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BACHELOR'S THESIS

Memes and Math Instruction:

What is the role of math memes on students' cognitive load, performance, and motivation?

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Abstract

The seductive details effect, in educational psychology, is the phenomenon in which embedding eye-catching but irrelevant features into a lesson can derail student learning. However, whether this effect is truly detrimental to students' learning is still debated in the literature (Alexander, 2019; Eitel and Kühl, 2019). This study investigates the role that memes might play in learning math. Specifically, we look at the effect of including two main types of math memes into a lesson: the mathematical meme, which incorporates learnable math concepts into its humor, and the emotional meme, which captures subjective math experiences without learnable concepts (Bini et al, 2020). We found that while there is no significant effect of the memes on cognitive load and performance, the mathematical meme does intrigue students significantly more, making them curious about the lesson to come.

Contents

1 | Introduction

Imagine a classroom of students, listening to a lecture, knowing that they will soon be tested on the material. Each student has a limited amount of mental capacity that they can devote to process the lesson. As the professor fills up the students' mental capacities with relevant information to pass the exam, they occasionally also throw in some highly interesting but irrelevant information to motivate students to pay attention. The students, unsure whether they will be tested on the irrelevant material, try to remember those details--alongside the main lesson takeaways. This causes their memory to overload, because they were holding onto unnecessary--or extraneous--information. In the realm of educational psychology, these interesting but irrelevant tidbits are called *seductive details*. In this study, we explore whether one form of seductive details, Internet memes, might have a detrimental effect on students' comprehension of a daunting subject that might require more motivation than most: mathematics.

1.1 Seductive Details

The *seductive details effect* refers to the phenomenon wherein including interesting but educationally irrelevant content in the instructional materials can result in poorer learning outcomes (Harp & Mayer, 1998; Sundararajan & Adescope, 2020). Research by Harp and Mayer (1998) looking into the mechanisms of how these seductive details work indicates that they operate via "diversion," causing learners to develop coherent but *inappropriate* mental schemas about the main takeaways of the lesson; in turn, these seductive details are more harmful when placed at the beginning of content, as they give learners the wrong framework for interpreting the lesson-to-come.

1.1.1 Cognitive Load

The detrimental effects of seductive details are thought to be related to cognitive load that occurs during multimedia instruction, which refers to a combination of words (spoken or printed) and visuals (static or dynamic) used to teach (Mayer & Moreno, 2003). In the context of multimedia learning, cognitive load is the amount of working memory that is required of the learner to process a lesson, and a load that exceeds a learner's capacity can prevent effective learning from taking place (Mayer & Moreno, 2003). Cognitive load has been traditionally divided into three different types: (1) intrinsic load, (2) germane load, and (3) extraneous load, the last of which is most relevant to seductive details.

Intrinsic load, sometimes called representational holding, represents the inherent complexity of the task or material (Um et al., 2012; Leppink et al., 2013; Mayer & Moreno, 2003; Mayer & Moreno, 2010). More complex content is more difficult to hold in working memory for long periods, so according to Mayer and Moreno (2003), having prior knowledge or exposure to the material would reduce this type of load.

Germane load, sometimes called essential processing or generative processing, reflects the amount of mental effort or critical thinking that students invest in a subject, not determined by the inherent nature of the content, but as a result of well-designed instruction that is conducive to learning (Um et al., 2012; Leppink et al., 2013; Mayer & Moreno, 2003; Mayer & Moreno, 2010).

Extraneous load, sometimes called incidental processing, refers to aspects of the instructional design that trigger irrelevant processing and which divest cognitive resources from learning the intended content (Um et al., 2012; Leppink et al., 2013; Mayer & Moreno, 2003; Mayer & Moreno, 2010). Of the cognitive load subtypes, extraneous load is often regarded a moderating variable for the "seductive details effect, " in that the inclusion of seductive details often incurs undue extraneous load on the learner, which then results in reduced learning (Sundararajan and Adesope, 2020).

1.1.2 Mixed Results

While there is a wealth of literature supporting the *coherence principl*e-- the notion that multimedia instruction should avoid incorporating seductive details for its harmful effects on learning (i.e. Sung and Mayer, 2012) -- there has been a fair amount of mixed results and criticism of seductive details research. For example, Alexander (2019) argues that the potency of a graphic's seduction can be entirely context-dependent and subjective, with some participants not necessarily finding the so-called "seductive" condition all too interesting. Sundararajan and Adesope's (2020) meta-analysis on several seductive details publications reveals that there is not a standard manipulation check to determine whether a stimulus is "relevant" or "interesting" outside the context of the study in question. Furthermore, much of the seductive details literature occurs within a laboratory setting rather than within the context of a classroom; Maloy et al (2019) found no harmful effects on learning when employing seductive details in an ecologically valid, flipped classroom setting. Even within laboratory settings, several recent studies have also found inconclusive results or undetectable effects despite having sufficient sample sizes (i.e. Eitel and Kühl, 2019).

1.1.3 Math and Seductive Details

Notably, Sundararajan and Adesope's (2020) meta-analysis found that in two studies featuring math or statistics lessons, seductive details have been shown to not only *not* harm but actually *enhance* learning; the authors suggest that seductive details therefore have the potential to motivate or situationally intrigue students who might be initially intimidated by the complexity of math. This suggests that in certain contexts––i.e., learning daunting subjects like math––encountering seductive content can foster positive emotions towards the lesson and boost students' drive to learn (Um et al., 2012) or displace students' anxiety and better allow them to perform on tests (Isen et al., 1987).

