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THE EFFECTS OF A LEARNING STRATEGIES INTERVENTION IN A POST-SECONDARY STEM CLASS

A Thesis in

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by

Joseph Tise

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The thesis of Joseph Tise was reviewed and approved* by the following:

Rayne Sperling  
Associate Dean, Undergraduate & Graduate Studies  
Professor of Education (Educational Psychology)  
Thesis Advisor

Peggy Van Meter  
Director of Undergraduate and Graduate Studies  
Associate Professor of Education (Educational Psychology)

Pui-Wa Lei  
Professor in Charge, Educational Psychology  
Professor of Education (Educational Psychology)

*Signatures are on file in the Graduate School
ABSTRACT

Despite the demonstrated benefits of self-regulated learning, (SRL), many students do not spontaneously engage in SRL. This has led practitioners, policy makers, and researchers to call for increased focus on teaching students to self-regulate; one approach is to teach cognitive learning strategies. Much of the SRL intervention literature shows promising results. For example, students show gains in reported strategy use, metacognitive awareness, and academic performance. The current study tests the implementation of a contextualized cognitive learning strategies intervention in a college-level biology course. The overarching goal of the study was to examine the effectiveness of an intervention aimed at teaching students to use two cognitive learning strategies in the biology domain: creating analogies and elaborative interrogation. These strategies were taught using Wittrock’s (1994) generative learning model of science comprehension. Participants in the intervention group included 79 volunteers and control group participants included 61 volunteers from the same course. It was hypothesized that the intervention would positively impact treatment participants’ metacognitive awareness, SRL strategy use, and academic performance (measured by the Jr. MAI version B, SRSI-SR, and exam performance, respectively). Further research questions addressed whether pre-survey differences in self-efficacy, strategy use, and metacognitive awareness existed in students who elected to attend the intervention compared to the control group. Results indicated that treatment and control participants were no different regarding their pre-survey metacognitive awareness, self-efficacy, or strategy use. The intervention appeared to increase students’ reported SRL strategy use, but demonstrated little benefit for metacognitive awareness and academic performance. A discussion of these results, limitations of the study, future research recommendations, and conclusions are discussed in detail.
# TABLE OF CONTENTS

LIST OF FIGURES ........................................................................................................................................................................ vi

LIST OF TABLES ................................................................................................................................................................................ vii

ACKNOWLEDGEMENTS .......................................................................................................................................................................... viii

Chapter 1 Introduction ......................................................................................................................................................................... 1

Chapter 2 Review of Literature ......................................................................................................................................................... 3

Review of the SRL Intervention Literature .................................................................................................................................... 3
  The relationships among SRL, metacognition, and cognitive learning strategies ........................................................................ 4
  Metacognition ...................................................................................................................................................................................... 5
  Cognitive strategies in SRL interventions .................................................................................................................................. 7
  Academic achievement ....................................................................................................................................................................... 8
  Factors that impact intervention effectiveness .......................................................................................................................... 9

Generative Learning Strategies .......................................................................................................................................................... 11
  Components of the generative learning model .......................................................................................................................... 11
  Types of generative strategies ....................................................................................................................................................... 12
  Present Study .................................................................................................................................................................................... 13

Chapter 3 Methods ............................................................................................................................................................................... 16

Research Questions .............................................................................................................................................................................. 16
  Participants and Design ................................................................................................................................................................... 16
  Measures ......................................................................................................................................................................................... 16
    The Jr. Metacognitive Awareness Inventory—Version B. ........................................................................................................... 22
    The Self-Regulation Strategies Inventory – Self-Report ........................................................................................................... 23
    The Motivated Strategies for Learning Questionnaire—self-efficacy subscale .................................................................. 23
    Academic Performance ................................................................................................................................................................. 24

Intervention Materials ......................................................................................................................................................................... 26
  Worksheet 1 ..................................................................................................................................................................................... 27
  Worksheet 2 ..................................................................................................................................................................................... 27
  Worksheet 3 ..................................................................................................................................................................................... 27

Procedures ......................................................................................................................................................................................... 27
  Intervention implementation ............................................................................................................................................................ 28
  Data Analysis .................................................................................................................................................................................. 34

Chapter 4 Results ................................................................................................................................................................................ 37

Research Question 1: Differences in Metacognitive Awareness, Self-efficacy, and Strategy Use by Condition ......................... 37
Research Question 2: Effect of Strategy Instruction on Metacognitive Awareness ................................................................. 39
Research Question 3: Effect of Strategy Instruction on SRL Strategy Use .................................................................................. 42
Research Question 4: Effect of Strategy Instruction on Academic Performance ........................................................................ 43
Chapter 5 Discussion and Conclusions ........................................................................48

Intervention Participants are Similar to Control Participants ..................................48
Findings Supporting Intervention Effectiveness .......................................................49
Findings Not Supporting Intervention Effectiveness ................................................50
Limitations and Conclusions .................................................................................52

References .............................................................................................................55

Appendix A  Intervention Worksheets ......................................................................65
  Worksheet 1 ..........................................................................................................65
  Worksheet 2 ..........................................................................................................68
  Worksheet 3 ..........................................................................................................71

Appendix B  Types of Peer Teaching ......................................................................72

Appendix C  Pre- and Post-Survey ........................................................................73
LIST OF FIGURES

Figure 3-1: Outlier analysis for self-report final course grades. .................................................. 26

Figure 3-2: General timeline of the intervention. ................................................................. 29

Figure 4-1: Estimated marginal means for pre/post Jr. MAI scores. Min possible mean =
18, Max possible mean = 90. .............................................................................................. 41

Figure 4-2: Estimated marginal means for SRSI-SR pre/post survey scores. Min possible
mean = 28, Max possible mean = 140. ............................................................................... 43

Figure 4-3: Population pyramid comparing distributions of self-reported course grade
between control and treatment conditions. .............................................................................. 44

Figure 4-4: Population pyramid comparing distributions of self-reported course grade
between control and treatment conditions. .............................................................................. 45

Figure 4-5: Distribution of the differences between pre- and post-survey achievement
measures (control group). ........................................................................................................ 45

Figure 4-6: Distribution of the differences between pre- and post-survey achievement
measures (treatment group). .................................................................................................... 46
LIST OF TABLES

Table 2-1: General definitions of SRL, metacognition, and learning strategy. ....................... 5
Table 2-2: Definitions of terms used by De Backer et al. (2012) to describe regulation of cognition. ............................................................................................................ 6
Table 3-1: Research questions and corresponding measures. ................................................ 16
Table 3-2: Demographic information for participants. ............................................................ 19
Table 3-3: Majors. ................................................................................................................. 20
Table 3-4: Other demographics. .......................................................................................... 21
Table 3-5: Framework for the Strategy Instruction Intervention. ....................................... 33
Table 3-6: Participant selection process. .............................................................................. 35
Table 4-1: Descriptive statistics for variables included in RQ1-4. ........................................ 37
Table 4-2: Assumptions for Independent T-tests for RQ1. .................................................. 38
Table 4-3: Independent t-test results for RQ1. ..................................................................... 39
Table 4-4: Assumptions for Mixed-design ANOVAs. ........................................................... 40
Table 4-5: Comparison of means from pre- to post- by condition for metacognitive awareness (RQ2) and SRL strategy use (RQ3). ......................................................... 42
Table 4-6: Median differences pertaining to RQ4. ............................................................... 47
Table Appendix B: Definitions of Peer Teaching. ............................................................... 72
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Chapter 1

Introduction

Often, we think about education as learning content such as math facts, the scientific method, or reading comprehension strategies. However, the best learners not only learn facts and content, but also plan, monitor, and evaluate their own learning. Indeed, accurate monitoring, as well as knowledge and use of learning strategies are characteristics that distinguish novices from experts (Gagne, Yekovich, & Yekovich, 1993; Kardash, 2000) and low from high achieving students, respectively (Pintrich & De Groot, 1990; Weinstein, Husman, & Dierking, 2000). Teachers, parents, and advisors cannot always tell learners what to learn or how to learn it. Thus, it is imperative that students begin to take control of their learning by becoming behaviorally, motivationally, and metacognitively active participants in their own learning process. That is, they ought to become self-regulated learners (Zimmerman, 1986).

