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Improving Metacomprehension and Calibration Accuracy Through Embedded Cognitive and Metacognitive Strategy Prompts

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IMPROVING METACOMPREHENSION AND CALIBRATION ACCURACY THROUGH EMBEDDED COGNITIVE AND METACOGNITIVE STRATEGY PROMPTS

by

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ABSTRACT

IMPROVING METACOMPREHENSION AND CALIBRATION ACCURACY THROUGH EMBEDDED COGNITIVE AND METACOGNITIVE STRATEGY PROMPTS

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A societal shift from print-based to digital texts has afforded the ability to embed reader support within an instructional text. Numerous factors make eBooks an attractive option for colleges and universities, though undergraduates consistently reaffirm a preference for print-based materials. Given that many undergraduates arrive to college with a deficiency in reading comprehension skills and metacognitive awareness, digital text is able to offer an additional layer of support. A sample population of college undergraduates (N = 80) read an expository text on the basics of photography in the form of a fill-in field PDF. The most robust treatment (mixed) read the text, generated a summary for each page of text, and then was prompted with a metacognitive strategy self-question. The metacognitive treatment received metacognitive strategy prompts only, and the cognitive group implemented the cognitive strategy (summarization) only. A control group read the text with no embedded support.

Groups were compared on measures of achievement, attitudes, cognitive load, and metacomprehension and calibration accuracy. Results indicated that a combination of embedded cognitive and metacognitive strategies in digital text improved learner achievement on high-level questions, yielded more accurate predictive calibration, and strengthened the relationship between metacomprehension and performance. Because cognitive load was reported to be significantly higher in the mixed strategy condition, the trade-off between the benefits of embedded reading support and the effects on mental demand should be investigated in more depth. This study found that providing embedded cognitive and metacognitive support in text lead to more accurate calibration and stronger metacomprehension judgments, both of which are common attributes of an academically successful learner.

Keywords: metacomprehension, calibration, cognitive strategy, metacognitive strategy, embedded support, and cognitive load.

This dissertation is dedicated to my brilliant wife, who supported my academic pursuit, and to my two young children, who carried me through it.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Introduction

On average, a U.S. citizen consumes more than 100,000 words and approximately 12 hours' worth of information each day (Bohn & Short, 2012). The accessibility to the Internet and increasing availability and usage of mobile devices has led to a modern "information society" (Hudson, 2012, para. 19). As a result, college students have more access to content using the smart phone in their pockets than previous generations had available to them in an entire lifespan. This shift towards reading digital text or eReading, is steadily climbing as the number of Americans who own an eReading device increases annually, as does the number of eBooks being read (Pew Research Center, 2012). In higher education, eBooks are an emerging technology, and the Horizon Report (2011) identified this trend as being "on the near-term horizon," predicting a more mainstream presence of eBooks in educational institutions within the next 12 months (p.5). In the present study, the term eReading refers to the act of reading eBooks, eText, or digital text, all of which are used interchangeably. These terms are in contrast to the term "print-based text," which is the traditional format of physical hardcover and softcover printed texts.

Digital text offers numerous technological benefits over traditional print-based texts such as affordability, portability, and the ability to search, define, and annotate text electronically. However, readers of digital text still suffer from problems specific to eReading like cognitive mapping, where they lack the ability to use visual cues in the text as peripheral markers to understand its context. Consequently, undergraduates repeatedly affirm their preference for print-based rather than digital text (Dillon, 1994; Li, Poe, Potter, Quigley, & Wilson, 2011; Schilit, Price, Golovchinsky, Tanaka, & Marshall, 1999; Woody, Daniel, & Baker, 2010). Despite students' preferences for print-based over digital text, the lucrative nature of digital text and its low overhead cost to produce and distribute pushes forward the trend of eReading in higher education (Miller, Nutting, & Baker-Eveleth, 2012). Still, digital text remains an unsettling option for readers who are expected to comprehend course materials with which they may already be disengaged or unmotivated to read.

While digital course materials seem advantageous financially and logistically, many college undergraduates do not transfer the same reading strategies they use when reading print-based text (Schugar, Schugar, & Penny, 2011), they become less accurate in gauging understanding (Ackerman & Goldsmith, 2011), and they are more likely to attempt to multitask with other technologies simultaneously (Junco & Cotten, 2011). One approach to ensure readers remain engaged while reading digital text and become active participants during reading is to keep them tethered to the content through the use of embedded generative strategies: learning techniques that translate and organize incoming information in order to enhance their comprehension, motivation, and attention (Wittrock, 1985).

Generative Model of the Teaching of Comprehension

Wittrock's (1991) model of the teaching of comprehension builds on his seminal research on generative learning, or making meaning by assigning prior knowledge and past experiences to new material in order to construct new meaning for text. This model targets summarization as a key strategy to comprehension. Although many studies confuse summarization and paraphrasing techniques, a summary is more concise than a paraphrase, focusing only on the key ideas and main points in the text. More, a paraphrase asks the reader to draw on prior knowledge and personal experiences, whereas a summary generates knowledge from the existing information in the text (Grabowski, 2004). In the present study, the generative technique of summarization was used as in the tradition of Wittrock and Alesandrini (1990), where the reader generates original sentences similar to the original text, rather than rearrange the original text into a modified version. The model of the teaching of comprehension predicts that summarizing the text into a reader's own words is far more beneficial than selecting and modifying existing text sentences. Reading comprehension is a direct result of generative relationships between the reader and the text, and simply selecting important information is not sufficient; a reader must generate his or her own meaning for the activity to become generative (Grabowski, 2004). Possessing an awareness of generative activities during reading and being able to gauge progress are other attributes of readers that must be fostered. Constant self-questioning and comprehension monitoring lead to a heightened consciousness of metacognitive knowledge, or "knowing about knowing" (Metcalf & Shimamura, 1994).

Metacognition

A highly self-regulated reader is one who actively seeks solutions to instructional problems and situations and uses strategies and self-evaluation to monitor, alter, and evaluate his or her own cognition. According to Zimmerman's (1990) model of self-regulated learning, metacognition is one of three components of the larger framework of self-regulation, which also includes motivational and behavioral processes. Flavell

(1976) defines metacognition as "one's knowledge concerning one's own cognitive processes and products or anything related to them" (p.232). Through the lens of reading research, metacognition manifests itself in comprehension monitoring, or assessing the level of understanding while reading (Baker & Brown, 1984). Prompting the reader with an embedded metacognitive prompt can facilitate comprehension monitoring by reminding the reader to stay focused, constantly evaluate the progress of his or her learning, and assess the effectiveness of the cognitive strategy being implemented.

Metacognitive strategies are defined as strategies activated to gauge progress towards or away from cognitive goals (Garner, 1987). There are a variety of metacognitive strategies, including reflective prompts, self-explanations, self-generated inferences, and self-questioning (used in the present study), where the readers are prompted to monitor their own metacognitive processes while reading (Fiorella, Vogel-Walcott, & Fiore, 2012). These self-questioning strategies encourage the reader to monitor comprehension during and after learning activities and to revise these processes accordingly in future learning situations (Bannert, Hildebrand, & Mengelkamp, 2009; Zimmerman, 1990). Metacognitive self-questioning examples include, "Which main points haven't I understood yet; Am I focusing all of my mental effort on the material; and Do I know enough about the material to answer the questions correctly on the comprehension posttest?" (Berthold, Nuckles, & Renkl, 2007; Sitzmann & Ely, 2010). The relationship between cognitive and metacognitive strategy use is codependent; cognitive strategies are activated to make cognitive progress, and metacognitive strategies monitor this progress (Flavell, 1979).

Readers' inabilities to diagnose poor comprehension while reading are referred to as "production deficiency" (Flavell, 1970). This deficiency may be remedied through the use of embedded prompts, or explicit directives to the reader to self-question and monitor future comprehension. Moreover, it is not sufficient to simply prompt the reader to engage in cognitive or metacognitive activity while reading; adequate training on the use of the strategy must also be provided beforehand (Azevedo & Hadwin, 2005; Bannert & Reimann, 2011; Kramarski & Feldman, 2000).

Historically, readers who are expected to demonstrate comprehension of expository text consistently fail to recognize when to activate cognitive and metacognitive strategies to ensure understanding of content. Regardless of the text medium, most readers lack accurate metacomprehension or the ability to precisely gauge their understanding of text during the act of reading (Maki & Berry, 1984). The false sense of belief that he or she has attained readiness for assessment often results in overconfidence in comprehension and is called "illusion of knowing" (Glenberg & Epstein, 1985). Conversely, the extent to which judgments are accurate or inaccurate is referred to as calibration accuracy and is measured by the difference between perceived and actual performance (Bol & Hacker, 2012; Lin & Zabrucky, 1998).

The Problem

While accurate judgment is critical to the reader in terms of allocation of study time, test readiness, and effective study habits (Glenberg, Sanocki, Epstein, & Morris, 1987), many readers generate "self-distractions" during reading, and this results in poor comprehension accuracy (Rigney, 1978). Prompting the reader to employ a blend of cognitive and metacognitive strategies during reading increases learning outcomes at the recall and comprehension levels (Berthold et al., 2007; Lee, Lim, & Grabowski, 2010). Further, encouraging the reader to monitor her metacognitive processes while reading heightens metacognitive awareness and leads to an improved learning performance (Azevedo & Cromley, 2004; Lee et al., 2010; Sitzmann & Ely, 2010; Thiede, 1999). It is then logical to project that reminding the readers to estimate their whole understanding of the text while activating a repertoire of cognitive and metacognitive strategies would not only enhance their comprehension of the material, but also increase chances of improved learning outcomes and a more accurate level of metacomprehension and predictive calibration.

Because of its easy adaptability, digital text provides a unique opportunity that print-based text does not: the ability to embed cognitive and metacognitive strategy prompts directly throughout the instructional materials. In doing so, a personalized eReading experience enables the reader to concentrate on the level of understanding and monitor future comprehension. Given the increasing adoption rate of eBooks among higher education institutions (Abutaleb, 2012) and students' deficiencies in monitoring metacognitive skills during reading (Ackerman & Goldsmith, 2011), eReading provides an opportunity to ensure a more positive experience wherein comprehension is facilitated and judgment accuracy is enhanced through the use of embedded support devices such as prompts. The very nature of eReading allows for easy customization of the materials. The focus of this study was to examine the effects of embedded cognitive, metacognitive, and mixed prompts in digital text on metacomprehension and calibration accuracy.

Literature Review

Numerous studies have investigated the effects of embedded prompts on achievement, and while most of that previous research focuses on embedding either cognitive or metacognitive strategies, a fewer number of studies implement a combination of the two. Even more limited is the existing research that examines embedded cognitive and metacognitive prompts through the lens of metacomprehension and calibration accuracy. Mastery in these areas of judgment often correlates with improved academic performance and high self-regulated learners who are metacognitively aware are usually successful in the learning environment (Grabowski, 2004). Providing the reader cognitive tools to regulate his or her comprehension, raising the reader's metacognitive awareness to monitor the effectiveness of these strategies, and asking the reader to self-evaluate his or her overall understanding are all familiar tactics to increase reading comprehension, but it is the confluence of all three approaches in one digital setting during the act of reading that this study will investigate. Given that readers of digital text require more metacognitive support than print-based readers because of production deficiencies, it becomes evident that there is a need for research that examines the use of combined cognitive and metacognitive strategy use during reading (Ackerman & Goldsmith, 2011; Dunlosky & Lipko, 2007).

Cognitive Strategy Use

The term *cognitive strategy* is defined as the mental procedure used by a learner to assimilate and retain new information and knowledge, which is then translated into performance (Rigney, 1978). Generative strategies fall under the broader category of cognitive strategies and can be any learning activity that creates meaning or relationships among the information in the text. For instance, strategies such as summarizing, paraphrasing, prediction-making, and creating mnemonic devices are generative because of the meaning that the learner constructs. Simpler strategies such as tracing, highlighting, or underlining cannot be considered generative in nature, as these techniques merely select the information in a text and do not generate any meaningful relationships (Grabowski, 2004). Jonassen (1985) and Rigney (1978) note that a reader's use of generative strategies cannot necessarily be controlled, but it can be stimulated. This activation may come in the form of embedded prompts in digital text. Importantly, the reader's generative skills impact the effectiveness of the strategy; Rigney (1978) describes two components of successful cognitive strategy use: the "orienting task" as a prompt for the learner to activate the strategy, and individual learner differences, which account for variation in the quality and capability to execute the cognitive strategy.