However, the amount of literature involving seductive details in the context of math remains limited. The current study intends to add to this body of knowledge, using Internet memes, contemporarily interesting content that is positively regarded by many of today's undergraduate students (Reddy et al., 2020).

1.2 Math and Memes

Dawkins (1976) defines the earliest conception of a meme as content that is replicated, altered, and propagated through a culture or group, comparable to a biological gene that reproduces, mutates, and proliferates within a species.

A quick dive into social media groups that share memes about math ("math memes") will reveal curious sentiments: There exist Internet memes that highlight the irony of students learning math for the sake of understanding memes instead of passing their math classes (Figure 1.2A), and there exist memes that juxtapose how meticulously students treat calculations in their memes with how frivolously they answer their formal math assessments (Figure 1.2B). These cultural artifacts suggest that the increased prominence of meme culture can encourage students to *informally* learn math (Bini et al., 2020).

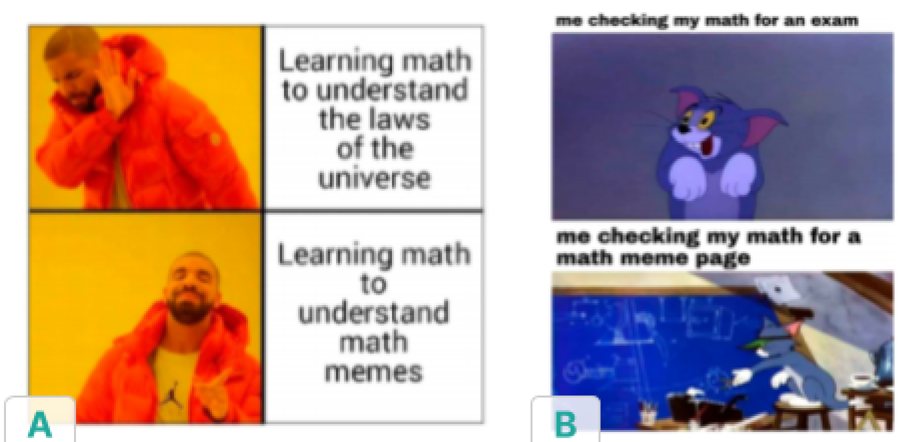

Figure 1.2 (A & B). Memes that emphasize how learning is taken more seriously for the sake of meme culture, can be found on the Mathematical Mathematics Memes Facebook group.

1.2.1. Mathematical vs. Emotional Memes

Bini et al's (2020) ethnographic foray into math meme groups identified two main types of memes that pertain to math: the mathematical meme and the emotional meme. A mathematical meme is a meme that underlyingly encodes verifiable mathematical statements (Figure 1.2.1A); this type of meme humorously combines a *mathematical statement* with a *meme base*, or template. Because mathematical memes present a mathematical concept using a recognizable framework, understanding the relationships between the concepts depicted in these memes becomes a puzzle--or "riddle" (Bini et al., 2020, pg. 4)--that encourages critical thinking.

Figure 1.2.1A. Mathematical meme from Mathematical Math Memes, Facebook, that encodes a verifiable math concept: that multiplication by the complex number, i , will result in a 90° rotation.

Bini et al, (2020) distinguishes between mathematical memes and memes that convey an emotion or sentiment *about* math, which they call emotional memes. Emotional memes, while commonly shared in meme groups, present subjective feelings about the experience of math, instead of encoding a provable mathematical concept. Ethnographic observations further reveal that members of mathematical meme groups tend to interact differently with these two types of memes: Mathematical memes that require conceptual comprehension may foster more active comment sections, wherein members can explain the meme or discuss incorrect statements contained within the meme. On the other hand, emotional memes often do not invite rigorous discourse and instead encourage reactions, such as the "like'' or emoji icons, to reflect the sentiments expressed in the emotional meme (Figure 1.2.1B).

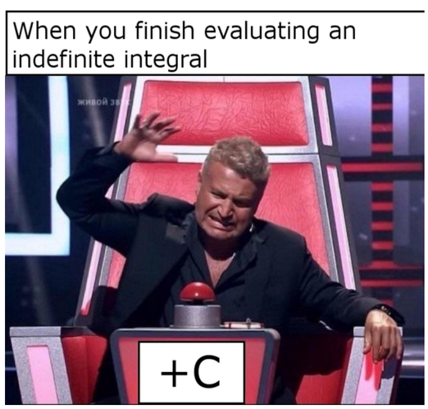

Figure 1.2.1B. Emotional meme from Mathematical Memes for Logarithmically Scaled Teens, Facebook, that captures the relatable, frustrating calculus experience of remembering to put +C at the end of an indefinite integral. Reactions to seeing the accuracy of this person's face may include a thumbs-up or laugh emoji.