The overarching goal of this study was to examine the effectiveness of an intervention aimed at teaching students to use two cognitive learning strategies within an SRL framework in the biology domain: creating analogies and elaborative interrogation. Self-regulated learning is conceptualized in many ways (Panadero, 2017; Puustinen & Pulkkinen, 2001), but the most common models include four general assumptions about learning and regulation: (a) Learners are active and constructive participants in their learning process, (b) Learners have the ability to monitor, control, and regulate aspects of their behavior, cognition, motivation, and parts of their environment, (c) Self-regulated learners are goal-oriented, and goals are used as standards against which progress is judged, and (d) Self-regulated learners’ activities mediate the relationship between personal or contextual characteristics and achievement/performance (Pintrich, 2000).
There are a variety of sources from which students learn to self-regulate. These include, but are not limited to, explicit instruction, trial and error, and observational learning.

Self-regulated learning entails being cognitively and metacognitively adaptive in schoolwork, and immediate and long-term achievement is dependent upon this adaptability (Dent & Koenka, 2016; Patrick, Ryan, & Kaplan, 2007). Higher-achieving students tend to use self-regulation strategies more frequently and more effectively than lower-achieving peers (Dent & Koenka, 2016; Zimmerman, 1986, 2002). Additionally, self-regulated learners set goals for learning, which in turn maintains their focus on goal-directed activities (Schunk & Greene, 2018). Self-regulated learning has also been shown to be closely associated with academic delay of gratification and calibration of performance (Chen & Bembenutty, 2018).

Despite the myriad of benefits gleaned from being an effective self-regulated learner, research finds that students typically do not have the necessary self-regulatory skills sought by employers, colleges, and trade schools alike (DiDonato, 2013; Winne & Jamieson-Noel, 2003). Further, recent research has also shown that students do not usually regulate their learning spontaneously (i.e., without being explicitly prompted; Lazonder & Rouet, 2008; Raes, Schellens, De Wever, & Benoit, 2016). This research, taken together, has resulted in many calling for instruction that promotes students’ self-regulated learning skills (DiDonato, 2013; EU Council, 2002; National Council of Teachers of Mathematics, 2000). The current study addressed these issues by implementing a contextualized cognitive learning strategies intervention in a college-level biology course. Utilizing a quasi-experimental, pre/post-survey design, it was hypothesized that students who attended the out-of-class intervention would report higher SRL strategy use, metacognitive awareness, and would achieve a higher final course grade than the control group.
Chapter 2

Review of Literature

In this study, the effectiveness of a learning-strategies intervention within the context of biology and delivered via course learning assistants (LAs) was investigated. This chapter reviews the relevant literature about learning strategies and interventions, with mention of the potential LAs have to deliver such interventions. An overview of the SRL intervention literature is presented. This is followed by a discussion of identified gaps in the literature, and a rationale for the proposed next-step study.

Review of the SRL Intervention Literature

Broadly, SRL interventions vary on many aspects such as duration, intensity, and who leads them (de Boer, Donker, & van der Werf, 2014). Interventions can be as brief as one session (e.g., Tajika, Nakatsu, Neumann, & Maruno, 2007) or as extensive as an entire school year (e.g., Cantrell, Almasi, Carter, Rintamaa, & Madden, 2010). Another common difference found among interventions is who implements them. In de Boer and colleagues' (2014) meta-analysis of 94 learning strategies interventions, 57 were administered by teachers, 21 by researchers, and 16 by computer. These proportions should not be taken as representative of all SRL interventions, however, because of the strict inclusion criteria set by the researchers (e.g., studies had to be contextualized within core subjects such as reading or math, no pre-test differences existed between control and treatment groups, groups within studies needed at least 10 people). Further, some interventions may focus on only one subprocess of SRL (e.g., goal setting; Buzza & Dol, 2015) while others may take a more comprehensive approach and elect to focus on more than one
subprocess. For example Cleary, Platten, and Nelson (2008) tested the effectiveness of the Self-Regulation Empowerment Program (SREP) with eight urban high school students. The intervention lasted eight weeks, and specific modules of the intervention targeted specific phases of Zimmerman’s model of SRL. Changes in participants’ SRL strategy use and motivational beliefs were measured as outcomes, in addition to academic achievement.

Despite variations, SRL interventions tend to be effective. Specifically, strategy instruction interventions are typically moderately to highly successful, and this is true regardless of the strategy used or the number of strategies taught (Schraw & Gutierrez, 2015). Usually, effectiveness of SRL interventions are measured in terms of academic achievement gain or strategy use differences from pre- to post-test. For example, Ragosta (2010) reported in his meta-analysis that the mean effect size for cognitive strategy interventions was 0.67. He also found that metacognitive strategy interventions were effective, with a mean effect size of 0.29. Finally, Ragosta reported that overall effect sizes, regardless of the content of the intervention (e.g., cognitive strategy, metacognitive strategy instruction), were small to moderate for academic achievement (0.27; SE = 0.06), self-efficacy (0.37; SE = 0.11), and strategy use (0.28; SE = 0.07).

The relationships among SRL, metacognition, and cognitive learning strategies.

Since SRL and metacognition are commonly conflated (Dinsmore, Alexander, & Loughlin, 2008), their definitions, relationships, and distinctions will now be discussed in relation to cognitive learning strategies. Although many models of SRL exist (Panadero, 2017; Puustinen & Pulkkinen, 2001), common among most is the incorporation of metacognition as a necessary component of SRL (Dinsmore et al., 2008). Table 2-1 offers general definitions of the three constructs at hand.
Table 2-1: General definitions of SRL, metacognition, and learning strategy.

<table>
<thead>
<tr>
<th>Construct</th>
<th>General Definition</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRL</td>
<td>Students are self-regulated to the extent that they are behaviorally, motivationally, and metacognitively active participants in their own learning processes.</td>
<td>(Zimmerman, 1986)</td>
</tr>
<tr>
<td>Metacognition</td>
<td>“metacognition is cognition about the information input to or output by cognition, as well as information about the operations that work on information.”</td>
<td>(Winne, 2018, p. 38)</td>
</tr>
<tr>
<td>Cognitive learning strategy</td>
<td>Goal-directed, intentionally-invoked, and effortful behaviors and thoughts that a learner engages in during learning and that are intended to influence the learner’s encoding process.</td>
<td>(Weinstein &amp; Mayer, 1986; Weinstein &amp; Meyer, 1991)</td>
</tr>
</tbody>
</table>

As illustrated through the definition of SRL above, SRL is conceptualized as superordinate to metacognition; metacognition is used in the more general self-regulated learning process. SRL may include (among other things such as environmental management behaviors) use of cognitive learning strategies as well, cognitive learning strategy use can be monitored, evaluated, and controlled through metacognition.

