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# Interplay of Germane Load and Motivation During Math Problem Solving using Worked Examples

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***Abstract:*** *Out of all the measures of cognitive load, germane load is crucial in determining one's motivation towards learning. The dynamics between the two becomes even more important when individuals are required to grasp understanding of complex content such as the one presented by math. Current stud explores the relationship between the three facets of cognitive load-intrinsic, extraneous and germane along with surveying if there exists any correlation between germane cognitive load and motivation. Results indicated that germane cognitive load was positively correlated with intrinsic cognitive load and negatively correlated with extraneous load. Another interesting finding was positive correlation between germane cognitive load and interest sub-dimension of motivation.*

***Key Words:*** germane cognitive load, motivation, worked example

## INTRODUCTION

There have been infinite discussions within education communities on how to build and reinstate student motivation when teaching complex content. Common dilemma educators face circle around learners losing motivation towards learning or being cognitively overloaded by the content taught. Over the past years, research has exposed educators to numerous instructional strategies that would be helpful in combating this dilemma. Worked examples is one of the many strategies that helps educators in this regard. This study explores learners' cognitive load and motivation when two different formats of worked examples (full and completion) were used to teach complex math content (systems of equations).

## LITERATURE REVIEW

The primary goal of the study was to explain, from the cognitive load perspective, the relationship between three facets of cognitive load (intrinsic, extraneous, and germane) and if correlation existed between germane cognitive load and any of the four subdimensions of motivation (probability of success, challenge, anxiety and interest).

### COGNITIVE LOAD THEORY

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According to Sweller (2003), our working memory is the limiting base for information that needs to be stored in the long-term memory as schema. Cognitive load theory stresses on the need to optimize instructional materials in learning so that working memory is not overloaded. Learning processes that are supported by working memory, can be affected by intrinsic factors such as difficulty of the instructional material, extraneous factors like how instructional material is taught and/or by germane factors like motivation of the learner to understand the material and/or to further learning.

Intrinsic cognitive load is defined by the difficulty offered by instructional materials (Sweller & Chandler, 1991). There are two factors that determine learner's intrinsic cognitive load: element interactivity and learner's expertise. Element interactivity is defined by levels of interaction between elements within instructional materials. Expertise, on the other hand, helps explain why some material is difficult for some learners as compared to others.

Extraneous cognitive load refers to the mental load caused by improper instructional design (Sweller & Chandler, 1991). Germane cognitive load refers to the cognitive load induced during learning to build new schema and/or to automate existing schema for easy information retrieval (Sweller et al., 1998).

### Worked Examples

One of the widely studied and well applied instructional strategies is worked examples. It has been proven to be effective in reducing cognitive load and optimizing learning (Booth, Lange, Koedinger, & Newton, 2013; Kaluga, 2007; Paas & van Gog, 2006; Renkl, 1997; Sweller & Cooper, 1985). Richey and Nokes-Malach (2013) studied partial support in worked examples (similar to completion worked examples). Results indicated that partial support promotes constructive cognitive activities and facilitates deeper understanding of the materials.

### Task Difficulty

Task difficulty implies categorizing instructional task/learning material as easy or difficult. Some tasks are inherently categorized as easy or difficult, while for other tasks, criteria are developed to make such categorization. Existing literature on cognitive load theory has been focused on expertise (low- or high- prior knowledge) and instructional strategies to understand the two-way interaction between them (Clark, Ayres & Sweller, 2005; Reisslein, Atkinson, Seeling, & Reisslein, 2006). Research suggested that task difficulty can differentiate the function of instructional strategies and inform us of which instructional strategies should be used, when and where they should be used, and how they should be used. Despite all the research on task difficulty, little is known about how expertise and instructional strategies interact with task difficulty during complex learning processes.

### Cognitive Load and Motivation

Out of the three facets of cognitive load, germane cognitive load contributes to the construction and automation of schema (Kirchner, 2002). Sustained mental effort to increase germane cognitive load can best be explained by learner's motivation. This connection also reflects in the effort to develop cognitive load measurement questionnaire to measure three facets of cognitive load separately as opposed to Paas's (1992) measurement of overall cognitive load.

Motivation to acquire understanding of the instructional material or further learning leads to an increase in germane load. Out of the several subdimensions of motivation, four are being studied in the current study using the motivation questionnaire.