This study highlights the educational potential that mathematical memes have to teach math within meme groups. However, the authors reveal that while there exists scholarship on the potential of memes to promote critical thinking in domains such as political science (Wells, 2018; Huntington, 2017), there is a significant lack of literature that explores mathematical memes within math education. Coupled with Reddy et al. 's (2020) survey of student attitudes towards the incorporation of memes into the classroom, which returned positive responses, there is much need to see whether memes would hurt or harm (i.e. have a seductive details effect on) students learning math.

2 | Hypothesis

The lack of empirical research into the effectiveness of memes, an increasingly prevalent online phenomenon, in instruction of math, a subject students tend to fear, motivates the current research question: What is the role of the two types of math memes on students' perceived cognitive load, perceived motivation, and performance?

The first hypothesis concerns the role of memes in **cognitive load** and **performance**. Given that: 1) mathematical memes encourage more critical engagement online than the emotional memes (Bini et al., 2020); and 2) interesting but irrelevant content (i.e., "seductive details") appear to increase extraneous cognitive load and impede learning (Harp & Mayer, 1998), one hypothesis is that mathematical memes should bolster student test performances more than the emotional meme. Further, the emotional meme should result in a higher extraneous load than the mathematical meme or a control condition featuring no memes. On the other hand, the role of seductive details in math and statistics is less clear (Sundararajan & Adescope, 2020); thus, it is possible that the emotional meme will not significantly increase cognitive load and consequently, will not impede test performance.

A second question is how the use of memes impacts **motivation** to learn math. While the amount of literature involving memes in math education remains limited, given how favorably students regard the idea of embedding memes into engineering lessons and tests (Reddy et al., 2020) and given the existence of math memes that express Internet users' desire to understand math memes (Bini et al., see Figure 1.2), we hypothesize that both memes would have a positive effect on motivation.

If a type of meme is found to facilitate learning outcomes and foster positive, motivating affect as a result of this study, the case for incorporating memes within math instruction can be made. Embedding memes in math, in turn, may help to scaffold students who might not perceive themselves to be mathematically-inclined to engage with and/or appreciate the complexities of the subject when they otherwise would have not.

3 | Methods

3.1 Participants

Participants include 404 undergraduate students (286 females, 108 males, and 10 non-binary) attending UC San Diego, who participated via the online SONA platform.

3.2 Materials and Stimuli

The materials for this study include a math lesson adapted from the YouTube lesson by blackpenredpen (2018), which discusses the mathematical extension to factorials. This relatively obscure mathematical concept was chosen to minimize the chances that participants would be familiar with the content prior to the lesson. As per the suggestions of Guo, Kim and Rubin (2014), the tutorial video leverages Khan-Academy-style “dynamic drawings” instead of static slideshow notes in order to promote baseline engagement across all conditions and help minimize the drop-out rate of participants who might otherwise find math on static slides too hard to follow, especially in a SONA study. The video lessons were each roughly around 12 minutes and 30 seconds.

Participants were randomly assigned to one of three groups. Because the seductive details effect have been shown to be more prominent when placed at the start of a lesson (Harp and Mayer, 1998), each group contains a video lesson that both starts and ends with one of three stimuli: a mathematical meme, emotional meme, or the control stimulus (see Figure 3.2A-C).

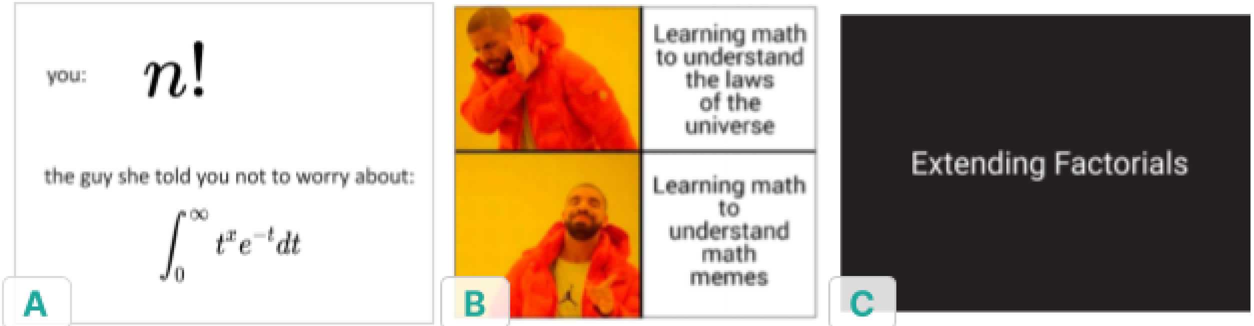

Figure 3.2. (A) A mathematical meme using a recognizable meme base and encodes the notion that the Pi function (the integral depicted) extends the factorial. **(B)** This emotional meme is irrelevant to the lesson but does convey humorous irony to encourage students to learn math. **(C)** The control stimuli is a simple title of the lesson, meant to represent a typical math lesson that starts without introducing any new information or eye-catching stimuli at the beginning.

3.3 Procedure and Measures

The Qualtrics survey used for data collection flows as follows:

3.3.1 Consent, Demographics, Disposition

Participants first read a brief overview of the purpose of the task and provide informed consent before continuing. The following stage asks the participants for demographic information, including their gender, year in college, and major. Since research has shown that attitudes about math often affect learning (Ashcraft & Ridley, 2005), we also asked about participants' inclinations towards math and calculus, using a 5-point Likert scale from "I HATE doing [math/calculus]" to Neutral to "I LOVE doing [math/calculus]." After the lesson, participants are further asked about their highest calculus level.