Summarization prompts. There is abundant research on infusing text with a cognitive strategy (e.g. see Grabowski, 2004, for a comprehensive list). In particular, summarizing has been a consistently effective cognitive strategy for reading comprehension (Anderson & Thiede, 2008; Berkowitz, 1986; Doctorow et al., 1978; Palinscar & Brown, 1984; Wittrock & Kelly, 1984). Wittrock and Alesandrini (1990) compared a control group with a treatment group that generated analogies and a treatment that generated summaries while reading for comprehension. In the summary condition, participants were instructed to summarize, in their own words, each paragraph of a 5,200-word text. Results from the posttest indicated that asking the reader to summarize a text after reading significantly increased their comprehension levels and produced a slightly higher performance than the analogies treatment. Importantly, these findings reinforce the generative model of the teaching of comprehension.

Summarization leads to an improvement in reading comprehension. Linden and Wittrock (1981) supported their hypothesis that instructing readers to generate text-relevant summaries would lead to higher levels of reading comprehension. Similarly, in an effort to promote generative processing during reading, Doctorow et al. (1978) found that prompting readers to generate their own sentences after reading significantly increased posttest performance in terms of recall, and that this strategy was most beneficial for low-level readers. Instructing readers to produce summaries activates the process of generative learning, whereby information is selected for its importance, re-organized and meaning is generated instead of merely stored for recall. These newly formed relationships help the reader re-conceptualize his or her understanding of the subject matter and lead to increased comprehension through the development of generative models in the brain structure (Wittrock, 1992).

Still, the impact of using a cognitive strategy, namely summarization, on achievement levels hinges on the quality of the strategy. Simply prompting the reader to use a cognitive strategy is not sufficient; the cognitive strategy used must be utilized effectively. Anderson and Thiede (2008) evaluated the quality of summaries by identifying the number of gist idea units, number of details, and number of idea units, all indicators of the quality of the cognitive strategy use, in relation to metacomprehension accuracy. It was determined that generating a summary immediately after reading the content, when compared to writing a delayed summary, produced more details in the summary, but not necessarily more important content. Therefore, it is not the length of the summary, but the quality of the strategy use that is critical to understanding.

Metacognitive Strategy Use

Sitzmann, Bell, Kraiger, and Kanar (2009) prompted learners in technology-delivered instruction with two types of self-regulatory questions: Self-monitoring, which focuses on setting goals and using effective cognitive strategies during reading, and self-evaluative questions, which focus on the progress being made towards the learning goals. Results indicated a significant improvement in learning achievement for those who received the prompts. This finding supported previous research that observed an increase in achievement for those receiving metacognitive prompts (Bannert et al., 2009; Kauffman, 2004; Kramarski & Gutman, 2006; Lin & Lehman, 1999; Sitzmann & Ely, 2010; Veenman, Elshout, & Busato, 1994).

Integrating metacognitive prompts directly into the instructional materials reminds readers to activate and implement metacognitive strategies and significantly increases retention and test performance. Bannert et al. (2009) compared groups of readers across two conditions: The control group ($n = 27$) read an expository text with no metacognitive prompting, and the experimental group ($n = 29$) experienced the same text with the inclusion of computer-based metacognitive support. The experimental condition outperformed the control on the posttest in recall, knowledge, and transfer-level questions. Research consistently points to the advantages of providing the reader with both cognitive and metacognitive support.

Metacognitive prompts. The purpose of embedding self-questioning metacognitive prompts in text is to develop the reader's self-regulatory processes rather than simply provide feedback to the learner (Fiorella et al., 2012). Integrating metacognitive support directly into the learning activity is useful because it focuses the reader's attention on the instructional materials and on the quality and effectiveness of the reader's own cognitive processes (Bannert et al., 2009). Bol, Hacker, Walck, & Nunnery (2012) prompted learners with questioning strategies, called guidelines, in both group and individual settings. Findings suggested higher calibration accuracy for those receiving the questioning and self-monitoring prompts.

Mixed Strategy Use

There have been few studies to examine the effects of combining metacognitive and cognitive strategy prompts on the learner. Lee et al. (2010) found that participants receiving the combination of cognitive strategy and metacognitive feedback prompts (n = 223) performed significantly better on an achievement test, increased learners' self-regulation, and improved the quality of the use of generative strategies in a computer-based learning environment compared to those who did not receive cognitive or metacognitive support.

The findings from Lee et al. (2010) are consistent with an earlier study on embedded metacognitive, cognitive, and mixed prompts. Berthold et al. (2007) prompted learners (n = 84) with either cognitive, metacognitive prompts, or a combination of the two types of prompts while writing a learning protocol, which is a written response to a course activity. The cognitive strategy prompts asked the learner to summarize the main points, and the metacognitive prompts required the participant to monitor his or her understanding and evaluate current status of comprehension. Similar to Lee et al. (2010), the study revealed that the blend of cognitive and metacognitive prompts produced significantly higher learning outcomes.

Mixed strategy prompts. Providing mixed prompts means prompting the reader with both a cognitive and metacognitive strategy. In doing so, the question of sequencing becomes important. Wirth (2009) differentiated between *feed forward prompts*, which elicit future activity, and *feedback prompts* that reference past learning behavior with the intention to improve future performance. Cognitive prompts that require the generative technique of summarization are considered feedback prompts since the reader reflects on the previously learned material. Metacognitive prompts are typified as feed forwarding prompts since they trigger future cognitive and metacognitive activity through comprehension monitoring. Previous research does not indicate which sequencing is more beneficial (providing the cognitive or the metacognitive prompt first), so it was of interest to this study whether the order of prompts plays a significant role.

Metacomprehension

Metacomprehension is the relationship between an individual's ratings of comprehension of the textual material and his or her actual performance on a comprehension test (Anderson & Thiede, 2008; Maki & Berry, 1984; Nelson, 1984). Most commonly, metacomprehension is measured at the end of a text, where readers are asked to make a global judgment on the question, "How well do you think you understood the text?" The term *metacomprehension* is often used interchangeably in previous research and is sometimes referred to as calibration of comprehension (Glenberg & Epstein, 1985), ease of comprehension (Maki & Serra, 1992), monitoring accuracy (Thiede & Anderson, 2003), predictive accuracy (Wiley, Griffin, & Thiede, 2005), feeling of knowing (Glenberg et al., 1987; Morris, 1987), judgment accuracy, and global judgment (Dunlosky & Lipko, 2007). A common method for measuring metacomprehension is to calculate the difference between a reader's perceived and actual level of understanding of an entire text, and this is an important factor in determining test readiness, allocation of study time, and confidence. In general, most readers exhibit poor metacomprehension (Glenberg et al., 1987; Hacker, Bol, & Bahbahani, 2008; Lin & Zabrucky, 1998; Maki, 1998).

Calibration

Similar to metacomprehension is calibration, or the "degree to which judgments or performance accurately reflect actual performance" (Bol, Hacker, O'Shea, & Allen, 2005, p.270). Whereas metacomprehension measures ask the reader to evaluate her global level of understanding of the text, calibration specifically asks for a prediction of performance on a test. Calibration accuracy is calculated by asking the reader to predict his or her future performance on the posttest and then measuring the absolute difference between the two scores. If a reader estimates an 80% on the posttest but only receives a 70%, she would be considered overconfident; a score of 90% would signify underconfidence, and a score of 80% suggests that she is well calibrated (Dunlosky & Lipko, 2007). Calibration is measured in either the context of *prediction*, the accuracy of estimated future performance on a test, or *postdiction*, the accuracy of estimated level of performance following a test.

There are emerging patterns in both types of calibration accuracy, though findings have been observed as a function of achievement level. Learners tend to be poorly calibrated; higher-achieving students do report a higher correlation of calibration but are typically underconfident, whereas lower-achieving students estimate performance that is much less accurate, but are more overconfident in their predictions and postdictions (Bol et al., 2005; Bol, Riggs, Hacker, Dickerson, & Nunnery, 2010; Glenberg & Epstein, 1985; Glenberg et al., 1987; Kruger & Dunning, 1999). Embedding generative learning strategies within the text may improve calibration. Maki et al. (1990) saw improved calibration accuracy when the text required more active processing while reading, and Walczyk and Hall (1989) found an increase in calibration accuracy using embedded questions in the text compared to a plain text. Predicting comprehension of a text (metacomprehension) and predicting future performance on a test (calibration) are different; Maki (1998) found that readers exhibited a higher correlation between comprehension ratings and performance than they did for predicted and actual test performance. Therefore, it is important to investigate both metacomprehension and calibration as measures of understanding.

Cognitive Load

Also of importance to this study was whether embedding prompts overtaxed the reader's cognitive load and negatively impacted his or her performance. Because of the large body of existing literature on cognitive load theory (see Sweller, 1988; Sweller, Van Merrienboer, & Paas, 1998), only a brief explanation will be provided here. Essentially, the working memory capacity of a reader is limited, so in order to optimize learning resources, the material being learned should not contain a large number of interacting or contradicting elements or media, as this results in a high working memory load and cognitive overload (van Gog & Paas, 2008) that prevents schema formation. It is suggested that providing the reader with metacognitive prompts to monitor performance could serve as a distraction to the material and possibly increase the cognitive load placed on the reader, which would have a negative influence on learning performance (Van Gog, Kester, & Paas, 2010). Moreover, Salomon (1984) differentiates between learners' beliefs about perceived influence of external events on mental effort rather than the actual cognitive attributes of the events themselves. Ayres (2006) demonstrated that mental effort might fluctuate during task performance, so it is also of significance to observe these incremental differences in mental effort to better understand the overall cognitive load associated with a task.

Hypotheses and Research Questions

The main research focus of this study was to investigate the effects of cognitive and metacognitive prompting on the accuracy of metacomprehension and calibration. Also of interest was the impact of prompting on achievement, attitudes, cognitive load, and whether the quality of cognitive strategy influenced judgment accuracy. The purpose of this study was to determine whether a significant difference existed between treatments (cognitive, metacognitive, and mixed) in terms of the dependent variables of achievement, metacomprehension and calibration absolute accuracy, cognitive load, and attitudes.

Using the generative model of the teaching of comprehension in accordance with previous research, the first hypothesis was that readers in the mixed strategy treatment (cognitive + metacognitive) would score significantly higher on the comprehension posttest compared to the other conditions. Previous studies have shown a positive effect for mixed strategy use, but no effect for either cognitive or metacognitive strategy use only (Berthold et al., 2007; Lee et al., 2010), when both treatments were implemented in the same study.

The second hypothesis stated that the mixed strategy treatment would produce a greater absolute accuracy for metacomprehension judgments, and it would result in more accurate calibration. Foley, Kajer, Thompson, and Willert (1990) found that more active processing during reading results in a more accurate sense of comprehension.

A third hypothesis posited readers who generate high quality summaries would produce more accurate metacomprehension and calibration. It should be acknowledged that participants receiving only the cognitive strategy prompts would not produce equivalent summaries; therefore, the cognitive strategy would have variation in terms of its effectiveness. Anderson and Thiede (2008) found a positive relationship between the higher number of idea units generated in a summary and the corresponding metacomprehension judgments.

Given the findings on college students' preferences for print-based text over digital text (Dillon, 1994; Li, Poe, Potter, Quigley, & Wilson, 2011; Schilit, Price, Golovchinsky, Tanaka, & Marshall, 1999; Woody, Daniel, & Baker, 2010), attitudes towards this style of instructional text was of interest to this study. Further, the impact of the presentation format on the mental demand on the reader was also investigated. Van Gog et al. (2010) observed an increase in cognitive load when prompting performance monitoring. Accordingly, the following research questions were examined:

1. How do the treatments (cognitive, metacognitive, and mixed) impact attitudes towards embedded strategies in digital text?

2. How do treatments differ in terms of how the embedded prompts impact mental demand (cognitive load)?

CHAPTER II

METHOD

Participants

An a priori power analysis using the statistical program G*Power indicated that a target sample size of 80 participants would be sufficient to detect an appropriate effect size of 0.5 (Cohen, 1988). The participants ($N = 80$) were derived from a population of undergraduate college students originating from one mid-sized university (student body population approximately 9,000) in the mid-Atlantic region. Their participation was voluntary, though extra credit was offered as an incentive. For those students who requested extra credit but did not wish to participate in the study, an alternative assignment was provided. The study participants were chosen based on convenience sampling, as the researcher is a current faculty member at the institution.

Participants were drawn from 16-week courses taught at the mid-sized university in the mid-Atlantic region during the Spring 2013 semester. The courses included the curriculum-level English courses, ENGL101: *College Composition* and ENGL211: *Professional and Technical Writing.*

Table 1 presents the demographics from the study, which revealed that 45% of the participants were male and 55% were female. In addition, academic standing was reported as follows: 18% freshman, 38% sophomore, 28% junior, and 18% senior. Age ranges were also collected as part of the demographic information; 75% of participants were between the ages 18-21, 18% were between 22-25, 3% reported age as between 26-30, and 4% were above the age of 40. It also should be noted that during the data collection, four participants completed the treatment by copying and pasting text into the summary text boxes, negating the effect of summarization. As a result, these cases were excluded from the total sample.

