2.16	6.33	2.94
Total time in seconds	992.25	181.28	1370.88	352.31	1183.27	338.45
Cognitive load	11.53	3.88	17.96	4.36	14.77	5.23
Pre self-efficacy test	21.50	4.15	23.55	4.13	22.53	4.26
Post self-efficacy test	26.74	3.92	22.48	6.98	24.59	6.05

A one way ANOVA was performed to determine if there was a general multimedia effect on learners' achievement, self-efficacy and cognitive load. The achievement score for each participant was defined as the total test score divided by the total time spent in seconds (Achievement score = $\text{Test score}_{\text{total}}/\text{Time}_{\text{total in seconds}}$). The self-efficacy score for each participant was obtained by subtracting the post self-efficacy test from the pre self-efficacy test (Self-efficacy = $\text{Self-efficacy}_{\text{pretest}} - \text{Self-efficacy}_{\text{posttest}}$). The results showed significant differences between interactive and non-interactive multimedia groups for achievement, $F(1, 221) = 288.08$, $p < 0.001$, self-efficacy, $F(1, 221) = 22.04$, $p < 0.001$, and cognitive load, $F(1, 221) = 134.19$, $p < 0.001$. This confirmed that there was a multimedia effect on learners' achievement, self-efficacy and cognitive load as mentioned in research question one.

In answering research question two, a repeated measures analysis was performed with multimedia (=interactive and non-interactive) as the between-subjects factor and pre- or post self-efficacy tests as dependent measures. For the interactive multimedia group there was a significant change between pre ($M = 21.50$, $SD = 4.15$) and post ($M = 26.74$, $SD = 3.92$) self-efficacy tests, $F(1, 219) = 28.37$, $p < 0.001$. For the non-interactive multimedia group the change was not significant with a slight decrease in mean scores from pre- ($M = 23.55$, $SD = 4.13$) to post ($M = 22.48$, $SD = 6.98$) self-efficacy tests. There was a significant interaction between self-efficacy and multimedia, Wilk's $\lambda = 0.764$, $p < 0.001$, $\eta^2 = 0.24$ (Figure 2), which suggests that learners' self-efficacy could be affected by the type of multimedia used in problem solving.

Research Question 3 investigated the role of self-efficacy as a mediator between multimedia and achievement. A path analysis was performed with multimedia (interactive or non-interactive) as the independent variable, achievement as the dependent variable, and self-efficacy as the mediator. The correlation analysis revealed that achievement was significantly correlated with multimedia ($\alpha = -0.753$, $p < 0.01$, 2-tailed) and self-efficacy ($\alpha = 0.341$, $p < 0.01$, 2-tailed), and multimedia was significantly correlated with self-efficacy ($\alpha = 0.497$, $p < 0.01$, 2-tailed). Multiple regression and simple linear regression analyses were performed. The standard errors and coefficients for the variables are shown in Table 2.

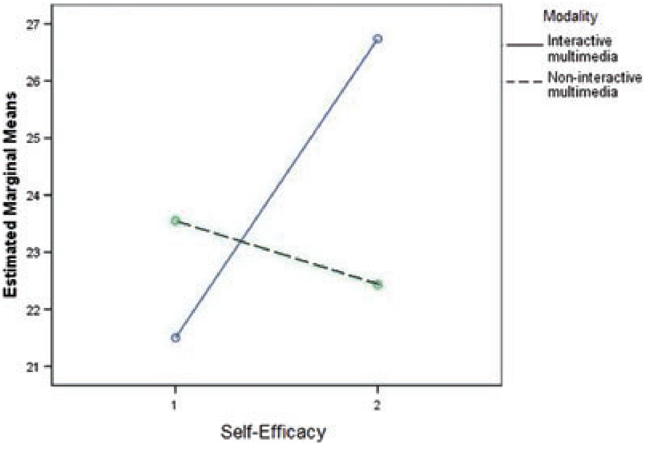

Figure 2: Repeated measures for pre/post self-efficacy tests in interactive and non-interactive multimedia problem solving

Table 2: Regression analyses

Dependent variable	*Causal variable*	*B*	*SE*	*T*	*P*
Achievement	Modality	−1.748	0.469	−3.727	0.001
	Self-efficacy	1.140	0.076	14.941	0.001
		Adjusted $R^2 = 0.531$		$n = 222$	
Self-efficacy	Modality	3.327	0.350	9.505	0.001
		Adjusted $R^2 = 0.290$		$n = 222$	

Results showed a mediator effect for self-efficacy. The variable of self-efficacy was significantly predicted by multimedia and at the same time predicted significantly achievement. Multimedia was a significant predictor for both achievement and self-efficacy. The model below represents the paths among variables with self-efficacy as the mediator (Figure 3).