3.3.2 Pre-Test

Next, participants take a 4-question, multiple choice pretest meant to assess their familiarity with calculus concepts, such as limits, integrals, and derivatives, that are shown in the lesson, as well as a question to evaluate a basic factorial (3!). While the pre-test does not filter out low performers, the pretest scores are controlled in the analysis in order to see whether treatment effects appear within similarly calculus-competent participants.

3.3.3 Randomized Group Assignment

Following the pre-test, the participant is randomly assigned to one of the three video lesson groups outlined in Materials and Stimuli (See 3.2). Using the Qualtrics page-timer, participants are unable to progress onto the rest of the study without having watched the 12.5-minute video lesson at 1x speed.

3.3.4 Cognitive Load Measures

All participants are then asked to self-rate their cognitive load. Collecting these ratings immediately after the lesson rather than after participants have tested on the material avoids confounding students' initial reactions to the lesson with their attitudes towards their perceived performance on an assessment (Um, Plass, Hayward, & Homer, 2012). Measurements of the different types of cognitive load (intrinsic, germane, and extraneous) are gathered through a 4-item questionnaire (See APPX 1), adapted from Leppink et al.'s method involving 10-items to measure cognitive load types (2013)[1].

Each item on the questionnaire leverages a slider scale from 0, representing "not at all the case," and 10, representing "completely the case." Item 1 corresponds to intrinsic cognitive load and assesses the perceived complexity of the lesson itself. Items 2 and 3 correspond to extraneous cognitive load and ask participants to rate how "unclear" and "ineffective" they perceive instructional materials to be. And item 4 corresponds to germane cognitive load, measuring the degree to which the lesson "enhanced [the participant's] knowledge and understanding" of the concepts (See APPX 1).

3.3.5 Motivation Measures

To again avoid participants' self-reports being affected by the pressure of a post-test, the student motivation measures immediately follow the section on cognitive load; these measures are akin to the "satisfaction" measures obtained in Sung and Mayer's (2012) study on the coherence principle. Motivation measures are obtained using a 6-item questionnaire (See APPX 2)., adapted and expanded from Isen and Reeve's (2006) method to measure intrinsic motivation.

To maintain a consistent scale, each item follows the same 0- to 10-point slider scale used to measure cognitive load. Items 1 and 2 ("stimulus intrigue") ask participants to rate the intrigue generated by seeing the stimuli at the beginning of the lesson (either a meme or the title). Items 3 and 4 ("lesson motivation") gauges the amount of attention students invested and the amount of enjoyment they receive from the lesson. And items 5 and 6 ("future motivation") assess students' appreciation of the math involved and their willingness to learn similarly-structured material in the future. This breakdown of motivation corresponds to different levels of motivation participants may feel at different timepoints in the learning process.

3.3.6 Post-Test

After the self-reported measures, participants are then tested on their retention and transfer of the concepts discussed in the lesson, as is common protocol for studies examining the effects of various instructional features (Plass & Kalyuga, 2019; Mayer & Moreno, 2003; Mayer & Estrella, 2014; Fiorella, Stull, Kuhlmann, & Mayer, 2018; Um, Plass, Hayward, & Homer, 2012). The lesson-specific questions are mostly multiple choice or select-all-that-apply, with some free-response questions. Retention questions harken back to concepts specifically mentioned in the video lessons, while transfer questions require participants to apply what they recall from the lesson to questions not explicitly addressed in the video.

Nonetheless, when it comes to learning math, the line between retention and transfer questions remains debatable. Thus, the scores from these two sections were combined to form a composite

[1] Leppink's (2013) method involved a 13-item self-ratings questionnaire, but due to length constraints, the current study uses only 4 items, based on the items that generated the highest signals during the pilot stage.

post-test score. Simple math questions like “1+1 =?” are also peppered into the post-test section to check for attention.

3.3.7 Manipulation Checks

Participants are then asked to rate how interesting and lesson-relevant they find all three stimuli (mathematical meme, emotional meme, and title), regardless of which stimulus they were assigned to. The order in which these three stimuli are presented is randomized. These ratings serve as manipulation checks for the selection of stimuli: the memes should be more interesting than the title, and the emotional meme should be the least relevant to the lesson.

4 | Results

Results have been analyzed using the following key paradigms:

Pre-lesson variables, including pretest scores, highest calculus levels, and calculus inclination, were tested using one-way ANOVAs to ensure no significant differences between the three groups prior to seeing the stimuli. Gender is also considered a pre-lesson variable, but being categorical, is not subject to an ANOVA.

Then, using multiple linear regression analyses, these pre-lesson variables are included as covariates alongside participants' assigned Condition (i.e. Mathematical Meme, Emotional Meme, Control) to predict the *post*-lesson variables of interest: cognitive load, motivation, and post-test performance. If the coefficients of Condition are significant, an ANOVA and subsequent Tukey test are then run on the linear model to evaluate whether there are significant effects of assigned Condition.

Manipulation checks are also reported in order to inform later discussion involving the Coherence Principle, which states that stimuli that are interesting but not relevant to the lesson are likely to be detrimental to learning.