**Metacognition.**

Metacognition refers to thinking about one’s own cognition and cognitive processes. While the focus of cognition is typically a specific task or concept, the focus of metacognition is cognition itself. Metacognition is generally described as having two overarching components: knowledge of cognition and regulation of cognition (Schraw, 1998).

Knowledge of cognition is comprised of declarative, procedural, and conditional metacognitive knowledge. Declarative metacognitive knowledge concerns what students know about themselves as learners and what influences their learning (e.g., I study best in the morning).
Procedural metacognitive knowledge concerns students’ knowledge of how to do something (e.g., I know how to effectively paraphrase). Conditional metacognitive knowledge concerns students’ knowledge of when to do something or when to use a particular strategy (e.g., I know to draw diagrams when learning geometry).

Regulation of cognition involves students’ abilities to plan, monitor, and evaluate their thinking (Schraw, 1998). Students allocate appropriate resources and choose strategies to use while planning. They engage in on-line awareness of comprehension when they monitor (e.g., a student may ask themselves “Do I know what the author means in this paragraph” as they read). Finally, students evaluate their cognition with regard to efficiency and the end products of learning (e.g., “Did I do this the best way?”). De Backer, Van Keer, and Valcke (2012) provide additional descriptions of these subcomponents of regulation of cognition, which are outlined in Table 2-2, below.

Metacognition plays an important role in effectively using learning strategies. Students must not only be aware of what a given learning strategy is, but also how and when to use it (Schraw, 1998). Further, we know that metacognitive regulation is trainable and adult learners can develop it (De Backer, Van Keer, Moerkerke, & Valcke, 2016; De Backer et al., 2012; Kuhn, 2000; B. L. Schwartz & Perfect, 2002). With this in mind, it has been recommended that learning strategy instruction teach students when, why, and how to use strategies (Donker, de Boer, Kostons, Dignath van Ewijk, & van der Werf, 2014).

Table 2-2: Definitions of terms used by De Backer et al. (2012) to describe regulation of cognition.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacognitive planning</td>
<td>Thinking how, when, and why to anticipate during learning, resulting in the selection of appropriate strategies, the allocation of resources, and the development of an action plan to attain learning goals.</td>
</tr>
</tbody>
</table>
Metacognitive monitoring involves the on-line quality control of one’s strategy use, comprehension, and progress.

Metacognitive evaluation involves checking correctness, completeness and/or effectiveness of proposed solutions, and/or making judgements and reflections toward one’s personal efficiency, the perceived task difficulty, and/or one’s self-efficacy.

**Cognitive strategies in SRL interventions.**

Interventions intended to promote self-regulated learning often focus on strategy use, which is one component of the SRL process. Strategies can be defined in several ways, but for the purpose of this study, the following definition by Zimmerman (1989) is adopted: “actions and processes directed at acquiring information or skill that involve agency, purpose, and instrumentality perceptions by the learners” (p. 329). There are also several categories of strategies, including motivational, metacognitive, and cognitive strategies. Since the current study utilized cognitive strategies, only this type is discussed further.

The term “cognitive strategy” appears to have been used first by Gagne (1977), and Weinstein (1978) (Rosenshine, Meister, & Chapman, 1996). As stated above, in Table 2-1, cognitive strategies can be defined as goal-directed, intentionally-invoked, and effortful behaviors and thoughts that a learner engages in during learning and that are intended to influence the learner's encoding process (Weinstein & Mayer, 1986; Weinstein & Meyer, 1991). Cognitive strategies can be subcategorized into three main types: rehearsal, elaboration, and organization (Donker, de Boer, Kostons, Dignath van Ewijk, & van der Werf, 2014; Pintrich, Smith, Garcia, & McKeachie, 1991). Elaboration strategies such as those utilized in this study are effective because they help students store information in long-term memory by connecting prior-knowledge to to-be-learned information (Donker et al., 2014; Wittrock, 1985). Some example methods of elaboration include creating practice test questions, drawing a diagram, paraphrasing, and asking “why” questions to uncover deeper meaning. Through elaboration, learners play an
active, initiating role in their own learning (Collins, Brown, & Newman, 1990; King, 1994; Palincsar & Brown, 1984; Rosenshine et al., 1996; Singer, 1978), which is necessary for self-regulation.

In order to be effective, strategy instruction should be embedded within all content areas, be modeled by teachers or other self-regulated students, and be discussed explicitly in the classroom (Schraw & Gutierrez, 2015). It has been shown that teaching learning strategies is most effective when done in a domain-specific way, as opposed to outside of any particular domain (Garner, 1990). Further, it is recommended that strategies be practiced until fully automatized (Schraw & Gutierrez, 2015). Simply telling students that strategies exist and instructing their use is not sufficient. Since strategies are consciously implemented and are controllable, students need to have sufficient knowledge about the strategies, and sufficient motivation to apply them (Donker et al., 2014; Wittrock, 1990). Thus, strategy instruction interventions should focus on teaching students when to use the strategy in addition to how (Pressley, 2000), and should also emphasize the utility value of the strategy. Therefore, the most effective strategy instruction programs emphasize metacognitive conditional knowledge (i.e., knowing when to use the strategy; Schraw & Gutierrez, 2015).

**Academic achievement.**

A large body of research supports that cognitive strategies impact learning. For example, in college student populations, as studied here, Tuckman and Kennedy (2011) conducted a quasi-experimental study in which they taught 351 first-year college students four learning strategies in a dedicated learning-strategies course. Compared to their peers who did not take the course, these students achieved higher GPAs and were statistically significantly more likely to graduate. Further, in Nordell’s (2009) study of college biology students (n = 68), students who attended a
learning strategies workshop series performed significantly better on a subsequent exam than those who did not. Nordell’s workshop series focused on note-taking skills, lecture preparation, reading strategies, and self-assessment strategies.

**Factors that impact intervention effectiveness.**

Several factors are known to impact the effectiveness of SRL interventions. These factors include how learning outcomes are measured, and length and intensity of the intervention. Whether outcomes are measured via standardized or unstandardized methods sometimes drastically affects findings. For instance, the mean effect size (Hedge’s $g$) for academic achievement as measured by standardized methods is 0.17. However, the effect size is .49 when measured with unstandardized (i.e. researcher or teacher-developed) methods (Ragosta, 2010). Chiu, (1998) found similar discrepancy regarding standardized versus unstandardized achievement measures. In his meta-analysis, non-standardized tests of academic achievement yielded an average $d$ of 0.61, while standardized measures yielded an average effect size of 0.24.

In addition to how outcomes are measured, other aspects such as length and intensity can influence an intervention’s effectiveness. Findings on these two fronts appear muddled. Ragosta (2010), for example, found that studies of longer duration appeared to produce larger effect sizes for the outcome of SRL strategy use, but Hattie, Biggs, and Purdie (1996) found that short programs lasting one or two days appeared more effective (mean Hedge’s $g = .58$) than interventions lasting three or four days (mean Hedge’s $g = .28$), but interventions lasting four to thirty days proved the most effective (mean Hedge’s $g = .76$). Schraw and Gutierrez, (2015) also reported that interventions spanning six weeks to several months are the most effective. But, de Boer and colleaugues, (2014) found that 10-week interventions were slightly (0.1 standard
deviations) more effective than 20-week interventions. As can be seen, it is not clear exactly how
the duration of SRL interventions impacts effectiveness.