Table 1

*Descriptive Statistics for All Participants (*N *= 80)*

	Treatment				
	Mixed	Metacognitive	Cognitive	Control	Total (%)
Gender					
Male	8	10	4	14	45.0
Female	12	10	16	6	55.0
Academic Standing					
Freshman	6	2	2	4	18.0
Sophomore	7	8	10	5	38.0
Junior	4	6	4	8	28.0
Senior	3	4	4	3	18.0
Age Range					
18-21	14	14	17	15	75.0
22-25	4	5	1	4	17.5
26-30	1	0	1	0	2.5
31-35	0	0	0	0	0
36-40	1	0	0	0	1.25
40+	0	1	1	1	3.75

Research Design

A 2x2 factorial, fully crossed, randomized true experimental between-subjects design was conducted on the sample of 80 voluntary participants (see Table 2). Participants were randomly assigned to one of four treatments: *Mixed* (cognitive and metacognitive strategies embedded), *metacognitive* (embedded metacognitive strategy), *cognitive* (embedded cognitive strategy), and *control* (no embedded strategy). Once the target sample size of 80 was reached, data collection was concluded. All participants completed the Metacognitive Awareness of Reading Strategies Inventory (MARSI) and took a knowledge pretest prior to reading the expository text. While reading, all participants also selected a metacomprehension rating and made a calibration judgment to indicate their levels of understanding of the text. At the conclusion of the expository text, an attitude survey towards the instructional materials, and a cognitive load measurement were administered prior to completing the criterion-referenced comprehension posttest. The dependent variables that were measured included pre and posttest achievement scores, metacomprehension accuracy, calibration accuracy, attitudes towards the instructional materials, and cognitive load. The covariates were the quality of the cognitive strategy use, which applied only to the mixed and cognitive conditions, the score on the MARSI and the score on the photography pretest.

Table 2

2x2 Factorial Design Representing the Three Treatment Conditions and One Control

	Metacognitive Prompts	No Metacognitive Prompts
Cognitive Prompt	Mixed *(Group 1)*	Cognitive *(Group 3)*
No Cognitive Prompt	Metacognitive *(Group 2)*	Control *(Group 4)*

Measures

Metacognitive awareness of reading strategies inventory (MARSI). The reader completed this independent measure prior to reading the text (See Appendix B). The MARSI is a 30-item questionnaire developed by Mokhtari and Reichard (2002). The MARSI was found to be highly reliable (α = .849). The global reading strategies (GLOB) subscale consisted of 13 items (α = .724), the problem-solving strategies (PROB) subscale consisted of 8 items (α = .628), and the support reading strategies (SUP) subscale consisted of 9 items (α = .717). Appendix H provides the detailed means for individual questions on the MARSI and for each of the three subscales. In the present study, the scores on the MARSI were used to delineate participants into one of three groups, which describe the reader's strategy usage: High (mean score of 3.5 or higher), medium (mean of 2.5 to 3.4), or low (2.4 or lower) (Mokhtari & Reichard, 2002). Results indicated the majority of participants identified themselves in the medium category (60%), followed by the high strategy usage category (31.3%), and the low strategy usage category (8.8%).

Photography pretest. A 10-question criterion-referenced photography pretest (See Appendix C) determined the level of prior knowledge each participant had in this content area. The purpose of the photography pretest was to identify participants with a high level of knowledge in the subject of photography. While the photography pretest addressed major concepts covered in the text, it did not prime the reader's performance on the subsequent comprehension posttest. The content validity of the photography pretest underwent an expert review.

Calibration. Upon completion of the treatment instruction, calibration accuracy was determined by the absolute difference between the predicted score and actual score. Using a scale of 1-100, the participant was asked to predict his or her score on the comprehension posttest.

Metacomprehension. Upon completion of the text, metacomprehension absolute accuracy was determined by asking the participants, "How well do you think you understood the text?" Readers then indicated their level of understanding using a Likert-type scale that ranges from 1-100 (very poorly to very well). Though metacomprehension typically has been measured on a 7-point Likert-type scale, more recent research has used a 100-point scale in order to evaluate an absolute measurement, as the comprehension posttest also totaled 100 (Netfield & Schraw, 2002). Absolute metacomprehension accuracy is measured by the difference between the comprehension rating and the performance on the comprehension posttest. A Pearson's R correlation coefficient was calculated for each group to determine the strength of the relationship between the judgment and performance.

The quality of cognitive strategy use. Two writing professionals independently rated the quality of summaries generated by each participant in the cognitive strategy and mixed strategy treatments, and an inter-rater reliability of .89 was calculated using a Pearson correlation. The summarized text was coded into idea units, which they were further coded into gist (main idea) or detail units. Three separate scores were calculated for each summary: (a) number of gists, (b) number of details, (c) number of total words (Anderson & Thiede, 2008).

Attitudes towards instructional materials. A survey instrument measuring attitude towards the instructional materials was administered to all participants across all conditions (See Appendix D). The survey consisted of 11 Likert-type scale items. The Likert-type items ranged from *Strongly Agree* to *Strongly Disagree* (1-5, respectively). The survey was derived from an attitude measurement developed by Johnsey, Morrison, and Ross (1992). Questions on the survey were modified slightly to contain Likert-type items specific to this study such as "It was easy to retain my attention on learning the material in the module" and "I would prefer digital text to print text in a future course." A Cronbach's Alpha of .922 was reported for the present study.

Cognitive load measurement. The survey instrument was an adaptation of the NASA Task Load Index (NASA TLX), originally developed by Hart and Staveland (1988). The original NASA TLX reported a reliability of .83. This adaption by Gerjets, Scheiter, and Catrambone (2006) implemented a subjective rating scale (0 -100) and included four subscales: Mental effort (1 item), mental demand (2 items), performance (2 items), and frustration level (1 item). It did not include the original NASA TLX subscales of physical demand and temporal demand. Additionally, to investigate whether there is a difference in task load during the act of reading, the mental effort subscale (1-item: How hard did you have to work in your attempt to understand the contents of the learning environment?) was implemented a total of seven times throughout the instructional text for all treatments. Ayres (2006) suggested that rating mental effort during task performance could produce different results from a post-performance rating. Reliability for the instrument was α =.80 in the subscales of mental demand, performance, and frustration, and $\alpha = .89$ for the mental effort repeated measure (See Appendix E).

Comprehension posttest. A 15-question criterion-referenced comprehension posttest (See Appendix G) was used to measure learning performance and to analyze the accuracies of metacomprehension and calibration. The comprehension posttest consisted of five recall-level questions, five comprehension-level questions, and five application-level questions. An example of a recall-level question is "The sequence that light travels through a camera is ______." Comprehension-level questions asked the reader to demonstrate an understanding of photography concepts, for example, "Which of the following pictures illustrates the use of a shallow depth of field (DOF)?" An application-level question applied the knowledge to a new situation. Application-level questions asked the participant to evaluate photos and to select the appropriate manual settings on a camera for a given scenario. An example on the comprehension posttest read: "Imagine this: You are sitting on the beach when you look out over the ocean and notice a humpback whale surfacing in the distance. You want to capture this moment with a picture. Quick! Which of the following settings would be best to capture the action of the whale?" A blueprint for the comprehension posttest can be seen in Appendix F. The test items were reviewed by a content expert for validity. The Kuder-Richardson formula (KR-20) was used to calculate reliability coefficient of .56.

Instructional Materials

All participants, regardless of the treatment, read an expository text on the basics of photography. The text was in the form of a 37- page PDF with fillable fields that was created using Adobe Acrobat 8.0 Professional. It was expert reviewed by a professional photographer. The expository text was approximately 2,000 words in length, and had a Flesch-Kincaid grade level of 12. In the opening pages of the text, the participants viewed a notification form that explained the purpose of the study, the risks and benefits of participation, instructions on how to withdraw from the study, and contact information for each of the researchers. Then, the participants proceeded to the MARSI, which consisted of 30 Likert-type scale items, and a photography pretest that was used to determine the level of prior knowledge or expertise on the instructional content. Immediately before and after reading the expository text portion of the PDF, all groups were asked to record the start and end time to calculate the amount of time spent reading the text.

Counterbalancing. The mixed treatment groups encountered the cognitive and metacognitive prompts on subsequent pages, separate from the expository text. To determine whether the sequencing of prompting is significant, the mixed condition was counter-balanced and subdivided into two groups. The first group (Mixed 1A) received the cognitive and then the metacognitive prompt, and in the second subgroup (Mixed 1B), the order was reversed.

Treatments

Mixed. The participants in the first treatment condition completed a direct instruction training exercise on using the cognitive strategy of summarizing, completed the MARSI, took a 10-question criterion-referenced photography pretest, then read the text (containing cognitive and metacognitive strategy prompts). Then, each participant made a metacomprehension judgment and a calibration prediction of performance, and completed an attitude survey and cognitive load measurement survey before taking the comprehension posttest. The metacognitive and cognitive prompts appeared on subsequent pages and were separate from the instructional text. As mentioned previously, in the first subgroup (Mixed 1A), the reader encountered the cognitive strategy prompt wherein she summarized the content. The following page contained metacognitive self-questions that prompted a participant to evaluate and monitor her cognitive progress. In the second subgroup (Mixed 1B), the order of prompts was reversed. The reader was prompted with a metacognitive strategy, a cognitive strategy, and a question about their mental effort.

Metacognitive. The participants in the metacognitive condition completed the MARSI and photography pretest. As they read the materials, readers experienced the same metacognitive prompts and mental effort rating as in the mixed condition but did not complete the cognitive strategy training, nor were they prompted to implement a cognitive strategy while reading the text. The metacognitive prompts were interrogative and were adapted from previous metacognitive research by Berthold et al. (2007) and Sitzmann and Ely (2010). These questions can be found in Appendix A. The metacognitive condition also made two judgments (metacomprehension and calibration) before completing the attitude survey, cognitive load measurement survey, and comprehension posttest.

Cognitive. Following the completion of the MARSI and the photography pretest, the third group completed the same direct instruction training exercise on using the cognitive strategy of summarizing. The text contained the same cognitive prompts and mental effort rating as in the mixed treatment. At the conclusion of the text, the cognitive treatment made two judgments (metacomprehension and calibration) and completed the attitude and cognitive load measurement surveys prior to the comprehension posttest.

Control. The control group completed the MARSI, the photography pretest, and then read the expository text minus any cognitive or metacognitive prompts (but including the mental effort question) and made both metacomprehension and calibration judgments, completed the attitude and cognitive load measurement surveys, then the comprehension posttest. In an effort to hold time constant across treatments, the control group experienced additional pages that gave them the opportunity to review the material in lieu of the cognitive and/or metacognitive strategy prompts. After completing the posttest, the control read a short article to prevent disruptions while the other treatments completed the tasks. A sequence of each condition can be seen in Table 3.

Procedure

Participants were randomly assigned to a treatment in a chronological fashion. The researcher assigned the first participant to a computer with the treatment for group one. The next participant was placed in group two, and so on. Prior to opening the PDF file containing the instruments and instruction, a moderator gave a brief overview on how to complete, save, and then submit the PDF file. All participants were instructed on what to do if there was any question.

The participants opened the PDF file at a computer workstation and proceeded as directed by the instructions (for a sequence of events in each condition, see Table 3). Upon completion, each participant submitted the PDF file to a secure, online workflow via Adobe Reader Professional by clicking on the "Submit Form" button in the upper-right hand corner of the PDF. These files were stored online in a private Adobe account, but in order to ensure confidentiality, each of these files was coded numerically. Further, the files were backed up on a removable flash drive and stored under lock and key in the main researcher's office. Data will be destroyed within one year of the acceptance of the manuscript for publication.

Table 3

Moving Left to Right, a Sequence of Instruction for Each Condition

		Sequence of Instruction												
		MARSI	Photography Pretest	Cognitive Strategy Training	Expository Text *(with cognitive & metacognitive prompts)*	Expository Text *(with cognitive prompts only)*	Expository Text *(with metacognitive prompts only)*	Expository Text *(no prompts)*	Metacomprehension Rating	Calibration Judgment	Attitude Survey	Cognitive Load Measurement	Comprehension Posttest	Article
Treatments	Mixed	x	x	x	x				x	x	x	x	x	
	Cognitive	x	x	x		x			x	x	x	x	x	
	Metacognitive	x	x				x		x	x	x	x	x	
	Control	x	x					x	x	x	x	x	x	x

Analysis

Table 4 shows the hypotheses, research questions, and the corresponding analysis methods that were used to evaluate each. SPSS statistical software was used to analyze the data. Participants were categorized as having high, medium, or low reading strategy usage based on their mean scores on the MARSI. Mokhtari and Reichard (2002) identify these categories as follows: High (mean of 3.5 or higher), medium (mean of 2.4 to 3.4), and low (2.4 or lower). The differences in results of the achievement scores on the comprehension posttest across the treatments were investigated with analysis of covariance (ANCOVA) using the scores on the MARSI and the photography pretest as the covariates.