4.1 Pre-Lesson Variables

We found that pretest scores averaged 2.57 points out of 4 (SD =1.36) and was not significantly different between conditions ($F_{2,401}$ = 0.40, p >0.05). Participants' highest calculus level had a mean of 2.03, or a Calculus II level (SD = 1.07); calculus level was also not correlated with condition ($F_{2,401}$ = 0.81, p >0.05). Participants' calculus inclinations tended to be more negative than their math inclinations (Figure 4.1A-B), but neither was significantly different between conditions (math: $F_{2,401}$ = 1.749, p >0.05; calculus: $F_{2,401}$ = 2.031, p >0.05). Because the lesson that participants watch involves calculus, only calculus, not math, inclination is factored into the analyses with post-lesson variables below. Gender counts per condition in Table 4.1 were also factored into later analysis of the dependent variables .

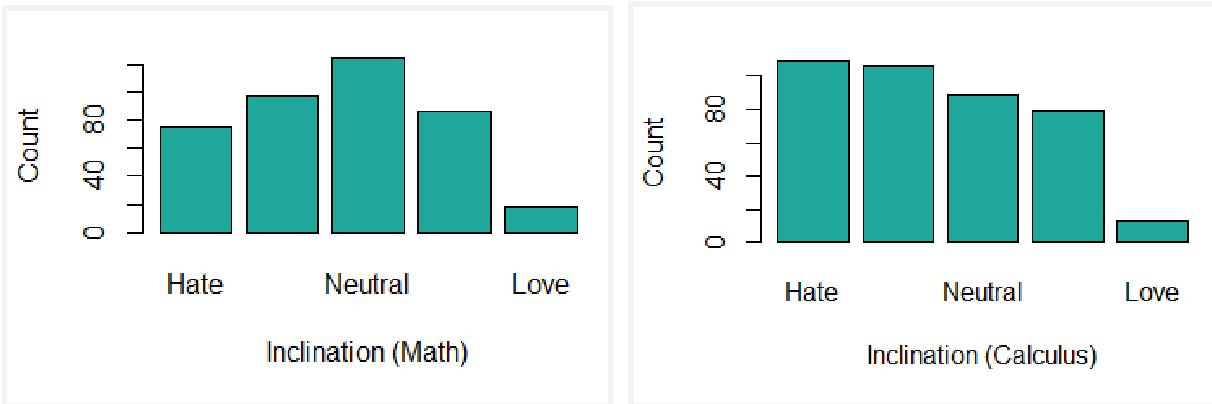

Figure 4.1 (A & B): Counts of Math and Calculus Inclinations. Participants' inclinations towards calculus skew more negative than their inclinations towards math, and there are relatively few participants who indicate "love" for either.

Table 4.1. Pivot Table Counts of Gender per Condition.

Gender	**Control Group**	**Emotional Meme**	**Mathematical Meme**	
Female	87	100	99	286
Male	48	32	28	108
Non-binary	3	3	4	10
	138	135	131	404

4.2 Cognitive Load

A variable measured after participants have seen the lesson, cognitive load is traditionally divided into three categories: (1) intrinsic load, representing the inherent complexity of the material being taught, (2) extraneous load, representing the aspects of a lesson that divert a learner's working memory resources away from the lesson's intended takeaways, and (3) germane load, representing the aspects of a lesson that promote relevant, task-oriented processing the material. Due to this traditional breakdown of cognitive load, these types are examined separately.

4.2.1 Intrinsic Load

Reflecting a sample of the 387 participants who answered, intrinsic load had a mean 6.78 out of 10 (on a scale from 0 to 10 with 10 being the most complex) (SD = 2.27). There was no significant effect of either of the meme conditions. However, in alignment with the literature definition of intrinsic load as the complexity of a lesson *in relation to* learners' prior knowledge (Leppink et al., 2013), pretest scores (coeff = -0.28, SE = 0.10), calculus level (coeff = -0.33, SE = 0.12), and calculus inclination (coeff = -0.41, SE = 0.10) were found to significantly correlate with intrinsic load.

4.2.2 Extraneous Load

Extraneous load, reflecting the lack of clarity in the instructional design that diverts learners' attention from intended takeaways, is aggregated across 2 self-rating items (APPX 1, #2-3). Across 395 participants, extraneous load had a mean of 4.15 out of 10 (on a scale from 0 to 10 with 10 being the highest load; the lower the better) (SD = 2.26). Extraneous was significantly correlated with pretest scores (coeff = -0.36, SE = 0.11), but not with any of the meme conditions.

4.2.3 Germane Load

Germane load, representative of how well the instructional design facilitates students' learning of the material, had a mean of 4.93 out of 10 (on a scale from 0 to 10 with 10 being the most *beneficial* amount of load) (SD = 2.53), across the 383 participants who responded. None of the stimuli conditions significantly correlated with germane load, but pretest scores (coeff = +0.58, SE = 0.39) and calculus inclination (coeff = +0.28, SE =0.12) did.

4.3 Motivation

The current study divides motivation into three stages: motivation prior to the start of a lesson (intrigue), motivation throughout the lesson (lesson motivation), and motivation surrounding math and future lessons (future motivation). However, because it is practice in educational research involving motivation is to provide an aggregate motivation measure, all results of the three motivation subtypes and the aggregate are reported, subject to Bonferroni-corrections to account for multiple comparisons (n = 4) of the same hypothesis (regarding group effects on motivation).