Intervention intensity, defined by number of sessions per week (de Boer et al., 2014), has
also been investigated as an aspect that may impact intervention effectiveness. While some
evidence suggests that less intensive interventions are more effective than more intensive
programs, other evidence suggests the opposite. For example, Bangert-Drowns, Hurley, and
Wilkinson (2004) found in their meta-analysis of writing-to-learn interventions that longer
assignments (i.e. more “intense”) were associated with smaller effect sizes. But de Boer and
others (2014) found that interventions with more intense sessions were, on average, .14 higher in
effect size (Hedge’s g) than those with less intensive sessions. This mixed finding could
potentially be attributed to the way in which intensity was operationalized. Operationalizing
intensity as number of minutes rather than number of sessions spent on the intervention could
further elucidate this relationship.

A further consideration is how long after the intervention the post-test occurred. Effect
sizes vary depending on outcome measure, and when the post-test occurs. For example, an
intervention’s effect size may be artificially inflated if students are asked to self-report their
metacognitive monitoring directly after completing a metacognitive intervention. It is conceivable
that the effect size might be lower one week, two weeks, or even months after the intervention’s
end because students are not being formally trained anymore and thus may stop using
metacognitive strategies they were taught. In sum, SRL intervention research is messy, and the
conclusions that can be drawn are sometimes unclear.

Beyond logistical considerations, student characteristics may also play a role in
intervention effectiveness. Students’ perceived self-efficacy, or their perceived ability to be
successful in completing a given task, may also affect intervention effectiveness. Students’
performance is presumed to be affected by self-efficacy, such that higher self-efficacy results in
more intense and more persistent effort (Bandura, 1977). Thus, it may be that students with higher self-efficacy perform more highly during the intervention and subsequent post-testing than those who do not. Alternatively, students with lower self-efficacy may decide not to attend the intervention at all—therefore creating a selection bias due to motivational variables. If an intervention group is more highly motivated (self-efficacious), any differences in outcomes could not be safely only attributed to the intervention.

**Generative Learning Strategies**

**Components of the generative learning model.**

Wittrock's (1994) model of generative learning is a functional model and as such, attempts to explain cognitive and neural processes learners use to comprehend information. Several main cognitive processes make up the framework for the model: knowledge, experience, and conceptions; motivation and attribution; generation; and metacognition. Knowledge, experience, and conceptions must be considered while teaching. Learners must not only be presented with correct information, but their erroneous knowledge, misunderstood experiences, and misconceptions must also be convincingly debunked for accurate knowledge construction to occur. Next, learners must take responsibility for their learning, and “[believe] that one can succeed at understanding complex everyday experiences through actively generating and testing concepts” to consciously generate meaning (Wittrock, 1994, p. 33). Learners also should engage in active generation of knowledge; not merely passive receipt of information. This generation could come in the form of creating paragraph headings, paraphrasing, drawing connections, or making tables/diagrams. The intent is to encourage learners to actively engage with the to-be-
learned information. Finally, learners must be metacognitively aware of their own learning process by monitoring and evaluating their generation of meaning.

More specifically, two types of meaningful relations are at the heart of these cognitive and neural processes: generation of relationships between the learner’s knowledge or pre-conceptions and new, to-be-learned information; generation of relationships between component parts of to-be-learned information (Wittrock, 1994). An example of the first type of relationship could be connecting the learner’s prior knowledge of the Earth’s geography and composition to that of a new terrestrial planet (e.g., Mars). An example of the second type of relationship might be that a learner makes connections between an animal’s circulatory system and their respiratory system (both of which are new to the learner).

Types of generative strategies.

Learners can generate these two types of meaning in several ways using generative strategies. A strategy can be considered generative if the student “creates” something. Some example strategies include creating analogies, concept maps, or creating practice test questions.

Elaborative strategies can be considered a special type of generative strategy. That is, elaborative strategies also help the learner generate meaning, but they do so specifically by employing the student’s prior knowledge. Thus, for a strategy to be generative and elaborative, it must result in the student “creating” something (e.g., a set of questions to be answered, an analogy) and it also must connect the to-be-learned information to prior knowledge. Therefore, elaborative strategies are particularly well-suited for creating connections between to-be-learned information and prior knowledge. As an example, creating analogies is a good way to generate meaningful relationships between prior knowledge and to-be-learned information. This is because learners can use a relationship they already know to learn a new relationship (e.g., learners can
understand the social structure of lions by relying on their knowledge of wolves’ social structures. The learners know that a wolf is part of a pack and can use this to learn that a lion is part of a pride).

It is important to note that not all generative strategies can also be considered elaborative. Generative-but-not-elaborative strategies can help facilitate connections among component parts of to-be-learned information. For example, learners could create concept maps to understand the relationships among parts of an ecosystem without necessarily relying on prior knowledge activation. A concept map of an ecosystem would help the learners understand the relationships among trees, herbivores, carnivores, the water cycle, and even run-off. Theoretically, this concept map could prove helpful even to students who have no related prior knowledge because it is still generative. Generative learning strategies should be chosen with intention and in accordance with the desired type of generated relationships.

**Present Study**

This study tested the effectiveness of an SRL strategy intervention focused on generative learning and delivered to biology undergraduate students by their learning assistants (LAs). Generative learning can be defined as “the process of constructing meaning through generating relationships and associations between stimuli and existing knowledge, beliefs, and experiences” (Hanke, 2012, p. 1356). In much the same way that learners are required to be active participants in their own learning (Zimmerman, 1998) to be considered self-regulated, learners must also be active and engaged during generative learning (Grabowski, 1996; Hanke, 2012).

Specifically, this study will address the following research questions and hypotheses:
1. Prior to the intervention, are there differences in self-reported metacognitive awareness, self-efficacy, or SRL strategy use between those students who elect to attend the intervention (treatment group) and those who do not (control group)?
   a. Hypothesis 1: Students who attend the intervention will report higher self-efficacy than those who do not attend. No accompanying hypotheses are posited regarding metacognitive awareness or SRL strategy use.

2. Does strategy instruction delivered via LAs increase students’ self-reported metacognitive awareness?
   a. Hypothesis 2: Strategy instruction will increase students’ self-reported metacognitive awareness.

3. Does strategy instruction delivered via LAs increase students’ self-reported SRL strategy use?
   a. Hypothesis 3: Strategy instruction will increase students’ self-reported SRL strategy use.

4. Does strategy instruction delivered via LAs increase students’ academic performance?
   a. Hypothesis 4: Strategy instruction will increase students’ academic performance.

Regarding research question (RQ) 1, no hypotheses related to students’ metacognitive awareness or SRL strategy use are being posited. This is because it is conceivable that students may attend the intervention if they are more metacognitively aware (and realize they need help), but also that they may not attend if they are more metacognitively aware (because they have a better handle on their own learning and do not need the help). Further, studies have shown that students have difficulty spontaneously engaging in self-regulatory strategy use (Lazonder & Rouet, 2008; Raes et al., 2016). However, it does logically follow that if students who attend the strategy sessions are hypothesized to be more self-efficacious, then they should also engage in
more SRL strategy use because these two constructs have been shown to be positively associated (Cleary, Dembitzer, & Kettler, 2015). Thus, no clear hypothesis emerges for this part of RQ1.
Chapter 3

Methods

Research Questions

The research questions addressed in this study are reproduced below in Table 3-1 along with their accompanying measures.

Table 3-1: Research questions and corresponding measures.