Participants were asked to make a global judgment (1-100) on the overall understanding of the text. Absolute metacomprehension accuracy was measured by the difference between the confidence rating and performance. A Pearson's R correlation coefficient was calculated to determine the relationship between metacomprehension and posttest performance. The relationship between the metacomprehension ratings and the comprehension posttest scores ranged from -1 to +1, with 0 indicating complete inaccuracy and +1 indicating excellent accuracy (Anderson & Thiede, 2008, Dunlosky & Lipko, 2007).

Each participant's calibration accuracy was computed using the absolute difference between test prediction and test performance (Bol & Hacker, 2012). A one-way between-subjects ANCOVA using the MARSI and photography pretest scores as the covariates was employed to test for significance between treatments.

To investigate the effect of the quality of cognitive strategy use on judgment accuracy, two writing professionals independently rated the quality of summaries generated by each participant in the cognitive strategy and mixed strategy treatments, and inter-rater reliability was determined. The summarized text was coded into idea units, of which they were further coded into gist (main idea) or supporting detail units. Three separate scores were tallied for each summary: (a) number of gists, (b) number of details, (c) number of total words (Anderson & Thiede, 2008). A Pearson product-moment correlation was calculated for the (a) total number of gists, (b) total number of details, and (c) total number of words across all groups, for metacomprehension and calibration judgments respectively. Participants were categorized as having high, medium, or low quality summaries (determined by the number of total idea units generated), and an ANCOVA using the MARSI and photography pretest scores as the covariates was used to seek significant differences.

An attitude survey was administered to participants in order to analyze their attitudes towards the embedding of strategies in digital text. The data gathered from the Likert-type questionnaire examined differences across treatments using a one-way between-subjects ANOVA.

A difference in cognitive load across treatments was analyzed in two ways. First, a 4 (groups) x 7 (trials) repeated measures ANOVA was conducted for the 1-item, mental effort question that is embedded throughout the text a total of seven times. Second, a one-way ANOVA using the total score on the cognitive load survey determined significant differences between the treatments.

Table 4

Hypotheses and Research Question Data and Analysis Methods

Hypotheses	Dependent Variables	Analysis
Readers in the mixed strategy treatment will score significantly higher on the comprehension posttest compared to the other conditions.	Comprehension Posttest	ANCOVA
The mixed strategy treatment will result in more accurate absolute metacomprehension and calibration.	Calibration & metacomprehension judgments, and comprehension posttest	ANCOVA Pearson R, Gamma
Readers who generate high quality summaries will result in more accurate absolute metacomprehension and calibration.	Calibration & metacomprehension judgments, comprehension posttest, and summaries	ANCOVA Pearson R
Research Question	Data	Analysis
How do the treatments (cognitive, metacognitive, mixed) impact attitudes towards embedded strategies in digital text?	Attitudes towards instructional materials	One-way ANOVA

Table 4 Continued

How do treatments differ in terms of how the embedded prompts impact mental demand (cognitive load)?	1-item mental effort repeated question, Cognitive Load survey	Repeated measures ANOVA, and one-way ANOVA

CHAPTER III

RESULTS

This chapter presents the results of the statistical analyses conducted to determine the effects of cognitive and metacognitive strategy prompts on the calibration and metacomprehension accuracy, learning performance, attitudes towards instructional materials, and cognitive load of college undergraduates ($N = 80$). Results are presented according to each of the three hypotheses and the two research questions. To account for prior knowledge of the instructional content and level of reading strategy usage, a one-way ANOVA was conducted between groups for the scores on the MARSI and the photography pretest, and no significant differences were found. The results of the MARSI and the photography pretest scores indicated homogeneity-of-regression between each of the conditions. Reading strategy usage was relatively consistent across all groups, as well as the level of prior knowledge of the subject matter. Table 5 presents the overall mean results for each of the measures.

Table 5

Mean Results Collapsed Across All Conditions

	n	MARSI	Photography Pretest	Posttest	Metacomprehension Absolute Accuracy	Calibration Absolute Accuracy	Attitude	Cognitive Load
Mixed	20	3.45 (.335)	55.00 (20.9)	69.20 (11.40)	15.95 (12.23)	9.05* (5.89)	2.73 (.99)	51.19* (15.53)
Metacognitive	20	3.37 (.511)	62.00 (18.52)	56.30 (19.24)	17.15 (15.80)	23.10* (18.64)	2.73 (1.01)	38.69* (15.82)
Cognitive	20	3.13 (.44)	51.00 (16.19)	64.70 (16.90)	18.00 (14.15)	14.80 (12.12)	2.87 (.87)	49.84 (13.52)
Control	20	3.02 (.49)	50.00 (11.70)	61.00 (16.38)	17.90 (17.25)	19.60* (9.76)	2.71 (.97)	37.30* (14.59)
Totals	80	3.25 (.48)	54.50 (17.50)	62.80 (16.62)	17.25 (14.71)	16.64 (13.36)	2.76 (.95)	44.25 (15.92)

Note. Entries are means of each condition. Values in parentheses are the standard deviation.
* $p < .05$ level, two-tailed

Hypothesis One

The first hypothesis predicted that the mixed strategy treatment group would perform significantly higher on the comprehension posttest compared to the other treatments. A one-way between-groups analysis of covariance (ANCOVA) was conducted to test this hypothesis. The independent variable (group) had four levels: Mixed, metacognitive, cognitive, and control and the dependent variable was the score on the comprehension posttest. The score on the photography pretest was used as a covariate. The preliminary analysis of the homogeneity-of-regression assumption indicated there was no significant difference between the covariate and the dependent variable as a function of the independent variable, $F(3, 72) = .53, p = .67$. The ANCOVA did not yield a significant difference between the four treatment groups on comprehension posttests scores using pretest scores as a covariate, $F(3, 75) = 2.32, p = .08$, partial eta squared = .09. There was not a strong relationship between the photography pretest score and the comprehension posttest score, as indicated by the partial eta squared value of .003.

Table 6

Mean Results of the Comprehension Posttest According to Question Type

	n	Recall-Level Items		Comprehension-Level Items		Application-Level Items	
		% Correct	*SD*	% Correct	*SD*	% Correct	*SD*
Mixed	20	67.00	21.79	70.00	18.92	70.00	23.84
Metacognitive	20	56.00	29.45	60.00	21.52	53.00	27.74
Cognitive	20	71.00	19.97	64.00	28.73	59.00	31.44
Control	20	55.00	25.03	62.00	24.19	65.00	19.33
Total	80	62.25	24.85	64.00	23.47	61.75	26.28

Note. Each question type (recall, comprehension, application) consisted of five questions. Scores are based on a scale of 100%

Another one-way between-groups ANCOVA was computed using the independent variable (group) with four levels (mixed, metacognitive, cognitive, and control) and the score on the comprehension posttest as the dependent variable. For this analysis, the MARSI score was used as a covariate in an effort to control for existing reading strategy usage. The analysis of homogeneity-of-regression again indicated that the relationship between the covariate and the dependent variable did not differ significantly as s function of the independent variable, $F(3, 72) = .525, p = .667$, and so this assumption was not violated. After adjusting for MARSI scores, there was no significant difference between the treatment groups on comprehension posttest scores, $F(3, 75) = 2.25, p = .09$, partial eta squared .083. The partial eta squared value of .000 did not indicate a strong relationship between the MARSI and comprehension posttest scores.

Contrary to the hypothesis that the mixed strategy treatment would perform better than the other treatments on the comprehension posttest, the data did not reveal a statistically significant difference between any of the treatment groups on the comprehension posttest while controlling for either the scores on the photography pretest or the MARSI. However, a one-way between-groups ANOVA revealed a trend towards a statistically significant difference between the mixed and metacognitive treatments (p = .066).

Hypothesis Two

The second hypothesis predicted that the mixed strategy treatment would produce (a) a more accurate metacomprehension judgment, and (b) a more accurate absolute calibration, or prediction of performance. A one-way between-groups ANCOVA using the photography pretest and the MARSI scores as covariates was conducted to test this hypothesis. Additionally, a Goodman and Kruskal gamma correlation (G) and a Pearson bivariate correlation coefficient were calculated for each condition. Table 7 presents the mean ratings for metacomprehension and calibration as well as the corresponding comprehension posttest performance and absolute accuracy of calibration for all groups.

Table 7

Means and Standard Deviations for Comprehension and Calibration Ratings and Accuracy

Condition	Metacomprehension Rating	Metacomprehension Accuracy	Predictive Calibration	Calibration Absolute Accuracy
Mixed	70.95 (13.08)	15.95 (12.23)	75.05 (10.06)	9.05* (5.89)
Metacognitive	74.80 (17.70)	17.15 (15.80)	77.90 (6.14)	23.10* (18.64)
Cognitive	74.25 (13.60)	18.00 (14.15)	76.05 (10.71)	14.80 (12.12)
Control	70.00 (17.63)	17.90 (17.25)	77.30 (12.47)	19.60* (9.76)

Note. Entries are means of each condition. Values in parentheses are the standard deviations.
* $p < .05$ level, two-tailed

Metacomprehension. A one-way between-groups ANCOVA did not yield significant differences between conditions ($p > .05$). However, a Goodman and Kruskal's gamma and Pearson's bivariate correlation coefficient were calculated to investigate the strength of the relationship between the metacomprehension ratings and the comprehension posttest scores in each of the four conditions (see Table 8). Similar to other correlation coefficients, gamma ranges from -1.00 to +1.00. A positive perfect relationship between variables produces a gamma close to +1.00, a gamma of 0.00 reflects no association between the variables, and a gamma close to -1.00 reflects a negative perfect relationship. Only in the mixed strategy condition did the reported gamma (G = .467) suggest that a significantly positive relationship existed between metacomprehension ratings and comprehension posttest scores ($p = .008$). As the metacomprehension rating increased, so did the score on the comprehension posttest.

In addition, a Pearson bivariate correlation coefficient was computed for each condition. Cohen (1988) suggests the following interpretations of the r value: small (.10-.29), medium (.30-.49) and large (.50-1.0). There was a strong positive relationship between metacomprehension ratings and comprehension posttest scores for the mixed strategy condition ($r = .586, p < .05$). Metacomprehension ratings explained a respectable 34.3% of the variance in participants' comprehension posttest scores.

Table 8

Goodman and Kruskal's Gamma Correlation and Pearson Product-moment Correlation Coefficient Between Metacomprehension Rating and Comprehension Posttest Score Across Treatments

Condition	*n*	Gamma	Pearson R
Mixed	20	.467*	.586*
Metacognitive	20	.255	.379
Cognitive	20	.152	.196
Control	20	.270	.315

* $p < .05$ level, two-tailed

Notably, reading strategy usage also played a role in the relationship between metacomprehension ratings and comprehension posttest scores. A Goodman and Kruskal gamma was computed for each of the reading strategy groups (based on the mean

MARSI score). Using the guidelines set forth by the MARSI creators Mokhtari and Reichard (2002), participants were categorized as having either low, medium, or high reading strategy usage. A significantly positive relationship was found between metacomprehension ratings and comprehension posttest scores for the low (G = .667) and medium (G = .287) reading strategy usage groups, but not for the high reading strategy usage group. Similarly, a Pearson bivariate correlation coefficient indicated a significantly positive relationship between metacomprehension ratings and posttest scores for the medium strategy usage category only ($r = .35, p < .05$).

Table 9

Goodman and Kruskal Gamma Correlation and Pearson Product-moment Correlation Coefficient Between Metacomprehension Rating and Comprehension Posttest Score Across Reading Strategy Usage Groups

MARSI Category	*n*	Gamma	Pearson R
Low	7	.667*	.393
Medium	48	.287*	.351*
High	25	.115	.231

* $p < .05$ level, two-tailed

Calibration. The hypothesis that the mixed strategy group would differ significantly in terms of calibration absolute accuracy while controlling for both the MARSI and the score on the photography pretest was confirmed. Using the dependent variable of absolute calibration (the difference between perceived and actual performance on the comprehension posttest), and the treatment group as the independent variable, a one-way between-groups ANCOVA was first computed using the photography pretest score as the covariate. The homogeneity-of-regression assumption was not significant, $F(3, 72) = .339, p = .797$. The results from the ANCOVA revealed the main effect for the independent variable (group) was statistically significant for calibration accuracy while controlling for the photography pretest scores, $F(3, 75) = 4.53, p < .05$, partial $\eta^2 = .153$ and explained approximately 15% of the variance in calibration accuracy ($r^2 = .162$). Since the Levene's Test of Equality of Error produced a significant result, it was assumed the error variance across groups was not equal. A Games-Howell post hoc test showed that the mixed strategy and control groups differed significantly ($p = .001$) as did the mixed strategy and the metacognitive strategy group ($p = .019$). The mixed strategy condition was better calibrated than the metacognitive and control conditions.