Based on the literature cited in the previous section, following research questions were developed for this study:

*Research Question 1:* Is germane cognitive load significantly correlated with intrinsic and extraneous cognitive load?

*Research Question 2:* Is germane cognitive load significantly correlated with subdimensions of motivation?

## RESEARCH METHODOLOGY

### PARTICIPANTS

One hundred and sixty participants were recruited from different undergraduate and graduate academic programs from a state university.

### INSTRUMENTATION

The instruments used in this study consisted of (a) instructional material, (b) pretest, (c) posttest, (d) learning conditions, (e) cognitive load measurement test, (f) questionnaire on current motivation.

**INSTRUCTIONAL MATERIAL**. The instructional material used in this study was based on middle school algebra textbook. The content covered questions from the topic of systems of equations. Modifications to questions was made upon feedback received from a University faculty member.

**PRETEST.** All participants were given the 10-question pretest after they gave consent for the study and completed the demographic survey. Pretest was used to determine whether the participant was in low- or high-prior knowledge group. Although questions on the pretest did not require complex mathematical calculations, participants were expected to have understanding of mathematical problem solving. They were required to solve pretest questions in 15 minutes. Questions were created with variations in difficulty (easy and difficult). Depending on the difficulty of the questions, total points to be acquired for any particular question ranged from 1 point to 2.5 points. The grading of the pretest was based on (1) correct responses and (2) the process of problem solving. In order to receive points for the process, participants were required to show all work related to the question. All questions were hand scored to provide credit for the work shown. Reliability was calculated to be 0.993 (Cronbach's Alpha). Same process of grading was followed when grading questions on the posttest and all instructional conditions.

**POSTTEST.** Posttest also consisted of 10 questions on systems of equations similar to the pretest. Same rationale as that of the pretest was followed in terms of difficulty, structure and grading.

**COGNITIVE LOAD MEASURE TEST (CLMT).** CLMT developed by Leppink et al. (2013) is a 10-question self-report questionnaire. Questions 1 through 3 were related to intrinsic cognitive load, questions 4 through 6 were related to extraneous cognitive load and questions 7 through 10 were related to germane cognitive load.

**Questionnaire on Current Motivation (QCM).** QCM, developed by Rheinberg, Vollmeyer, and Burns (2001) is also a self-report questionnaire that comprises of eighteen questions. Questions measured learner's motivation in four subdimensions-interest, probability of success, anxiety, and challenge.

## RESULTS

### Descriptive Statistics

The final analyses included 115 participants who were retained based on the results of the pretest. These were then divided into low- and high-prior knowledge groups. Of 115 participants, 33 were males and 82 were females. The average age of the participants was 23.1 (5.05) with age of participants ranging from 18 to 45 years.

**Effect of Germane Cognitive Load on Intrinsic and Extraneous Cognitive Load.** To address research question 1, correlation analysis was run with all three facets of cognitive load-intrinsic, extraneous, and germane. As predicted by Sweller (2010), results show that germane cognitive load is significantly positively correlated with intrinsic cognitive load ($r = .216$, $p < .05$ 2-tailed) and significantly negatively correlated with extraneous cognitive load ($r = -.264$, $p < .01$ 2-tailed). This finding confirmed research question 1. As mentioned in the literature, germane cognitive load is associated with schema acquisition and automation while extraneous cognitive load is created due to inappropriate instructional design and/or instructional materials. The significant negative correlation between extraneous and germane load suggested that reducing extraneous cognitive load could lead to an increase in germane cognitive load which, in turn, will improve learning and vice versa. Positive correlation between intrinsic and germane cognitive loads unveiled that when intrinsic cognitive load increases, learners increase their mental effort to understand the learning material.

**Effect of Germane Cognitive Load on Motivation.** To address research question 4, correlation analysis was run between germane cognitive load and subdimensions of motivation. It was found that germane cognitive load was significantly positively correlated with interest sub-dimension of QCM ($r = .264$, $p < .01$). Along with, this study also suggested that learner will invest mental effort if he or she is interested. This interest will, in turn, lead to active construction and/or automation of schema.

## Importance to the Field

This study predominantly finds its applications in both teacher education/preparation programs and middle/high school classroom settings as in both situations educators face the challenge of teaching complex content. Assessment and acknowledgement of students' prior knowledge during planning lessons on complex content and providing feedback are both important and crucial for effective instruction. Instructors need to put in practice teaching strategies like worked examples that will allow them to access students' prior knowledge and provide effective feedback.

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