The Sobel tests were conducted for the model. The coefficients and standard errors of the mediator for both multimedia and achievement were entered in the equation. A significance was detected with $t_{(220)} = 3.617$, $p < 0.001$. The results of Sobel tests showed that self-efficacy was a significant mediator for multimedia and achievement.

Discussion

The results indicate that multimedia had a significant impact on all three variables identified: cognitive load, achievement and self-efficacy, with the interactive multimedia group outperforming the non-interactive multimedia group. Also noteworthy is the role of self-efficacy as a mediator in learners' problem solving process. Based on the findings of the study, the following discussion focuses on (1) the effects of multimedia on learn-

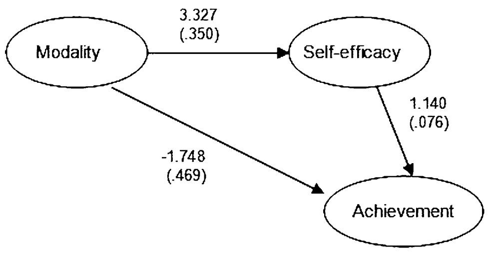

Figure 3: Path analysis model for multimedia, self-efficacy and achievement

ers' multiple rule-based problem solving and related design issues, (2) the change of self-efficacy in problem solving and (3) the effects of self-efficacy as a mediator on learners' problem solving.

Effects of multimedia on multiple rule-based problem solving

A multimedia effect was detected in the study. The interactive multimedia group scored significantly higher and spent less time in the problem-solving test than did the non-interactive multimedia group. The multimedia effect found in this study suggests that interactive multimedia may facilitate learners' multiple rule-based problem solving for the following reasons: (1) multiple sensory inputs, particularly motor manipulation, facilitated information process by reducing the cognitive load in memory workspace and (2) the interactive learner-content control promoted constructive and active learning, which would in turn enhance learners' engagement in problem solving. The results have revealed that learners in the interactive multimedia group experienced a lower cognitive load ($M = 11.53$, $SD = 3.88$) than those in the non-interactive multimedia ($M = 17.96$, $SD = 4.36$). Although Mayer's principle of spacial contiguity rule was applied to both designs, ie, interactive and non-interactive multimedia learning, it seems that in this particular study the difference lay in the availability of certain attributes of the software. The learner-content interaction enabled the learner to externalise the solutions through simulation without holding them in his or her working memory. This process could lead to a reduction in cognitive load. The study also confirmed Engelkamp's (1998) assumptions about manipulative memory encoding by showing the superiority of interactive multimedia learning. Participants with interactive multimedia were able to process complex problems more efficiently than those with the non-interactive multimedia. This may be largely due to the fact that information in haptic learning such as motor manipulation or enactment is coded in ways that can be efficiently retrieved later without overloading the working memory (Engelkamp, 1998). Based on the above observations and findings, it is suggested that future research on multimedia expand its existing framework to include other mode of learning such as manipulative learning in the design.

Change of self-efficacy in problem solving

There is a significant interaction between multimedia and self-efficacy with interactive multimedia group showing changes between pre and post self-efficacy tests (Figure 2).