Table 10

Analysis of Covariance for Calibration Absolute Accuracy by the Photography Pretest

Source	*SS*	*df*	*MS*	*F*	*p*
Group	2138.89	3	712.96	4.53	.006*
Error	11804.22	75	157.39		
Total	14092.49	79			

* $p < .05$ level, two-tailed

Another one-way between-groups ANCOVA was conducted using absolute calibration as the dependent variable, the treatment group as the independent variable, and the MARSI score as the covariate. A preliminary analysis of the homogeneity-of-regression assumption showed the relationship between the covariate and the dependent variable did not differ significantly as a function of the independent variable, $F(3, 72) = .235$, $p = .871$. Results of the ANCOVA indicated a significant difference between groups for calibration absolute accuracy while controlling for MARSI scores, $F(3, 75) = 4.943$, $p < .05$, partial $\eta^2 = .165$, and suggested that approximately 17% of the variance was explained by the MARSI score ($r^2 = .166$). Since equal variances were not assumed, a Games-Howell post hoc test revealed calibration absolute accuracy was significantly worse in the metacognitive ($p = .019$) and control group ($p = .001$) when compared to the mixed strategy group.

Table 11

Analysis of Covariance for Calibration Absolute Accuracy by MARSI Score

Source	*SS*	*Df*	*MS*	*F*	*p*
Group	2323.59	3	774.53	4.943	.003*
Error	11752.32	75	156.70		
Total	14092.49	79			

* $p < .05$ level, two-tailed

Hypothesis Three

The third hypothesis predicted that participants who generated higher quality summaries would produce (a) more accurate absolute metacomprehension judgments and (b) more accurate absolute calibration when compared to the other conditions. Throughout the text, each participant in the mixed strategy and cognitive strategy groups generated a total of seven summaries: One after each page of the expository text. These summaries were coded as containing (a) a gist (main idea from the text), and (b) supporting details (elaboration of a main idea). A supporting detail was considered any sentence that supported the gist of the text, but did not include the main idea. The total number of idea units was calculated as the number of total gists plus the supporting details in a summary. The length of the summary was also computed using the word count feature in Microsoft Word. Two writing instructors independently coded the participants' summaries. The Pearson r for inter-rater reliability was .89, and any disagreement was resolved through a discussion. In total, there were 36 available gists (main ideas) in the text. Table 12 gives an example of a section of the original text and a participant's corresponding summary of that section.

Table 12

Sample Passage from the Instructional Text and Participant's Corresponding Summary.

Original Passage	Participant's Summary
The focal plane is where the rays of light refracted by the lens converge to form a sharp, upside-down image. Light traveling from different distances from the camera needs varying degrees of refraction to focus at the focal plane, so a focusing mechanism moves the lens toward or away from the back of the camera. The position of the film (or in the case of a digital camera, the chip), and the focal plane coincide if the lens is correctly focused.	The focal plane is light passing through the lens to form an upside-down image. The position of the film or chip in the camera and the focal plane work together if the lens is correctly focused.
Exposure is the amount of light that is received by the camera film or digital chip, and is the product of the intensity of the light, the aperture size, and the shutter speed. Increasing the exposure time will capture more light from the image for a longer period of time. The light captured in this picture (left to right) demonstrates an increase in exposure time. A high exposure can simulate movement in a photo.	Exposure is the amount of light received by the camera. This also affects the aperture size, shutter speed, and light intensity. More exposure time will capture more light for a longer time. The shutter speed can be set at different speeds, which determines the length of exposure to light.
Like the aperture, the focal-plane shutter can be set at different speeds, which determines the length of time the film is exposed to light. Most digital cameras have an automated feature that	Digital cameras usually have this preset already, but you can certainly change it in the settings. The shorter the shutter speed, the sharper the image.

Table 12 Continued

ensures the image remains in focus. The shorter the time that the shutter is open, the sharper the image will be. The shutter speed is usually measured in fractions of a second (s), though some cameras allow for longer shutter speeds that remain open for minutes or hours. To put this in perspective, the blink of a human's eye translates to a shutter speed of approximately 1/30s.

Note. Sentences that represent a gist or a main idea of the text are double-underlined. Sentences that represent supporting details are single-underlined.

Table 13 provides the descriptive statistics for the quality of cognitive strategy use for the mixed strategy and cognitive strategy groups. An independent samples *t*-Test did not find a significant difference between the two groups in terms of the total idea units generated, the number of gists, the number of supporting details, or the length of the summary written ($p > .05$). These results suggested that the quality of cognitive strategy use was relatively similar regardless of whether or not participants received metacognitive strategy prompts in addition to the cognitive strategy.

Table 13

Mean Tabulations for Idea Units, Gists, Details, and Summary Length Across Groups

	n	Total Idea Units	Gists	Supporting Details	Summary Length
Mixed	20	36.65 (10.38)	18.55 (5.38)	18.10 (7.53)	595.10 (209.82)
Cognitive	20	36.3 (14.08)	18.65 (5.92)	17.65 (8.98)	599.65 (205.82)
Total	40	36.48 (12.21)	18.60 (5.58)	17.88 (8.18)	597.38 (205.16)

Note. Values in parentheses are standard deviations.

Metacomprehension. Participants were categorized into the high (n =13), medium (n = 13), or low (n = 14) group for quality of cognitive strategy use. The reading strategy usage groups were determined by using the 33% and 66% percentiles. Table 14 provides the means for the low, medium, and high quality of cognitive strategy use groups.

Table 14

Mean Results for Metacomprehension, Posttest Scores, and Absolute Metacomprehension Accuracy for Each of the Quality of Cognitive Strategy Use Groups

	n	Metacomprehension	Posttest	Absolute Metacomprehension Accuracy
Low	14	71.14	60.29	15.57
Medium	13	72.54	68.23	19.00
High	13	74.23	72.85	16.46

Calibration. A one-way between-groups ANCOVA using both the photography pretest score and the MARSI score did not yield significant differences in calibration absolute accuracy in terms of the quality of cognitive strategy use ($p > .05$).

The third hypothesis that the quality of cognitive strategy use would impact metacomprehension and calibration accuracy was not supported. However, a one-way between-groups ANOVA indicated a trend toward significance ($p = .059$) between high and low quality cognitive strategy use in terms of performance on the comprehension posttest. While not significant, the data suggested a higher number of idea units generated (i.e. higher quality summaries) could lead to a higher posttest performance.

Research Question One

A one-way between-subjects ANOVA was conducted to seek differences in attitudes towards the instructional materials between treatments. Cronbach's Alpha for the survey was high ($\alpha = .922$). Table 15 provides descriptive statics for each of the survey items. There was no significant difference detected in the mean total scores between groups.

Table 15

Descriptive Statistics for Each of the Attitudinal Items

Item	Mixed	Metacognitive	Cognitive	Control
1. The instructional materials were clear and easy to understand.	2.35 (1.46)	2.45 (1.47)	2.55 (1.19)	2.75 (1.25)
2. The instructional materials were at an appropriate level of difficulty.	2.50 (1.43)	2.95 (1.43)	2.40 (1.14)	2.75 (1.21)
3. The instructional materials facilitated learning.	2.65 (1.57)	2.55 (1.39)	2.55 (1.36)	2.55 (1.36)
4. My overall understanding of the content was enhanced.	2.70 (1.56)	2.45 (1.36)	2.65 (1.27)	2.75 (1.21)
5. Overall, the instructional module effectively facilitated learning.	2.65 (1.39)	2.5 (1.36)	2.6 (1.14)	2.8 (1.06)
6. I will be able to confidently perform the comprehension test.	2.70 (1.22)	2.75 (1.07)	2.90 (1.02)	2.70 (1.26)
7. I felt comfortable with the way the material was presented in the module.	2.75 (1.33)	2.45 (1.39)	2.5 (1.10)	2.65 (1.35)
8. It was easy to retain my attention on learning the material in the module.	2.85 (1.04)	2.95 (1.10)	3.35 (1.14)	2.90 (1.12)
9. I was not distracted during the module.	3.20 (1.01)	2.95 (1.32)	3.55* (1.19)	2.45* (1.28)
10. I would prefer this method of instruction in future modules.	2.75 (1.21)	2.90 (1.29)	3.10 (1.17)	2.65 (1.18)
11. I would prefer digital text to print text in a future course. (Explain).	3.00 (1.62)	3.15 (1.35)	3.45 (1.28)	2.90 (1.25)
Totals	2.74 (.99)	2.73 (1.01)	2.87 (.87)	2.71 (.97)

Note. Entries are mean scores. Values in parentheses are standard deviations of the means.
* $p < .05$ level, two-tailed

Research Question Two

The second research question investigated how each condition differed in terms of how the instructional materials impacted cognitive load. This was assessed in two ways: (a) a one-way between-groups ANOVA using the mean score on the cognitive load survey at the end of the instruction, and (b) a 4 (groups) x 7 (trials) repeated measures ANOVA using a mental effort rating that participants reported a total of seven times throughout the text. The means and standard deviations are presented in Table 15.

Table 16

Mean Results of Survey Items Measuring Cognitive Load

Item	Mixed	Metacognitive	Cognitive	Control
Mental Demand: How mentally demanding was the task?	60.70 (19.56)	56.50 (27.39)	61.60 (22.42)	54.15 (19.08)
Temporal Demand: How hurried or rushed was the pace of the task?	42.25 (25.13)	32.40 (27.13)	32.45 (27.93)	31.40 (23.50)
Performance: How successful were you in accomplishing what you were asked to do?	24.50 (17.24)	19.55 (14.92)	30.90 (20.00)	17.55 (19.76)
Effort: How hard did you have to work to accomplish your level of performance?	74.00* (17.54)	55.55* (25.63)	71.00 (13.14)	55.65* (23.55)
Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?	54.50* (32.40)	29.45 (32.37)	53.25 (29.75)	27.75* (30.61)
Totals	51.19* (15.53)	38.69* (15.82)	49.84 (13.52)	37.30* (14.59)

Note. Entries are mean scores. Values in parentheses are standard deviations.
* $p < .05$ level, two-tailed

A one-way ANOVA on the mean score of the cognitive load survey indicated a significant difference between the groups, $F(3, 76) = 4.77, p = .004$. A Tukey post-hoc test revealed the mixed strategy group ($M = 51.19$, 95% CI [43.92, 58.46]) reported a significantly higher level of cognitive load compared to the metacognitive strategy group ($M = 38.69$, 95% CI [31.28, 46.10]), $p = .047$, and the control group ($M = 37.3$, 95% CI [30.47, 44.13]), $p = .022$. Further, the post-hoc test also indicated a significantly higher level of cognitive load reported for the cognitive group ($M = 49.84$, 95% CI [43.51, 56.17]) when compared to the control group, $p = .046$. Additionally, results from a trend analysis lend support to the linearity in the relationship between the treatment groups and cognitive load in the target population, $F_{\psi}(1,76) = 4.20, p < .05$.

A significant difference also existed on the survey items *Effort* (How hard did you have to work to accomplish your level of performance?), $F(3, 76) = 4.572, p = .005$, and *Frustration* (How insecure, discouraged, irritated, stressed, and annoyed were you?), $F(3, 76) = 4.369, p = .007$. For the survey item measuring effort, a Tukey post-hoc test indicated a significantly higher level of cognitive load reported for the mixed strategy condition ($M = 74$, 95% CI [65.79, 82.21]) compared to the metacognitive ($M = 55.55$, 95% CI [43.55, 67.55]) and the control condition ($M = 55.65$, 95% CI [44.63, 66.67]). For the survey item measuring frustration, a Tukey post-hoc revealed a higher level reported for the mixed strategy condition ($M = 54.50$, 95% CI [39.34, 69.66]) compared to the control ($M = 27.75$, 95% CI [13.43, 42.07]). These findings suggested the mixed strategy condition required a significantly higher level of invested mental effort and resulted in nearly double the amount of frustration.