4.3.1 Aggregate Motivation

Learners' aggregate motivation had a mean of 4.63 points out of 10 (on a scale from 0 to 10, with 10 comprising the highest motivation) (SD = 1.76). After applying a Bonferroni-correction, there was no significant effect of assigned condition, only significant effects of calculus inclination (coeff = +0.44, SE = 0.8) and pretest scores (coeff = +0.20, SE = 0.8) on aggregate motivation.

4.3.2 Intrigue

Subjects' self-reported intrigue after having seen the stimuli of their condition, henceforth referred to as 'intrigue,' had a mean of 4.45 points (out of 10, 10 being the most intrigued) (SD = 2.51) across 401 participants.

The regression model predicting intrigue from the assigned group and pre-lesson covariates indicates that calculus inclination is significant in this subset of motivation (coeff = +0.33, SE = 0.12). However, more surprisingly, the model reveals that there is an even more significant, positive correlation between the Mathematical Meme group and intrigue (coeff = +1.11, SE = 0.31) (Intercept = 4.46, RSE = 2.45, df = 388, adjusted R^2 =0.048). Running an ANOVA on this model reveals that after a Bonferroni correction, calculus inclination is no longer significant, but assigned condition ($F_{2,\,388}$ = 6.59 , SS = 78.96, p < 0.01) remains a significant predictor of intrigue.

Given the significant ANOVA differences between condition means, the raw mean intrigue for each conditions was examined (Mathematical Mean = 4.95, SD = 2.42; Control Mean = 3.85, SD = 2.28; Emotional Mean = 4.57, SD = 2.70) (Figure 4.3.2). A post-hoc Tukey test involving intrigue and each of the condition levels revealed that there is a significant, Bonferroni-corrected difference between the Mathematical and Control groups (diff = 1.10, p < 0.001, CI = [0.39, 1.81]), but there was not a significant difference between the Mathematical and Emotional Meme conditions (diff = 0.38, p > 0.05, CI = [-0.34, 1.09]). The Tukey test also revealed a significant but smaller difference between the Emotional Meme and the Control group (diff = 0.71, p <0.05, CI = [0.01, 1.42]).

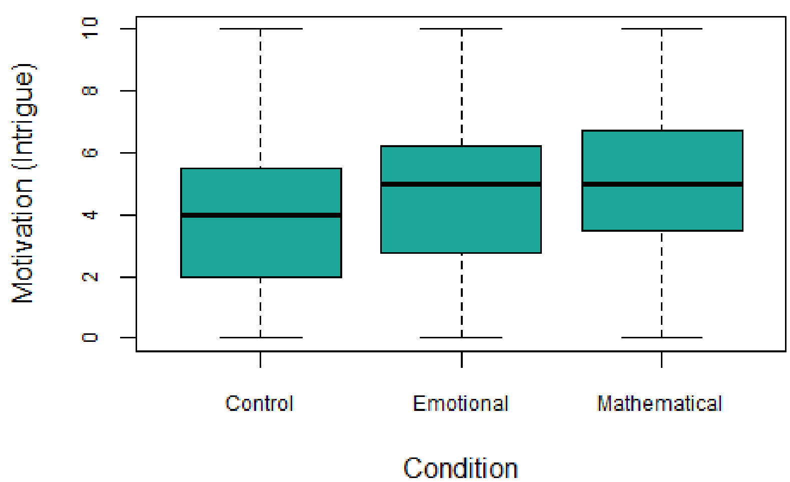

Figure 4.3.2: Intrigue vs. Condition. The Mathematical Meme condition has a higher mean intrigue score than the other two groups.

4.3.3 Lesson Motivation

The second subset of motivation, dubbed 'lesson motivation,' represents the amount of self-rated attention paid and enjoyment participants had derived from the lesson. This measure had a mean of 4.36 points (of 10, with 10 as the highest) (SD = 2.22). There was no significant effect of either of the meme conditions after a Bonferroni-correction on the coefficient p-values, and only pretest (coeff = +0.26, SE =0.10) and calculus inclination (coeff = +0.60, SE =0.10) significantly correlated with lesson motivation.

4.3.4 Future Motivation

The last subset of motivation, called 'future motivation,' (Mean = 5.10 points out of 10, SD = 2.08), represents the participants' willingness to learn similarly-structured lessons and their appreciation for math after receiving the lesson at hand. While future motivation did significantly correlate with calculus inclination (coeff = +0.38, SE = 0.10) and with pretest (coeff = +0.21, SE = 0.09), there was no significant correlation with the assigned condition.

4.4 Post-Test Performance

The 404 participants' aggregate post-test performance had a mean of 2.72 points out of a max of 7 correct (SD = 1.77) (Figure 4.4). When broken down into retention and transfer portions, retention scores had a mean of 1.39 points (SD =0.92), and transfer, 1.34 points (SD =1.09). Due to the short length of the combined post-test and the difficulty of parsing retention from transfer when it comes to math, only the aggregate post-test scores are considered for the analyses.