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to the intervention, are there differences in self-reported metacognitive awareness, self-efficacy, or SRL strategy use between those students who elect to attend the intervention (treatment group) and those who do not (control group)?</td>
<td>Jr. MAI Version B (Sperling, Howard, Miller, &amp; Murphy, 2002); MSLQ Self-efficacy subscale (Pintrich, Smith, Garcia, &amp; McKeachie, 1991); SRSI-SR (Cleary, 2006)</td>
</tr>
<tr>
<td>Does strategy instruction delivered via LAs increase students’ metacognitive awareness?</td>
<td>Jr. MAI Version B</td>
</tr>
<tr>
<td>Does strategy instruction delivered via LAs increase students’ SRL strategy use?</td>
<td>SRSI-SR</td>
</tr>
<tr>
<td>Does strategy instruction delivered via LAs increase students’ academic performance?</td>
<td>Self-reported course and exam grades, actual course and exam grades</td>
</tr>
</tbody>
</table>

Participants and Design

The overall sample size for the study was 140. Treatment participants included 79 volunteer undergraduate students enrolled in a sophomore-level biology course. Control participants included 61 volunteer undergraduate students in the same biology course who did not attend the intervention. Detailed demographic information pertaining to the treatment and control groups is presented in Tables 3-2 through 3-4, below. These tables were constructed using data obtained on the pre-survey. Students self-
reported information pertaining to each demographic characteristic. Because this intervention was implemented in an authentic context (i.e., in a real undergraduate biology course), no random assignment was possible. Thus, students could choose to participate in the intervention or not.

The treatment group was comprised of students who completed all portions of the study: pre-survey, all intervention session, and post-survey. The control group was comprised of students who elected to complete the surveys portion of the study, but did not attend any intervention sessions. Their lack of attendance was not explicitly explored, but one likely reason is scheduling conflict. Despite this limitation, the two conditions were similar overall in terms of gender, class rank, and major distributions. Further, each condition (treatment vs. control) had approximately equal percentages of Hispanic/Latino (7.6% vs. 9.8%), White (73.4% vs. 78.7%), Black/African-American (15.2% vs. 4.9%), Asian (7.6% vs. 9.8%), American Indian/Alaska Native (2.5% vs. 3.3%), and Native Hawaiian or other Pacific Islander (1.3% vs. 0.00%) students. Table 3-3 presents information about the participants’ majors. The majors were grouped according to general disciplines represented in the data. Biology-related majors included Biology, Biochemistry, and Biomedical engineering, among others. Social sciences included majors such as Philosophy, Education, and Psychology. Environmental majors included those such as Wildlife and Fisheries and Environmental Resource Management. Other majors included Engineering (not related to biology), Chemistry, and Undecided.

Descriptive statistics regarding the students’ self-reported GPA, lecture attendance, number of outside-help opportunities utilized, and number of learning strategies learned in the past are also presented, in Table 3-4. Overall, treatment and control groups were similar regarding these variables. The control group reported missing a slightly higher number of class sessions, but also reported a slightly higher GPA, than the treatment group.

The current study followed a pretest/posttest quasi-experimental design including two groups (one treatment and one control). The treatment group included students who attended all of the strategy instruction intervention sessions. The control group included students in the biology course but who did
not attend any of the intervention sessions. Students completed the pre-survey during the week preceding the first intervention session. Then, they completed the post-survey within one week of the intervention’s end (after the third session).
Table 3-2: Demographic information for participants.

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Treatment</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Male</td>
<td>18</td>
<td>22.80</td>
</tr>
<tr>
<td>Female</td>
<td>61</td>
<td>77.20</td>
</tr>
<tr>
<td>Taking at least one other Bio course</td>
<td>14</td>
<td>17.72</td>
</tr>
<tr>
<td>*Receiving outside help for the course</td>
<td>33</td>
<td>41.80</td>
</tr>
<tr>
<td>First year</td>
<td>37</td>
<td>46.80</td>
</tr>
<tr>
<td>Second year</td>
<td>32</td>
<td>40.50</td>
</tr>
<tr>
<td>Third year</td>
<td>5</td>
<td>6.30</td>
</tr>
<tr>
<td>Fourth year</td>
<td>5</td>
<td>6.30</td>
</tr>
<tr>
<td>Fifth year +</td>
<td>0</td>
<td>0.00</td>
</tr>
</tbody>
</table>

*Note: Outside help may include regular office hour visits, on/off campus tutoring, formal study groups, or informal help from friends.
Table 3-3: Majors.

<table>
<thead>
<tr>
<th>Major</th>
<th>Treatment</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology-related</td>
<td>42 53.16%</td>
<td>42 68.85%</td>
</tr>
<tr>
<td>Social sciences</td>
<td>4 5.06%</td>
<td>0 0%</td>
</tr>
<tr>
<td>Pre-med/Vet</td>
<td>18 22.78%</td>
<td>9 14.75%</td>
</tr>
<tr>
<td>Environmental</td>
<td>4 5.06%</td>
<td>7 11.48%</td>
</tr>
<tr>
<td>Other</td>
<td>12 15.19%</td>
<td>3 4.92%</td>
</tr>
</tbody>
</table>

Note: One student reported both Psychology and Biology as his major.
Table 3-4: Other demographics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Treatment</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>M (SD)</td>
</tr>
<tr>
<td>GPA</td>
<td>79</td>
<td>3.26 (.47)</td>
</tr>
<tr>
<td># of lectures missed</td>
<td>79</td>
<td>2.29 (1.10)</td>
</tr>
<tr>
<td># of outside help opp.*</td>
<td>33</td>
<td>2.21 (1.02)</td>
</tr>
<tr>
<td># of strategies learned previously*</td>
<td>62</td>
<td>2.23 (1.25)</td>
</tr>
</tbody>
</table>

Note: # of lectures missed is a coding system, were 1 = Every lecture attended, 2 = missed 1 or 2, 3 = missed 3 or 4, 4 = missed 5 or 6, and 5 = missed 7 or more lectures.
# of outside help opp. = the number of opportunities the student utilized for help in the course (e.g., office hours, tutoring).
*Not all students reported receiving outside help for the course or having learned strategies previously.
Measures

Several different constructs were measured via identical pre- and post- surveys. These surveys included the Jr. Metacognitive Awareness Inventory—Version B (Jr. MAI—Version B), the Self-Regulation Strategy Inventory—Self-Report (SRSI-SR), the self-efficacy subscale of the Motivated Strategies for Learning Questionnaire (MSLQ), student test grades, overall GPA, and other demographic information. Each measure is discussed in turn, next and can be found in Appendix C.

The Jr. Metacognitive Awareness Inventory—Version B.

Metacognitive awareness was measured by the Jr. MAI Version B, an 18-item self-report questionnaire that assesses students’ knowledge and regulation of cognition on a five-point Likert scale (Never – Always; Sperling et al., 2002). Although the Jr. MAI has not been used with post-secondary students before, the factor structure of the Jr. MAI has been validated using students in 12th grade (Kim, Zyromski, Mariani, Lee, & Carey, 2017). Kim and colleagues did not report reliability information, but their findings with secondary students lends credence for the use of the measure in this study, since the median age of participants is 19.