Repeated measures. In addition to the survey, a repeated measure of invested mental effort was implemented after each page of text, totaling seven trials (see Table 17). Participants answered the question, "How hard did you have to work in your attempt to understand the contents of the learning environment?", on a scale of 0-100 with 0 representing "low" and 100 representing "high" (see Figure 1). A one-way ANOVA was conducted to test for significance between groups. Because Mauchly's test indicated that the assumption of sphericity had been violated $\chi^2(20) = 116.95, p < .05$, the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = .68$). Results indicated a significant interaction effect for the level of reported cognitive load in the groups, $F(12.28, 311.02) = 2.345, p = .006$. A Tukey post-hoc test found several significant differences between groups in six of the seven trials.

Table 17

Mean Results of Repeated Measures of Invested Mental Effort Across All Trials

		Trials						
Group	*n*	1	2	3	4	5	6	7
Mixed	20	48.15* (25.07)	49.60 (20.16)	51.85 (20.29)	55.00 (17.24)	46.25 (18.06)	49.95* (21.16)	54.05* (18.54)
Metacognitive	20	32.45* (18.67)	49.75 (23.37)	42.55* (20.05)	42.80* (21.51)	38.00 (19.18)	35.80* (18.70)	40.55* (21.90)
Cognitive	20	53.00* (26.48)	60.65* (27.25)	59.60* (24.92)	58.90* (23.07)	45.90 (22.72)	54.70* (22.42)	52.90 (23.65)
Control	20	34.50* (22.69)	45.55* (22.16)	50.70 (21.23)	51.70 (24.34)	49.30 (23.51)	41.35* (17.80)	40.30* (20.25)
Total	80	42.03 (24.59)	51.39 (23.61)	51.18 (22.15)	52.10 (22.12)	44.86 (21.02)	45.45 (21.06)	46.95 (21.78)

Note. Entries are mean scores. Values in parentheses are standard deviations.
* $p < .05$ level, two-tailed

Trial 1. The mixed strategy condition ($M = 48.15$, 95% CI [37.72, 58.58]) and the cognitive ($M = 53$, 95% CI [42.57, 63.43]) conditions reported a significantly higher measurement compared to the metacognitive condition ($M = 32.45$, 95% CI [22.02, 42.88]). The cognitive condition also reported a significantly higher measurement compared to the control condition ($M = 34.5$, 95% CI [24.07, 44.93]).

Trial 2. The cognitive condition ($M = 60.65$, 95% CI [50.24, 71.06]) reported a significantly higher level of mental effort compared to the control condition ($M = 45.55$, 95% CI [35.14, 55.96]).

***Trial 3*.** The cognitive condition (*M* = 59.6, 95% CI [49.93, 69.27]) reported a significantly higher level of mental effort than the metacognitive condition (*M* = 42.55, 95% CI [32.88, 52.22]).

***Trial 4*.** Again, the cognitive condition (*M* = 58.9, 95% CI [49.23, 68.57]) posted a significantly higher level of mental effort than did the metacognitive condition (*M* = 42.8, 95% CI [33.13, 52.47]).

***Trial 5*.** No significant differences were found for the fifth trial.

***Trial 6*.** The mixed strategy condition (*M* = 49.95, 95% CI [41.00, 58.90]) and the cognitive (*M* = 54.70, 95% CI [45.75, 63.65]) conditions reported a significantly higher measurement compared to the metacognitive condition (*M* = 35.80, 95% CI [26.85, 44.75]). The cognitive condition also reported a significantly higher measurement compared to the control condition (*M* = 41.35, 95% CI [32.40, 50.30]).

***Trial 7*.** The mixed strategy condition (*M* = 54.05, 95% CI [44.62, 63.48]) indicated a significantly higher level of invested mental effort compared to the metacognitive condition (*M* = 40.55, 95% CI [31.12, 49.98]) and the control condition (*M* = 40.30, 95% CI [39.87, 49.73]).

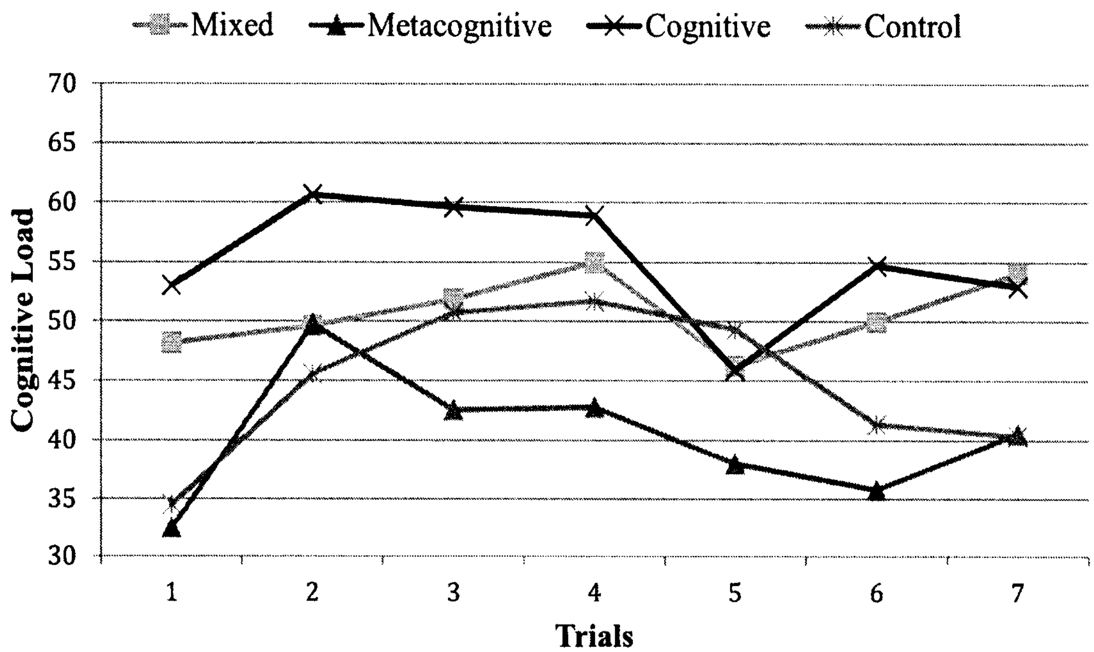

Figure 1. Mean responses of each condition for the invested mental effort repeated measure. The question on mental effort was administered seven times throughout the text and asked: "How hard did you have to work in your attempt to understand the contents of the learning environment?"

Summary

Overall, this study sought to improve metacomprehension and calibration accuracy as well as achievement. To examine the effects of the embedded strategies on metacomprehension and calibration accuracy, participants were analyzed for their level of reading strategy usage (based on the MARSI score) and their level of prior knowledge (based on the photography pretest score). Using these scores as covariates, participants were then evaluated for each of the dependent variables. Providing the reader with a combination of metacognitive and cognitive support during reading resulted in a positive correlation for metacomprehension ratings and score on the comprehension posttest, as well as for metacomprehension judgments and predictive calibration. The mixed strategy condition reported a statistically significant positive correlation between the metacomprehension ratings and the scores on the comprehension posttest (p = .008). Likewise, absolute metacomprehension accuracy (M = 15.95) and predictive calibration accuracy was most accurate in the mixed strategy condition (M = 9.05). The ordering of the strategy combination also demonstrated importance. Providing the metacognitive strategy prior to the cognitive strategy produced higher quality summaries. However, simply providing the reader with metacognitive support alone was more detrimental to the reader than just reading the text; the metacognitive condition predicted the highest level of test performance (M = 77.9), but scored the lowest (M = 56.3) and had the worst calibration absolute accuracy (M = 23.1) compared to all other groups. In terms of attitude towards the instructional materials, all conditions reported fairly similar results. Further, the data also revealed the highest levels of reported cognitive load existed in the mixed strategy and cognitive conditions (M = 51.19; M = 49.84, respectively). A significant difference in cognitive load existed between the mixed and metacognitive conditions, the mixed and control conditions, and between the cognitive and control conditions. These findings indicate that increased processing during reading lead to higher levels of cognitive load. This warrants further investigation into the benefits and trade-offs that may result by providing the reader with embedded cognitive and metacognitive reading support.

CHAPTER IV

DISCUSSION AND CONCLUSIONS

The focus of this research was to examine the effects of embedded cognitive, metacognitive, and mixed prompts in digital text on metacomprehension and calibration accuracy in an undergraduate sample population. Specifically, the purpose of this study was to determine whether a significant difference existed between treatments (cognitive, metacognitive, and mixed) in terms of achievement, metacomprehension and calibration absolute accuracy, attitudes, and cognitive load. Participants ($N = 80$) read a digital-based text on the subject of photography and were tested for differences in these areas. Depending on the treatment, participants either (a) read the text, generated summaries, and were prompted with metacognitive questions, (b) read the text and were prompted with metacognitive questions only, (c) read the text and generated summaries only, or (d) read the text with no intervention. This chapter interprets the results in light of the research literature. Also, a discussion on the limitations and implications of this research is presented.

Hypothesis One: Achievement

The first hypothesis predicted the most robust treatment, the mixed strategy (cognitive + metacognitive strategy), would score significantly higher on the comprehension posttest compared to the other groups. This hypothesis was not supported since no statistical significance was detected for the overall posttest score. Although the mixed strategy did outperform all other groups on the comprehension posttest, these differences in scores only approached statistical significance when compared to the treatment receiving metacognitive prompts only. The combination of cognitive and metacognitive strategies resulted in higher scores on comprehension and application-level items, though not significantly. Fiorella et al. (2012) reported similar results, which found gains in learning performance for higher-level, but not lower-level, test items. According to Wittrock's (1991) model of the teaching of comprehension, this mixed strategy approach should lead to a deeper level of cognitive processing and result in more meaningful learning.

However, a statistically significant difference in the overall posttest scores between groups did not exist. This finding is consistent with previous research that failed to identify any learning effects as a result of embedded generative learning prompts (Bannert & Reimann, 2011; Lee et al., 2010) or embedded metacognitive intervention (van den Boom, Paas, van Merrienboer, & van Gog, 2004; Veenman et al., 1994). One explanation for why the mixed strategy approach did not yield significantly higher posttest scores is likely the lack of quality in cognitive strategy use. The quality of the participants' summaries did not correlate with higher posttest scores, which seems counterintuitive. Anderson and Thiede (2008) also failed to find a difference between treatments in terms of the quality of cognitive strategy use. It is suggested that analyzing summaries in terms of the number of gists, supporting details, and length may not be a sufficient predictor of quality. Rather, the authors recommend the learner engage in a self-explanation to improve judgment accuracy, and eventually, academic achievement.

Additionally, previous research stresses the importance of cognitive strategy training (Bannert, 2006; Bannert & Reimann, 2011; Clarebout et al., 2010). Although this study included a brief tutorial on cognitive strategy use at the beginning of the instructional text, participants would benefit immensely from repeated practice and individualized feedback on the quality of their summarization skills over a more longitudinal experiment. This linear type of instruction sought to find differences between groups after only one session. Prior research indicates self-regulatory activity and metacognitive improvement take a lengthier amount of time to observe improvements, and when used in short bursts, this type of metacognitive intervention really only exposes those with a severe metacognitive deficit (Banner et al., 2009). Improving learning performance is apropos to this research, but the primary focus of the study was to improve both metacomprehension and calibration accuracy in undergraduates, which it succeeded in doing.

Hypothesis Two: Metacomprehension

Despite the mixed strategy treatment reporting the most accurate metacomprehension ratings, hypothesis two predicted that a statistically significant difference would exist between groups was not supported. To further explore this finding, the original hypothesis investigated the degree of strength that existed between the metacomprehension ratings and the comprehension posttest scores. In this context, the participants in the mixed strategy treatment yielded a significantly positive relationship between metacomprehension ratings and posttest scores as indicated by both a Goodman and Kruskal's gamma (G = .467) and a Pearson correlation coefficient ($r = .586, p < .05$), compared to the other conditions. These findings found that a strong relationship exists between the level of perceived understanding and the corresponding test performance for the readers who received a combination of cognitive and metacognitive strategy prompts. This study reinforces the findings of Thiede and Anderson (2003), which found a statistically significant relationship between metacomprehension ratings and comprehension posttest scores in cognitive strategy conditions. Walczyk and Hall (1989) also found that embedded comprehension self-assessments lead to more accurate metacomprehension ratings.

Hypothesis Two: Calibration

In congruence with Maki et al. (1990) study that found increased processing during reading improves the accuracy of test predictions, the present study supported the hypothesis, which anticipated the participants in the mixed strategy treatment would be significantly more accurate in their predictions of performance on the comprehension posttest. Overall, the mixed strategy group reported the highest accuracy in calibration across all groups and was significantly more accurate than both the metacognitive treatment and control group, while controlling for both the photography pretest and the score on the MARSI. Bol et al. (2012) reported that providing students with guidelines for calibration practice resulted in more accurate predictions and postdictions on the comprehension posttest; the embedded prompts in the current study behaved similarly to these practice guidelines.