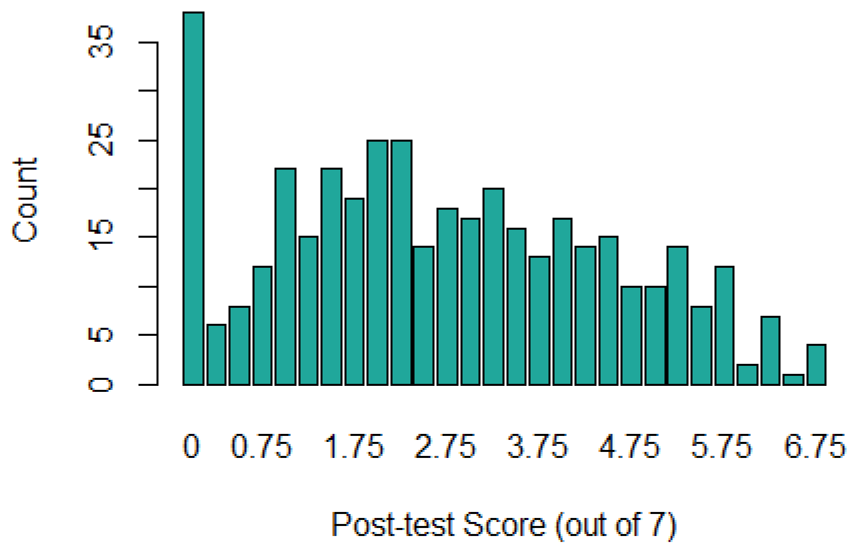

Figure 4.4: Counts of Post-test Scores. Participants averaged 2.72 points out of 7 (SD = 1.09) on the combined retention and transfer test.

The multiple linear regression run to predict post-test scores from participants' treatment group and pre-lesson covariates finds that pretest scores (coeff = +0.39, SE = 0.08) and calculus inclinations (coeff = +0.24, SE = 0.80), which aligns with the literature that math performance is often tied to students' attitudes about math (Ashcraft & Ridley, 2005), there was no significant effect of assigned condition on post-test performance.

4.5 Manipulation Checks

As an added measure of the relevance and how interesting each of the stimuli had been to all participants regardless of condition, the emotional meme stimulus had a mean lesson-relevance 4.63 points (out of 10 max) (SD = 2.93) and a mean interest-level of 6.39 points (SD = 2.65). The mathematical meme itself had a mean lesson-relevance of 6.93 points (SD = 2.48) and a mean interest-level of 5.93 (SD = 2.73). The control stimulus (a title) had a mean lesson-relevance of 6.32 points (SD = 2.84) and a mean interest-level of 2.47 points (SD = 2.16).

5 | Discussion

Overall, when accounting for the pre-lesson variables, we found that there was no effect of the meme conditions on any of the cognitive load types (intrinsic, extraneous, germane) or on post-test performance. And although there was also no effect on motivation as an aggregate variable, we did find that one subset of motivation, intrigue, was significantly correlated with one particular group: the Mathematical Meme condition. We dive into the interpretations of these results, summarized in Table 5, in the sections below.

Table 5. Summary of Results. Significant coefficients and directions of correlations are reported in the boxes. Coefficients are not normalized; scales used for cognitive load and motivation are all out of 10; post-test scores are out of 7.

	Pretest Score	Calculus Inclination	Highest Calculus Level	Mathematical Meme Condition	Emotional Meme Condition	Gender
Intrinsic load	-0.28	-0.41	-0.33			
Extraneous Load	-0.36					
Germane Load	+0.58	+0.28				
Aggregate Motivation (bonferroni-corrected)	+0.20	+0.44				
Intrigue (bonferroni-corrected)		+0.33		+1.10		
Lesson Motivation (bonferroni-corrected)	+0.26	+0.60				
Future Motivation (bonferroni-corrected)	+0.21)	+0.38				
Post-test performance	+0.39	+0.24				

5.1 Cognitive Load and Performance

The Seductive Details Effect states that interesting but irrelevant stimuli embedded into a lesson can worsen performance by placing undue extraneous load on the learner. Because the emotional meme was selected for being interesting but irrelevant to the lesson at hand (supported by the manipulation check rankings), it was expected that the emotional meme would result in the poorest performance and by extension, have the highest extraneous load. Given that the mathematical meme demonstrated the highest relevance and highest interest ratings from the manipulation checks, this condition was expected to have the highest post-test performance.

Neither of these expectations were the case, as there were no detectable differences between the means of each stimuli group for either performance or extraneous load. These findings suggest that even if a stimuli like the emotional meme satisfies the two requirements to be a “seductive detail” (being interesting and lesson- or task-irrelevant), it does not necessarily hurt learning anymore than a coherently interesting stimuli like the mathematical meme might help learning, thereby casting further doubt into the detrimental nature of seductive details in the context of math (Sundararajan & Adescope, 2020).

5.2 Motivation

In terms of motivation, we had expected that the inclusion of memes would motivate students more than the Control condition stimuli (a mere title). This hypothesis was supported: the mathematical meme was correlated with more intrigue than the control condition, with a 1.10-point mean-difference; the mathematical meme was correlated with an increase in intrigue ranging from +0.39 to +1.81 points (out of 10), compared to the control conditions. The increase in intrigue makes intuitive sense: because the mathematical meme embeds a novel mathematical concept and is shown at the start of the lesson, students would be more curious about how to make sense of the math in the meme, more so than how to make sense of a simple title, “Extending Factorials.”