Knowledge of cognition includes three sub-processes: (a) declarative knowledge (b) procedural knowledge, and (c) conditional knowledge (Schraw & Dennison, 1994; Sperling et al., 2002). Regulation of cognition includes component skills such as planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation (Artzt & Armour-Thomas, 1992; Baker, 1989; Schraw & Dennison, 1994; Sperling et al., 2002). The Jr. MAI has been used several ways. For example, as a predictor of science achievement (Sperling, Richmond, Ramsay, & Klapp, 2012) and in a study investigating the impact of metacognitive skills on learners’ memory in hypermedia environments (Schwartz, Andersen, Hong, Howard, & McGee, 2004). The internal consistency of the measure is good.
(α = .82; Sperling et al., 2002) and was good in the current study for both the pre-survey (α = .83) and the post-survey (α = .90). Two sample items from the measure are “I can make myself learn when I need to.” and “I decide what I need to get done before I start a task.”

**The Self-Regulation Strategies Inventory – Self-Report.**

Self-regulated learning strategy use was measured by the SRSI-SR (Cleary, 2006), a 28-item self-report instrument that measures students’ use of SRL strategies. It is comprised of three subscales addressing adaptive strategies such as managing the learning environment and help-seeking as well as maladaptive strategies such as avoiding studying. The three subscales are managing behavior and the environment, seeking information, and maladaptive regulatory behaviors (this subscale was reverse coded). Students responded to statements addressing their SRL strategy use using a Likert-scale type ranging from 1 (never) to 5 (always). The SRSI-SR has been used with undergraduate and graduate students as an outcome in SRL intervention research (Cleary et al., 2008; Delen, Liew, & Willson, 2014) and as a criterion variable in predictive studies (Follmer & Sperling, 2016). Cronbach’s alpha for the measure is high (α = .92; Cleary et al., 2015) and is also high for the current study in both the pre-survey (α = .87) and post-survey (α = .91). Two sample items follow: “I make sure no one disturbs me when I study” and “I try to forget about the topics that I have trouble learning.”

**The Motivated Strategies for Learning Questionnaire—self-efficacy subscale.**

Self-efficacy was measured by the MSLQ’s self-efficacy subscale (Pintrich et al., 1991). The MSLQ subscales are scored using a Likert-type scale from 1 (not at all true of me) to 7 (very true of me). The MSLQ was designed such that individual subscales could be used alone (Pintrich et al., 1991) and has been used to study relationships between grit, future time perspective, self-efficacy, and other motivational constructs (e.g., Muenks, Yang, & Wigfield, 2018). The self-efficacy subscale has also been
adapted for use to examine the gender gap in post-secondary STEM discipline pursuit (Jungert, Hubbard, Dedic, & Rosenfield, 2018). The internal consistency in the subscale for the current study was high for both pre-survey ($\alpha = .96$) and post-survey ($\alpha = .97$). Two example items are “I believe I will receive an excellent grade in this class.” and “I'm certain I can master the skills being taught in this class.”

**Academic Performance.**

The students’ self-reported grade on their most recent exam (Exam 4) was used as a measure of their prior knowledge. Students reported what letter grade (e.g., A, C+) they had earned on Exam 4, which was taken 13 days before the intervention began. Exam 4, like the previous three exams, was multiple-choice and was administered at the campus e-testing center.

Post-survey self-reported course letter grades (e.g., A, C+) were used as the measure of academic performance. The post-survey was taken a few days before the final exam, and thus students’ self-reported course grades were quite representative of their actual final grades.

**Validity of self-report grades.** Concerns about the validity of using students’ self-reported grades abound. While students may misrepresent their actual grades either intentionally or unintentionally, a subset of the overall sample allowed their actual course grades (i.e., not self-reported) to be accessed and used for research. To address the validity concerns, the subsample’s self-reported Exam 4 grades and course grades were correlated with their actual (not self-reported) Exam 4 and course grades.

Ten participants were flagged as outliers with respect to the discrepancy between their self-reported grade in the course and their actual grade in the course. These outliers were identified by comparing boxplots of total course points (which are used to calculate the final course grade) at each level of self-reported course grades (e.g., A-, B, C+; see Figure 3-1). Upon inspection of their individual grades, it became apparent that nine of these students had not completed the lab portion of the course,
which was worth 25% of the course grade. That is, nine of the 10 students received a grade of zero for their labs. For the analysis of validity of self-report grades, these nine were deleted due to the obvious, significant impact the lab grades had on their final course grades. The other student (Participant 153 in Figure 3-1) was retained because a lab grade was present for this student and they were not identified as extremely influential by SPSS (like the other nine outliers were). For all analyses pertaining to the research questions, these ten outliers were retained. That is, they were only excluded while ascertaining the validity of students’ self-reported grades.

Generally, students’ self-reported grades in the course were valid. The validity of these self-report grades was assessed by correlating treatment group students’ self-reported course grade from the post-survey (taken one week before the end of the course) and the actual course final grade. Before deleting the nine treatment participants that were identified as outliers, the correlation (Spearman’s rho) between self-report and actual course grades was $\rho = .55; p < .01$. After deleting the nine outliers, the magnitude of the correlation increased greatly ($\rho = .85; p < .01$). Exam 4 self-report grades were highly correlated with actual Exam 4 grades ($\rho = .97, p < .01$). Further, actual Exam 4 grades and actual course grades were moderately correlated ($\rho = .70, p < .01$) as were self-reported Exam 4 grades and self-reported course grades ($\rho = .80, p < .01$), lending validity evidence as support for using self-reported Exam 4 and course grades over actual grades (which were not available for the entire sample).

The nine deleted outlier participants were similar to the other participants in terms of their average exam grade (Outliers’ mean = 90.85%, SD = 4.92%; Others’ mean = 83.53%, SD = 8.66%) and self-reported university GPA (Outliers’ mean = 3.62, SD = .34; Others’ mean = 3.25, SD = .46).
Figure 3-1: Outlier analysis for self-report final course grades.

**Intervention Materials**

The first two worksheets included approximately one page of text that explained the concept of generative learning, the two types of connections made in generative learning, and a description of the strategy they would be learning. Each worksheet explained that the strategies they would be learning should be used to help generate one or both of the two types of meaningful relationships, and in so doing, their understanding of the material would benefit. Students were also told when each strategy should be used (analogies when comparing two things and elaborative interrogation when presented with a fact). In describing each strategy, the students were told what the necessary components of the strategies were. They were also presented with examples and practice with the strategy. Please refer to Appendix A for all worksheets.
Worksheet 1

Worksheet 1 included statements that prompted the students to use elaborative interrogation. Students were asked to answer “why” questions generated by the course instructor. These “why” questions intended to help students generate meaning from what they had learned in the course, as well as what they had read in their textbook. Additionally, Worksheet 1 prompted students to generate their own elaborative interrogation question, and then answer it.

Worksheet 2

Worksheet 2 included several questions asking students to create analogies using the content they learned during their class sessions and while reading their textbook. These analogies focused on drawing relations between components of the new material, and between the new material and their own prior knowledge, experiences, or the real world.

Worksheet 3

The third worksheet included a review of Generative Learning and the two strategies that were presented. Students were encouraged to use one or both of the strategies in a new content area of biology. Students were allowed to use any strategy, even if it was not covered in the intervention.

Procedures

Student participation in the study was first solicited in class and then again via two follow-up emails, which included the pre-survey link. The pre-survey was released 5 days before the start of the intervention and closed a few hours before Session 1. Immediately after the intervention concluded (after Session 3) the post-survey was released and remained open for one week. The intervention sessions were
led by the course learning assistants (LAs). Because many roles similar to LAs exist in higher education and because the terminology can become confusing, a table describing several types of “peer-teachers” is included in Appendix B. In postsecondary education, LAs are often either peers or near-peers of the students they assist (i.e. undergraduates assist fellow undergraduates). The specific procedures that were undertaken during each intervention session are described next, in detail.