Additionally, self-efficacy has shown a positive correlation with test scores and a negative correlation with time spent in problem solving and cognitive load. That is, the more confident the participants were about themselves as learners, the higher the test scores would be, the less time they spent in problem solving and the lower the cognitive load. This may suggest that learners who are self-confident are more motivated and therefore more effortful (ie, an increase in germane load, see Sweller, van Merrienboer & Paas, 1998) in learning. From a design perspective, the decrease of intrinsic or extraneous load should be compensated by an increase in germane load. van Merrrienboer and Sweller (2005) argued that it is necessary to invest germane cognitive load in learning because instructional manipulation that leads to reducing extraneous load and freeing up cognitive resources is only effective if the students are motivated and actually use the freed resources in learning. Taken together, the results of the study indicate that learners' change in self-efficacy can influence their performance in complex problem solving, particularly in multiple rule-based problem solving. It appears that improved self-efficacy would positively affect learners' motivation, effort, as well as their germane load in learning. Therefore, instructional designers and educators should not only investigate how intrinsic and extraneous load can be reduced in learning but also the way that germane load must be increased to facilitate active learning.

Effects of self-efficacy on multiple rule-based problem solving

An important finding in this study was the mediator effect of self-efficacy on learners' problem solving. The present study proved that self-efficacy may mediate between multimedia and achievement. While multimedia may influence learner's achievement, self-efficacy could affect such achievement through a change in self-perception about one's ability to learn. However, considerations should be taken when interpreting the results of the present study. (1) Self-efficacy as a mediator has limited influence on achievement. The results of the present study indicated that self-efficacy showed a weaker correlation with achievement ($\alpha = 0.34$, $p < 0.01$, 2-tailed) than did multimedia ($\alpha = -0.75$, $p < 0.01$, 2-tailed), which suggests that other factors such as multimedia and cognitive load should be considered when examining the impact of self-efficacy on learners' problem solving ability. (2) Although there was a multimedia effect on self-efficacy, such effect should be understood in light of the high level of element interactivity of the problems in this study. With high intrinsic element interactivity such as multiple rule-based problems, the effort to alleviate cognitive load via interactive multimedia may have an effect on learners' self-efficacy. However, whether such effect can be generalised to other types of problems such as single rule-based problems requires further investigation.

Conclusion

Solving multiple rule-based problems is a complicated cognitive process. It involves multiple resources both in and outside of the mind. Facilitating such cognitive process thus requires careful planning. In this study, both external and internal conditions were examined to study affective and cognitive aspects of problem solving. The study showed that cognitive load was critical in learners' ability to solve problems. To ascertain the optimal condition in terms of alleviating high cognitive load induced by the multiple rule-based problems, interactive and non-interactive versions of multimedia learning were created. The results showed that providing learners with manipulative function in multimedia learning improves their self-efficacy, problem solving and reduces their cognitive load in learning.

It is believed that manipulative learning is encoded differently from perceptual learning (Engelkamp, 1998; Reed, 2006) and therefore is different from other types of learning such as verbal or visual learning. The findings of the present study confirmed Engelkamp's multimodal theory by showing the effects of interactive multimedia on problem solving. Consistent with the literature, the present study showed that self-efficacy has a positive impact on learners' achievement through an expansion of germane load. The findings revealed a significant mediator effect for self-efficacy in which self-efficacy mediated significantly between multimedia and achievement. It should be noted that the findings were limited to the present study. The generalisation of such findings requires further investigation that should go beyond multiple rule-based problem solving to include other types of problems such as single rule-based problems.

As with all empirical research, the study has shown some limitations. For example, the CLQ as a measure of cognitive load is marked by a subjectivity that may bias the results. Cook, Zheng, and Diaz (in press) suggest convergent measures be used that would combine direct and indirect measures in cognitive load such as dual-tasks, self-rating, eye-tracking and so forth. Another potential concern with the study is the limited variation in population. The subjects were mostly college students. As it was mentioned elsewhere in this paper, this limitation may affect the generalisability of the findings.

The study has contributed to the theory of multimedia learning by examining the relationships among multimedia, self-efficacy and achievement. It identified the mediating effect of self-efficacy in problem solving. It is suggested that the design of problems like multiple rule-based problems should focus on how to reduce cognitive load by incorporating multimodal theory and develop an environment that facilitates positive self-efficacy. Future study should be directed towards the investigation of multimedia effects on both single rule-based and multiple rule-based problems. Further investigation is needed to examine the relevant factors that facilitate the improvement of self-efficacy in learning. Finally, research in the future should include a more diverse population in terms of age, gender, race, ethnicity, grade level, etc. so that the findings can be generalised beyond the scope of the present study and applied to other educational settings.

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