The fact that ethnographic research on mathematical memes has revealed that that these stimuli generate more substantial discussions and inquiry into the involved concepts would further suggest that mathematical memes would make students more curious about the incoming lesson than emotional memes, which have been shown to invoke relatable reactions but not concept-relevant curiosity (Bini et al., 2020). However, this expectation was not supported by the non-significant post-hoc Tukey test between the Mathematical and Emotional Meme conditions. In other words, the emotional meme was also significantly more intriguing than the control condition, albeit to a lesser extent than the mathematical meme. This suggests that including math memes in general, whether emotional or mathematical, can help to intrigue students going into a lesson, with the mathematical meme producing slightly stronger intrigue, likely due to its “riddle-like” format.

Another interesting point to note is that while students’ intrigue could be partially explained by their existing inclination towards calculus, their curiosity had a non-significant correlation with pretest scores intended to measure their calculus competency. This finding might indicate that meme-inspired curiosity can motivate students regardless of their existing math skills.

5.3 Limitations and Future Work

One limitation of this research is that we did not ask whether students understood the memes that they saw either before or after the lesson. Furthermore, while we did ask participants to rate the interestingness and relevance of each stimuli to verify that the mathematical meme was both relevant and interesting and that the emotional was interesting but not too relevant, we had not asked whether that interestingness stemmed from humor.

Another important limitation was the one-shot nature of the math lesson. While the current study uses a singular lesson to introduce the obscure concept of how to extend factorials, many courses in mathematics are not so isolated in nature. This, in turn, raises questions regarding the ecological validity of this instructional approach across a series of related math lessons. The low mean of the post-test scores (2.72 out of 7 points, SD = 1.77) attests to the insufficiency of a singular math lesson. Furthermore, due to the online nature of the survey, calculus- and calculation-heavy post-test hands-on and free-response questions typical in math courses were avoided, thereby precluding more comprehensive assessments of math performance. Future iterations of this research could leverage a series of math lessons (perhaps in a real classroom environment), rather than a one-shot lesson, and measure whether there are changes in participants' calculus or math inclinations and whether motivation would translate into continued engagement and improvement with math. Given this study sample's overwhelmingly aversive attitude about calculus and the fact that calculus disposition was found to be a significant covariate in most of the dependent measures (Table 5), continued exploration into the longer-term motivating effects of math memes would be rather prudent.

Another possible limitation, related to the one-shot paradigm, is that the memes were presented briefly and not integrated into the lesson. Despite only appearing so briefly, a significant effect of the mathematical meme on intrigue was still detectable. The effectiveness of this subtle manipulation indicates that it might be worth interspersing memes throughout the lesson. This, which would allow us to see if the memes would have a significant effect on lesson motivation (attention and enjoyment throughout). Moving the stimuli to the middle might provide additional opportunity for sustained interest in the lesson, while simultaneously allowing learners to critically apply what they have learned from the lesson in order to decipher the memetic "riddle."

Finally, we used only one example of each meme type. Future work could test multiple different mathematical memes or emotional memes in the context of more math concepts, to disentangle item-specific effects from the more general manipulation.

6 | Conclusions

In an effort to explore the role of memes in math instruction, the current paper employs two different types of math memes with differing degrees of lesson-relevance, emotional memes (irrelevant) and mathematical memes (relevant), to gauge their effects on students' cognitive load, performance, and motivation against a control group. Although literature on the *seductive details effect* suggests that the irrelevant meme would negatively impact students' cognitive load and performance, results show that neither meme significantly affects students' cognitive load or performance, but the mathematical meme has been shown to significantly boost students' curiosity about the lesson content, irrespective of the students' existing calculus competency levels. Despite leveraging only subtle manipulations to compare effects of stimuli, this study's findings suggest that interesting stimuli like memes, regardless of relevance level, may not necessarily be detrimental to students' learning. The findings strongly support further investigation into whether the motivating potential of memes could translate into longer-term effects on math inclination and performance.

Appendix

APPX 1. Cognitive Load Questionnaire (4 items, adapted from Leppink et al., 2013)

Rate the following statements using the scale provided: 0 (not at all the case); 10 (completely the case)
Intrinsic Load: 1) The topics/concepts/formulas covered in this lesson were very complex. Extraneous Load: 2) The instructions and/or explanations were, in terms of learning, very unclear. 3) The instructions and/or explanations were, in terms of learning, very ineffective. Germane Load: 4) The lesson really enhanced my knowledge and understanding of factorials and their extensions.

APPX 2. Intrinsic Motivation Questionnaire (6 items, adapted from Isen & Reeve, 2006)

Rate the following statements using the scale provided: 0 (not at all the case); 10 (completely the case)
Beginning Intrigue: 1) I was intrigued by the beginning of the lesson. 2) I wanted to understand the rest of the lesson after seeing the meme/title at the beginning. Lesson Motivation: 3) I paid attention throughout the lesson. 4) I enjoyed learning this material. Future Motivation: 5) I can appreciate the math involved with this material. 6) I would like my future math lessons to be structured similarly.

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