**Intervention implementation.**

The intervention was delivered in three, 20-30-minute sessions and was run by the course LAs. Each session was held outside of normal class time. Table 3-5 below outlines the general framework of the intervention. The intervention was administered by one LA while 2-4 other LAs helped with logistics (e.g., collecting papers, answering questions). All three sessions were completed during two weeks between the course’s third and fourth tests. An overview of the timeline for the intervention is presented in Figure 3-2.
Figure 3-2: General timeline of the intervention.
**LA Training.** Approximately five days before Session 1, the LAs met with the researcher to discuss how each session would be implemented. A “lead LA” was selected at this time to read aloud the worksheets and generally run the sessions. A brief lesson about generative learning was given to the LAs. In it, the generative learning model was described, the two types of connections that students can generate to make meaning were described, and how the two learning strategies they would teach related to the model was explained. Then, the two learning strategies were explained more in depth so that the LAs would have a good understanding of what the students would be learning. Finally, the LAs were told that the researcher would be present but not able to field any questions that students might have—the LAs were told to answer any questions the best that they could.

**Session 1.** The first session started with the author explaining, passing out, and collecting a grade-release form. This form requested access to and use of the students’ course grades. After about 10 minutes, all of the grade-release forms were collected and the session began. The lead LA began by reading the first page of Worksheet 1 (Elaborative Interrogation; see Appendix A) aloud to the students. This was done to ensure that students would at least hear the reasoning behind the strategy and the instructions for using it. It was possible that if the LA did not read this aloud, many of the students may have simply skipped the first page—which contained the necessary information about the strategy and generative learning—and gone straight to answering the practice questions. After reading the information about the strategy aloud, the lead LA instructed the students to read the worksheet themselves before answering the practice questions. Then, the support LAs passed out the worksheet and students began. Once most students were finished, the support LAs collected the worksheet. Then, students were allowed to leave. Some elected to stay behind and listen to the course instructor review the worksheet and present some possible answers to the questions.
To ensure treatment fidelity, the author observed the session and recorded notes about the environment. The lead LA read the worksheet word-for-word. The lead LA’s tone was not varied much, but students did appear to pay attention during the reading. Through further observations, most students appeared to have read the first page of the worksheet as instructed after it was distributed. Students took about 10 minutes to complete the worksheet. The room was silent for the extent of that time.

Session 2. The second session started with the lead LA reading the first page of Worksheet 2 (Analogies; see Appendix A) in the same way and for the same reasons as Worksheet 1. Again, after reading the information about the strategy aloud, the lead LA instructed the students to read the worksheet themselves before answering the practice questions. Then, the support LAs passed out the worksheet and students began. Once most students were finished, the support LAs collected the worksheet. The course instructor was not present for Session 2, so once all worksheets were collected, the session ended.

To ensure treatment fidelity, the author observed the session and recorded notes about the environment. The lead LA asked about the recent spring football scrimmage before getting started. Again, the lead LA’s tone was not varied much while reading. After receiving the worksheet, about half of the students appeared to read the first page as instructed. Again, students took about 10 minutes to complete the worksheet. The room was mostly silent for the extent of that time, though about five instances of student conversation were observed.
Session 3. The third session started with the author gathering attention and advertising the post-survey to the students, which took about five minutes. The lead LA then read Worksheet 3 (practice; see Appendix A) to the students in the same way and for the same reasons as Worksheets 1 and 2. After reading the worksheet aloud to the students, the lead LA again instructed the students to read the worksheet themselves. Students were instructed to “write down as many responses as [they could].” Once most students were finished, the support LAs collected the worksheet and the session ended (the course instructor was not present).

Again, to ensure treatment fidelity, the author observed the session and recorded notes about the environment. The lead LA’s tone was not varied much. About half of the students appeared to immediately start writing responses on the worksheet. Students were given about 10 minutes to write down responses.
<table>
<thead>
<tr>
<th>Session</th>
<th>Component of Model Covered</th>
<th>To be Covered in Worksheets</th>
<th>Materials</th>
</tr>
</thead>
</table>
| 1       | Generation; relations among components of the new concept(s) | a) How we can generate meaning: Building relationships b/w new concepts and our experiences, real-world, and prior knowledge  
          b) Conditional knowledge of strategy  
          c) Teach elaborative interrogation | Worksheet 1 (Elaborative Interrogation) |
| 2       | Attention; Generation; relations b/w new concepts and experiences, prior knowledge | a) How we can generate meaning: Building relationships among components of new concepts  
          b) Conditional knowledge of strategy  
          c) Teach analogies | Worksheet 2 (Analories) |
| 3       | Generation; Metacognition; transfer | a) Brief review of strategies taught  
          b) Transfer: can the students use one or both of the strategies completely on their own? | Worksheet 3 (ask students to use one on their own) |
Data Analysis

Data were analyzed using SPSS version 25. Various statistical procedures were performed in accordance with the research questions (see Results). Before running the procedures, all relevant assumptions were checked. The details of each statistical procedure are discussed further, below.

**Missing data.** Data were analyzed for completeness and only those participants with no missing data were retained for analyses. That is, students must have answered every question of every measure on the pre and post-surveys (excluding demographic questions), signed the grade-release form allowing access to their course grades, and attended all three intervention sessions to be retained for data analysis in the treatment group. Since students in the control group did not attend any intervention sessions, they were unable to be offered the grade-release form. Consequently, students must have simply answered every question of every measure on the pre- and post-surveys to be retained for analysis in the control group. The full class size was 420 students, 316 students completed the entire pre-survey (answered every question), while only eight did not complete the entire survey. Despite this impressive response rate on the pre-survey, the post-survey only had 181 responses with 157 complete responses; 17 of whom did not complete the pre-survey. Thus, out of 324 students who took part in at least one part of the study, 140 total students were retained for analyses. Table 3-6 outlines the above information.
Table 3-6: Participant selection process.

<table>
<thead>
<tr>
<th>Total study N</th>
<th>N deleted</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial N = 324</td>
<td>All responses to pre-survey</td>
<td></td>
</tr>
<tr>
<td>316</td>
<td>8</td>
<td>Incomplete responses on pre-survey</td>
</tr>
<tr>
<td>181</td>
<td>135</td>
<td>Did not take the post-survey</td>
</tr>
<tr>
<td>157</td>
<td>24</td>
<td>Incomplete responses to post-survey</td>
</tr>
<tr>
<td>Final N = 140</td>
<td>Complete responses on post survey, but did not complete pre-survey</td>
<td></td>
</tr>
<tr>
<td>Treatment group:</td>
<td>Had complete pre/post-survey data, signed grade release, and attended all sessions</td>
<td></td>
</tr>
<tr>
<td>N = 79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control group:</td>
<td>Had complete pre/post survey data, attended no intervention sessions</td>
<td></td>
</tr>
<tr>
<td>N = 61</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Some students (n=4) took the pre or post-survey twice, resulting in two sets of complete pre or post-survey data. In these cases, the data from the students’ first time were retained because these indicated the students’ initial responses. Further, in three of these four cases, the student spent more time taking the survey the first time compared to the second time. The assumption here is that the students’ first responses are likely more valid because they presumably spent more time reading and responding to the questions—and thus the time taken to complete the surveys was longer. One of these four students spent nearly the exact same amount of time on both iterations of the survey.