Hypothesis Three: Quality of Cognitive Strategy Use

The findings did not indicate the quality of cognitive strategy use impacted metacomprehension or calibration accuracy. No statistically significant difference was detected between groups for the total idea units generated, gists, supporting details, or summary length. However, the mixed strategy treatment, which was counterbalanced by being subdivided into two groups (Mixed 1A and Mixed 1B), did observe significant differences between the subgroups in terms of total idea units generated and supporting details. The subgroup that received the metacognitive strategy prompt and then the cognitive strategy prompt (Mixed 1B) produced significantly more idea units than did Mixed 1A, which received the cognitive strategy and then the metacognitive strategy prompt. This finding suggested that prompting the reader metacognitively prior to implementing the cognitive strategy resulted in a higher quality summary, though the small sample sizes of each of the subgroups ($n = 10$) have little statistical power. Therefore, these results are not generalizable. Rather, this finding is merely informational and in need of further research.

Research Question One: Attitude

The first research question investigated whether or not the presentation of the instructional materials would affect participants' attitudes. No significant differences between groups were detected in attitudes towards the instructional materials. This non-significant finding is important to this study because it suggests the participants are not clearly disenfranchised by embedded reading strategies in digital text. However, across all groups, the attitudinal scores were neutral, so it cannot be argued that digital text is preferable to paper-based text either. Although recent studies have indicated students' preferences for digital text to paper-based text might be shifting towards digital (Weisberg, 2011), and there is no discernable difference in reading comprehension levels between the two forms of media (Schugar et al., 2011; Taylor, 2011), digital text still is not convincingly preferred.

One item on the attitude survey did yield a statistically significant difference between the cognitive and control groups. The cognitive strategy condition reported a significantly higher mean response the to survey item, "I was not distracted during this module" when compared to the control group. This suggested that the embedded cognitive strategy prompts might have been viewed as distracting rather than a support tool. However, the cognitive strategy condition did out perform the control in terms of comprehension posttest scores and calibration accuracy, so this trade-off of perceived distraction for improvement in achievement and judgment accuracy is a justifiable one.

Research Question Two: Cognitive Load and Invested Mental Effort

The second research question examined differences in cognitive load between treatment groups. Several significant differences existed between groups in terms of cognitive load. First, a significantly higher level of cognitive load was reported in the mixed strategy condition when compared to both the control and metacognitive conditions. Likewise, the cognitive strategy condition reported a significantly higher level of cognitive load than did the control condition. These results can be interpreted as a direct result of the embedded strategies; the amount of processing during reading translated into a higher perceived level of mental effort in the groups that required the most reader interaction. This finding is an important one since instructional strategy usage should always consider the cognitive strain imposed on learners (Bruner, Goodnow, & Austin, 1956). In this study, cognitive load was measured (a) at the end of the instructional text, and (b) as a single-item repeated measure embedded in the text.

According to the survey administered at the end of the instruction, cognitive load was significantly higher in the mixed strategy condition, when compared to the metacognitive and control groups. In terms of the subscales *Effort* (How hard did you have to work to accomplish your level of performance?) and *Frustration* (How insecure, discouraged, irritated, stressed, and annoyed were you?), the mixed strategy treatment reported significantly higher levels of cognitive load than the metacognitive and control groups.

The repeated measure of invested mental effort was administered a total of seven times throughout the text and asked the same question of readers in all groups: "How hard did you have to work in your attempt to understand the contents of the learning environment?" Participants indicated their perceived level of mental effort on a scale of 0-100 with 0 representing "low" and 100 representing "high." This subjective technique of rating mental effort is perhaps less effective than other methods such as physiological or task-and-performance-based techniques, since it assumes the reader is acutely aware of his or her cognitive processes (Sweller et al., 1998). Nonetheless, the mixed strategy condition reported significantly higher levels of invested mental effort in four of the seven trials, when compared to the other groups. Yet, the cognitive strategy condition reported significantly higher levels of invested mental effort in all but two of the seven trials. Although, the repeated measurement of invested mental effort throughout the text indicated a higher level existed in the cognitive strategy condition.

These results are surprising given that the mixed strategy condition required the most interaction from its readers (two prompts) compared to the cognitive strategy condition, which only required the generation of a summary. A possible explanation is that the metacognitive strategy prompts did not add to the level of cognitive load; rather, these self-questioning prompts deducted from the reader's perceived cognitive strain. The metacognitive condition reported levels of cognitive load that were slightly above those reported by the control. However, in terms of the comprehension posttest score and calibration accuracy, the metacognitive condition performed the worst.

Metacognitive Boundaries

The results of this study indicated that the mixed strategy condition had the most beneficial effects on its readers in terms of metacomprehension and calibration accuracy. In contrast, the metacognitive condition performed worst in comprehension posttest scores and calibration accuracy, even when compared to the control. This would suggest that providing the reader with metacognitive prompts only, in some cases, is more detrimental to the reader than providing no support at all. In this study, the poor performance of the metacognitive condition may be attributed to the complexity of the instructional content and the level of the participants' prior knowledge. Renkl, Berthold, Grosse, and Schwonke (2013) found that prompting learners with metacognitive self-explanation resulted in an increase in performance for advanced learners, but these same metacognitive prompts had a negative effect on learners who had little or no prior knowledge in the subject and viewed the content as complex.

Results also indicated that metacognitive prompting reduces the cognitive load associated with the reading task, as indicated by both the cognitive load measurement survey and the repeated measure of mental effort. The low levels of reported cognitive load and invested mental effort coupled with poor learning performance and calibration accuracy could represent a mistaken comfortability that the reader in the metacognitive condition experienced. While previous studies have shown positive learning effects result from metacognitive intervention (Bannert et al., 2009; Kauffman, 2004; Kramarski & Gutman, 2006; Lin & Lehman, 1999; Sitzmann & Ely, 2010; Veenman et al., 1994), the findings from this study indicated otherwise.

Limitations

There were some limitations identified with this study. Specifically, the length of the instructional text and the "text interestingness" (Lin et al., 2001) may have played roles in the findings. Participants were permitted a time limit of two hours to complete the study, though completion times varied widely among the participants. Longer participation times and repeated disruption of reading to record levels of exerted mental effort could have led to learner fatigue and a possible impact on posttest performance. Further, research has shown that comprehension predictions may be related to the level of interest of the participant (Lin, Zabrucky, & Moore, 1997). Prior to this study, the researcher sampled a separate population of undergraduates in order to determine a preference for instructional content, and "basics of photography" was selected. However, if the participants of this study failed to view the stimulus materials as interesting or meaningful, a threat to internal and external validity still may have existed (Morrison & Ross, in press). The poor reliability of the comprehension posttest also could have threatened validity.

Since a convenience sampling was used for this study, there may have been a threat to external validity or generalizability to all learners. This sampling may have threatened the population validity since all participants were college undergraduates enrolled in similar English courses at the same university.

Future research should address these limitations by reducing the treatment time with shorter stimulus materials and by providing a number of texts with varying themes in order to combat participant fatigue and disinterest in the study. Giving the learner instructional control has shown an increase in learner achievement (Hannafin & Sullivan, 1996; Nist, Simpson, Olejnik, & Mealey, 1991) and text interestingness has a direct relationship with improvement in recall and comprehension because of its motivational orientation (Lin et al., 2001).

Implications

Students who are academically successful tend to be well calibrated and higher self-regulated learners (Bol et al., 2012; Stone, 2000). Conversely, a failure to monitor comprehension accurately could lead to "miscalibration" (Kruger & Dunning, 1999) or an "illusion of knowing" (Glenberg et al., 1982), which could then result in a loss of valuable study time or a false sense of preparedness for achievement tests. The findings of this study demonstrate the added value of embedding a combination of cognitive and metacognitive strategies in digital text. Participants in the mixed strategy treatment outperformed all other groups in terms of posttest achievement and metacomprehension and calibration accuracy, but this treatment also reported high levels of cognitive load.

Providing the reader with cognitive and metacognitive strategies is not intended to simply raise the learner's self-awareness of his or her performance; rather, this type of support is meant to foster the development of a self-regulated learner (Fiorella et al., 2012). Lee et al. (2010) describes a conceptual framework for embedding both cognitive and metacognitive prompts in instructional text (see Figure 2). Summarization prompts (generative learning strategy prompts) boost generative activity, which is essential to learning new information. Providing the learner with metacognitive feedback (in this study, self-questioning metacognitive prompts) shapes the learner's self-regulation.

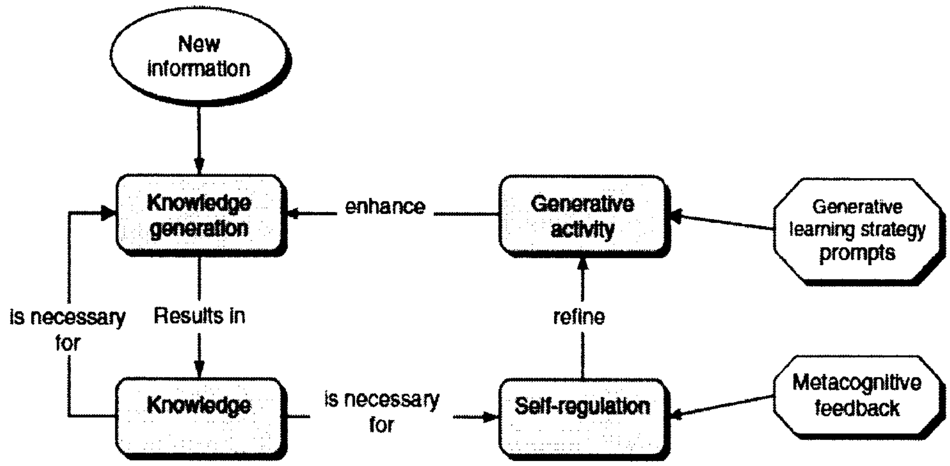

Figure 2. Generative learning conceptual framework (Lee et al., 2010).

As suggested by the results, providing metacognitive support alone might not be sufficient for the reader. Metacognitive inflation may occur when the learner is asked to gauge his or her understanding of the material without actually having to validate this by engaging in a generative activity such as summarization. This finding directly contradicts some of the existing metacognitive strategy research. However, it should be recognized that previous research focuses on learning performance and achievement, whereas the concentration of this study is on metacomprehension and calibration accuracy. This distinction is an important one to acknowledge.

Future studies should explore this area of research in greater detail. Also, the types of test-items should be examined in more depth, since the findings from this study along with prior studies reveal an effect on higher-order questions only. It may be possible that this embedded strategy approach may not be beneficial for instruction with lower-level questioning. Additional studies might also investigate the issue of cognitive load associated with this type of instructional treatment. This study relied on selfreporting of cognitive load and the amount of mental effort exerted, which has known issues with reliability. Further research is needed using more reliable measures of cognitive load in order to determine the frequency at which prompting becomes too taxing on the learner and begins to detract from the intended benefits of the mixed strategy approach.

Conclusions

The way that readers consume information, whether for leisure or academic purposes, is changing. The tools of a digital revolution can be met with resistance or they can be embraced and operationalized. This study argues for the latter. In academia, college undergraduates have deficiencies in judgment accuracy (Dunlosky & Lipko, 2007), predictive calibration (Lin & Zabrucky, 1998; Zabrucky, Agler, & Moore, 2009), and predictions of performance when reading digital-based text (Ackerman & Goldsmith, 2011). Because of these reasons, it is vital to consider embedding cognitive and metacognitive support directly into digital text.

The significant findings of this study contribute to the existing body of reading research in the areas of generative learning, metacognition, and cognitive load theory. Much of the previous research on embedded cognitive and metacognitive strategy use has explored this area by measuring the effects of either cognitive or metacognitive strategies; very few studies have investigated mixed strategy use, as this study did. Further, the majority of prior research in this area has focused on learning effects in terms of posttest achievement, whereas this study emphasized the improvement of learner metacomprehension and calibration accuracy. Although test performance is important, Pintrich (2002) argued that self-knowledge is essential to academic success, and in fact, a lack of metacognitive awareness is a constraint on learning. Last, this study investigated the effects of embedded prompting on cognitive load, which is often an important but overlooked variable in the existing body of research. The results of this research found that a combination of embedded cognitive and metacognitive strategies in digital text marginally improves learner achievement and greatly improves metacomprehension and calibration accuracy.

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APPENDIX A

METACOGNITIVE PROMPT QUESTIONS

Self-Monitoring Questions

1. Am I distracted during learning the material?
2. Am I focusing my mental effort on the material?
3. Do I have any thoughts unrelated to the material that interfere with my ability to focus on the text?
4. Are the summaries I am generating helping me to learn the material? *(applicable only to the subgroup experiencing Cognitive – Metacognitive prompting sequence)*
5. Do I understand all of the main points?

Self-Evaluation Questions

1. Do I know more about the material than when the module began?
2. Do I know enough about the material to answer at least 80% of the questions correctly on the comprehension posttest?
3. Do I understand all of the key points and concepts of the material?
4. Metacomprehension Judgment: How well do you think you understand the text?
5. Calibration Judgment: How well do you think you will perform on the comprehension test?
6. Some key concepts from the previous pages include *x*, *y*, and *z*. Are you confident in your understanding of these?

APPENDIX B

MARSI

Directions: Listed below are statements about what people do when they read *academic or school-related materials* such as textbooks or library books.

Five numbers follow each statement (1, 2, 3, 4, 5), and each number means the following:

1 means "I **never or almost never** do this."
2 means "I do this **only occasionally**."
3 means "I **sometimes** do this" (about **50%** of the time).
4 means "I **usually** do this."
5 means "I **always or almost always** do this."

After reading each statement, **select the number** (1, 2, 3, 4, or 5) that applies to you using the scale provided. Please note that there are no right or wrong answers to the statements in this inventory.

I have a purpose in mind when I read.

I take notes while reading to help me understand what I read.

I think about what I know to help me understand what I read.

I preview the text to see what it's about before reading it.

When text becomes difficult, I read aloud to help me understand what I read.

I summarize what I read to reflect on important information in the text.

I think about whether the content of the text fits my reading purpose.

I read slowly but carefully to be sure I understand what I'm reading.

I discuss what I read with others to check my understanding.

I skim the text first by noting characteristics like length and organization.

I try to get back on track when I lose concentration.

I underline or circle information in the text to help me remember it.

I adjust my reading speed according to what I'm reading.

I decide what to read closely and what to ignore.

I use reference materials such as dictionaries to help me understand what I read.

When text becomes difficult, I pay closer attention to what I'm reading.

I use tables, figures, and pictures in text to increase my understanding.

I stop from time to time and think about what I'm reading.

I use context clues to help me better understand what I'm reading.

I paraphrase (restate ideas in my own words) to better understand what I read.

I try to picture or visualize information to help remember what I read.

I use typographical aids like boldface and italics to identify key information.

I critically analyze and evaluate the information presented in the text.

I go back and forth in the text to find relationships among ideas in it.

I check my understanding when I come across conflicting information.

I try to guess what the material is about when I read.

When text becomes difficult, I reread to increase my understanding.

I ask myself questions I like to have answered in the text.

I check to see if my guesses about the text are right or wrong.

I try to guess the meaning of unknown words or phrases.

APPENDIX C

PHOTOGRAPHY PRETEST

Directions: For each question, select a response from the drop down list.

1. SLR and Non-SLR refer to ________.
2. The amount of light that the camera film receives is:
3. DOF stands for what?
4. If the focal length of a camera lens is 110mm, and the aperture is 10mm, the f-stop is:
5. An increase in exposure means an increase in the aperture size.
6. The aperture size along with the _______ shutter speed both affect exposure time.
7. The _________attracts the viewer's eye to a particular object or feature.
8. The two types of contrast in photographic composition are
9. A good rule of thumb for photographic composition is:
10. Select the photo that was taken using the lower *f*-number:


APPENDIX D

ATTITUDE SURVEY

Directions: Select your response in the drop down box using the following scale:

1 = Strongly Agree
2 = Agree
3 = Neutral
4 = Disagree
5 = Strongly Disagree

1. The instructional materials were clear and easy to understand.
2. The instructional materials were at an appropriate level of difficulty.
3. The instructional materials facilitated learning.
4. My overall understanding of the content was enhanced.
5. Overall, the instructional module effectively facilitated learning.
6. I will be able to confidently perform the comprehension test.
7. I felt comfortable with the way the material was presented in the module.
8. It was easy to retain my attention on learning the material in the module.
9. I was not distracted during the module.
10. I would prefer this method of instruction in future modules.
11. I would prefer digital text to print text in a future course. (Explain).

APPENDIX E

COGNITIVE LOAD QUESTIONNAIRE

Mental Effort (Repeated Measure):

How hard did you have to work in your attempt to understand the contents of the learning environment?
(0 = Low, 100 = High)

Mental Demand:

How mentally demanding was the task?
(0 = Low, 100 = High)

Temporal Demand:

How hurried or rushed was the pace of the task?
(0 = Low, 100 = High)

Performance:

How successful were you in accomplishing what you were asked to do?
(0 = Low, 100 = High)

Effort:

How hard did you have to work to accomplish your level of performance?
(0 = Low, 100 = High)

Frustration:

How insecure, discouraged, irritated, stressed, and annoyed were you?
(0 = Low, 100 = High)

APPENDIX F

COMPREHENSION POSTTEST BLUEPRINT

	Behavior			
Learning Objective	**Recall**	**Comprehension**	**Application**	**Total # of Questions**
1. Learner will evaluate the quality of photos.		1	2	3
2. Learner will determine the camera settings for a specific situation.			3	3
3. Learner will identify the basic processes of how a camera works.	4	4		8
4. Learner will recall a photographic technique.	1			1
Totals	**5**	**5**	**5**	**15**

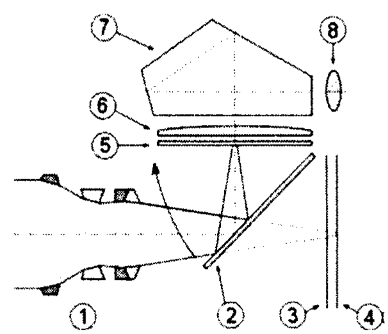
APPENDIX G

COMPREHENSION POSTTEST

Directions: Select the answer from the drop down box. Do not return to the text for review.

1. This type of camera is more automatic, and sometimes referred to as a *point and shoot*:
    a. Single Lens Reflex (SLR)
    b. Non-SLR
2. The sequence that light travels through a camera is:
    a. Lens – Aperture – Shutter – Sensor
    b. Sensor – Shutter – Lens – Aperture
    c. Aperture – Lens – Shutter – Sensor
    d. Shutter – Sensor – Lens – Aperture
3. The rule of thirds divides the photo into _____ equal sectors.
    a. 3
    b. 5
    c. 9
    d. 12

Use the figure on the right to answer questions 4 & 5

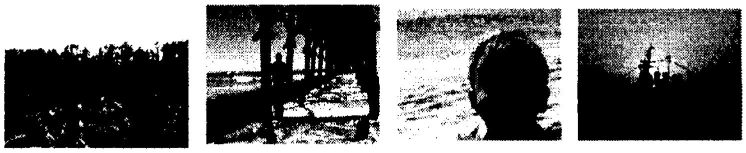


4. To increase or decrease the amount of exposure of a photo, which number on the illustration can be manipulated?

5. Which number represents the focal plane shutter?

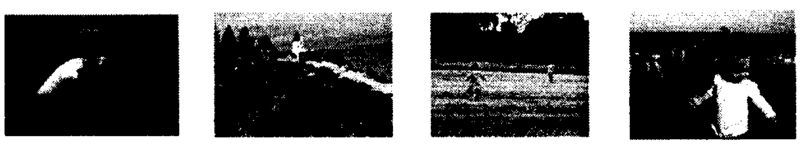
6. Increasing the *f*-stop, or *f*-number, ______ the aperture size by half.
    a. Increases
    b. Decreases
7. A small *f*-stop = ______.
    a. Large aperture
    b. Small aperture

8. Select the photo that was taken using a small *f*-stop:



9. Which edited version of this photo most appropriately conveys its meaning?

10. Select the photo that illustrates a shallow DOF:



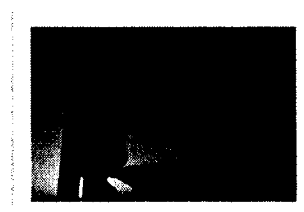
11. Select the description that most accurately evaluates this photo:

a. There are three different focal points in this photo, with a sizeable depth of field, and low tonal contrast.
b. There is one distinct focal point, there is no clear depth of field, and the tonal contrast is high.
c. This photo violates the rule of thirds, yet it has a good amount of tonal contrast, a shallow depth of field, and establishes a clear focal point.

12. Select the description that most accurately evaluates this photo:

   a. Although this photo does adhere to the rule of thirds, it does not use the tonal contrasts effectively to accentuate the subject and his guitar.
   b. The photo makes good use of tonal contrast, it follows the rule of thirds, and establishes a focal point effectively.
   c. While this photo uses tonal contrast effectively, the subject is off-center, and causes an imbalance in symmetry in the photo.

13. Which one of these combinations will achieve a silhouette photo such as this?
   a. High *f*-number, small aperture
   b. Small f-number, large aperture



14. You are sitting on the beach when you look out over the ocean and notice a humpback whale surfacing in the distance. You want to capture this moment. Quick! Which of the following settings would be best to capture the action of the whale?
   a. Shutter Speed: 1/1000, *f*/16
   b. Shutter spped: 1/10, *f*/4
   c. Shutter speed 1/1, *f*/1

15. You would like to achieve this photo below. Which of these settings would work?
    a. Shutter speed: 1/4, f/1.4
    b. Shutter speed: 1/1000, f/8

You have completed the study.

Please click the "Submit Form" button in the upper right hand corner.

APPENDIX H

MEAN MARSI MEASURES BY INDIVIDUAL QUESTION

MARSI Question #	Mixed	Metacognitive	Cognitive	Control
	M	*M*	*M*	*M*
1	3.85	3.75	3.35	3.45
3	3.25	3.65	3.00	3.40
4	3.65	3.75	3.25	3.15
7	2.80	3.40	2.65	3.05
10	3.20	2.70	3.60	3.00
14	3.65	3.60	2.95	3.35
17	3.70	3.60	3.60	3.25
19	3.70	3.75	3.50	3.15
22	3.35	3.30	3.95	2.85
23	3.05	3.10	2.80	2.80
25	3.45	3.45	3.35	3.25
26	3.45	3.05	3.15	3.30
29	3.00	2.65	2.65	2.75
GLOB Subscale	3.39	3.37	3.22	3.13
8	3.50	3.95	3.45	3.25
11	4.35	4.10	3.75	4.10
13	4.20	4.00	4.05	3.95
16	3.90	4.05	3.70	4.00
18	3.35	3.60	2.85	2.70
21	4.05	4.30	3.55	3.50
27	4.35	4.25	4.05	3.80
30	3.45	2.95	3.55	3.45
PROB Subscale	3.89	3.90	3.62	3.59
2	3.10	3.05	2.75	2.30
5	3.65	3.90	3.20	2.60
6	2.70	2.90	2.30	2.35
9	2.20	2.30	2.15	1.85
12	3.60	3.25	3.20	2.10
15	2.30	1.75	1.90	2.20
20	3.45	3.80	3.05	2.45
24	3.15	2.75	2.50	2.65
28	3.10	2.60	2.15	2.60
SUP Subscale	3.03	2.92	2.58	2.34
Total	3.46	3.37	3.13	3.02

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EDUCATIONAL BACKGROUND

Old Dominion University, *Ph.D. Instructional Design & Technology,* December 2013
University of North Carolina Wilmington, *Master of Arts in Teaching,* December 2006
The Ohio State University, *Bachelor of Arts in English,* December 2004

PROFESSIONAL EXPERIENCE

Brunswick Community College, Supply, North Carolina
Lead Developmental English Instructor: January 2007 – Present
Coastal Carolina University, Conway, South Carolina
Teaching Associate: August 2011 – Present
Ashford University, Online
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PUBLICATIONS

Reid, A. (2013). eReading: Supporting metacognition in a digital world. Conference proceedings of Society for Applied Learning Technologies (SALT) Washington Interactive Technologies Conference.

Reid, A., & Prudchenko, Y. (2013). Online behavior of the social media student. In D'Agustino, Steven (Ed.), *Immersive Environments, Augmented Realities and Virtual Worlds: Assessing Future Trends in Education* (pp. 161-176). Fordham University, New York: IGI Global.

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CONFERENCE PRESENTATIONS

Reid, A. (2013, October). eReading: Supporting metacognition in a digital world. University of North Carolina Wilmington Global Learning Technology Conference, Wilmington, NC.

Reid, A. (2013, August). eReading: Supporting metacognition in a digital world. Society for Applied Learning Technologies (SALT) Washington Interactive Technologies Conference, Reston, VA.

Reid, A. (2012, August). Twitter and the social media student. University of North Carolina Wilmington Global Learning Technology Conference, Wilmington, NC.

Reid, A. (2012, October). Twitter in the classroom: Engaging the social media student. North Carolina Community College Systems Conference, Raleigh, NC.