**Outliers.**

In addition to the analyses conducted assessing the validity of self-report grades (see section above), outlier analyses were also conducted pertaining to Research Question 1. Outliers were identified in both the treatment and control groups regarding self-efficacy. Since there was
no evidence that these observations were errors in data entry or measurement, analyses were run while both including and excluding the outliers. There were no differences in results between these two analyses, so the outlier observations were retained.
Chapter 4

Results

Descriptive statistics for all variables are presented in Table 4-1, below. Results pertaining to individual research questions are then discussed in detail.

Table 4-1: Descriptive statistics for variables included in RQ1-4.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Timepoint</th>
<th>Treatment</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>Median</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>Median</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>Pre</td>
<td>46.56 (7.74)</td>
<td>48.00</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Jr. MAI</td>
<td>Pre</td>
<td>68.84 (8.70)</td>
<td>70.00</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>72.39 (8.59)</td>
<td>72.00</td>
</tr>
<tr>
<td>SRSI-SR</td>
<td>Pre</td>
<td>107.70 (14.04)</td>
<td>106.00</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>111.97 (13.63)</td>
<td>112.00</td>
</tr>
<tr>
<td>Academic Performance</td>
<td>Pre</td>
<td>- 5 (B-) (F—A)</td>
<td>1—9 (F—A)</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>- 7.5 (Between B+ &amp; A-)</td>
<td>2—9 (D—A)</td>
</tr>
</tbody>
</table>

Research Question 1: Differences in Metacognitive Awareness, Self-efficacy, and Strategy Use by Condition

Research question (RQ) 1 was explored using two independent t-tests with condition (treatment/control) as the grouping variable and Jr.MAI scores and SRSI scores as the dependent
variables for each of the outcomes. Due to independent t-test assumptions violations, a Mann-Whitney U test was also conducted with condition (treatment/control) as the grouping variable and self-efficacy as the dependent variable. Assumptions checks for the three independent t-tests are presented below, in Table 4-2.

Table 4-2: Assumptions for Independent T-tests for RQ1.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>No significant outliers</th>
<th>Approximate normality</th>
<th>Equality of error variance</th>
</tr>
</thead>
</table>
| Metacognitive awareness  | Met                     | Control: K-S = .06, p = .20  
                           |                         | Treatment: K-S = .08, p = .20 |
|                          |                         | Levene’s F = .65, p = .42 |
| Self-efficacy            | Not met                 | Control: K-S = .14, p = .003  
                           |                         | Treatment: K-S = .14, p < .001 |
|                          |                         | Levene’s F = 4.24, p = .04 |
| SRL strategy use         | Met                     | Control: K-S = .06, p = .20  
                           |                         | Treatment: K-S = .05, p = .20 |
|                          |                         | Levene’s F = .31, p = .58   |

Note: K-S = Kolmogorov-Smirnov

The self-efficacy measure violated the assumptions for independent t-tests: absence of statistically significant outliers, approximate normality of the dependent variable for both groups of the independent variable, and homogeneity of variance. Thus, a Mann-Whitney U test was conducted as an alternative.

Results from the two independent t-tests that were conducted to address RQ1 are presented in Table 4-3. The first research question addressed if there were differences prior to the intervention in how participants in the treatment and control conditions scored on a measure of metacognitive awareness, self-efficacy, and self-reported SRL strategy use. It was hypothesized that students who attend the strategy instruction sessions will have higher self-efficacy at pre-
survey than students who do not, but there was no hypothesis related to metacognitive awareness or SRL strategy use. Independent-samples t-tests indicated no difference in average metacognitive awareness (Jr. MAI) scores or self-reported SRL strategy use between control and treatment participants (see Table 4.3). Further, the Mann-Whitney U test indicated no statistically significant differences in self-efficacy scores between control and treatment participants (Mann-Whitney U = 2229.00, p = .45, mean rank difference = -5.24).

Table 4.3: Independent t-test results for RQ1.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>t(138)</th>
<th>p-value</th>
<th>95% confidence interval</th>
<th>Mean difference (control – treatment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacognitive Awareness</td>
<td>-0.80</td>
<td>0.42</td>
<td>(-4.02, 1.70)</td>
<td>-1.16</td>
</tr>
<tr>
<td>Strategy Use</td>
<td>-1.95</td>
<td>.05</td>
<td>(-9.53, 0.07)</td>
<td>-4.73</td>
</tr>
</tbody>
</table>

**Research Question 2: Effect of Strategy Instruction on Metacognitive Awareness**

The second research question addressed whether or not strategy instruction (treatment) increased students’ reported metacognitive awareness. To address RQ2, a mixed-design ANOVA was utilized with time (pre/post) and condition (treatment/control) as the independent variables and Jr.MAI scores as the dependent variable. All assumptions for this analysis were met, see Table 4.4 for details.
Table 4-4: Assumptions for Mixed-design ANOVAs.

<table>
<thead>
<tr>
<th>Research Question</th>
<th>No significant outliers</th>
<th>Approximate Normality</th>
<th>Homogeneity of Variance</th>
<th>Homogeneity of Covariance</th>
<th>Sphericity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (Metacognition)</td>
<td>Pre-survey: Met</td>
<td>Pre-survey: K-S = .06, $p$ = .20</td>
<td>Pre-survey: Levene = .65, $p$ = .42</td>
<td>Box’s M = 5.20, $p$ = .16</td>
<td>N/A*</td>
</tr>
<tr>
<td></td>
<td>Post-survey: Met</td>
<td>Post-survey: K-S = .05, $p$ = .20</td>
<td>Post-survey: Levene = .10, $p$ = .76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 (SRL strategy use)</td>
<td>Pre-survey: Met</td>
<td>Pre-survey: K-S = .03, $p$ = .20</td>
<td>Pre-survey: Levene = .31, $p$ = .58</td>
<td>Box’s M = 6.44, $p$ = .10</td>
<td>N/A*</td>
</tr>
<tr>
<td></td>
<td>Post-survey: Met</td>
<td>Post-survey: K-S = .05, $p$ = .20</td>
<td>Post-survey: Levene = 3.77, $p$ = .05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Sphericity assumption was not applicable because there were only two groups for each factor in the Mixed-design ANOVA.
It was hypothesized that students’ reported metacognitive awareness would be positively impacted by the treatment. This hypothesis was not supported. Results from a mixed-design ANOVA indicated a statistically significant main effect for time ($F_{(1, 138)} = 23.05, p < .001, \eta_p^2 = .14$), no statistically significant main effect for condition ($F_{(1, 138)} = 1.55, p = .22, \eta_p^2 = .01$), and no statistically significant time x condition interaction ($F_{(1, 138)} = 0.66, p = .42, \eta_p^2 = .01$). That is, students in both the treatment and control conditions exhibited statistically significant increases in their metacognitive awareness scores, and these increases were of approximately the same magnitude. Figure 4-1 (below) illustrates these findings. Table 4-5 presents the difference in means between post- and pre-surveys associated with both conditions and metacognitive awareness and strategy use.

Figure 4-1: Estimated marginal means for pre/post Jr. MAI scores. Min possible mean = 18, Max possible mean = 90.
Table 4-5: Comparison of means from pre- to post- by condition for metacognitive awareness (RQ2) and SRL strategy use (RQ3).

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Control Pre-Survey</th>
<th>Control Post-Survey</th>
<th>Treatment Pre-Survey</th>
<th>Treatment Post-Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacognitive Awareness</td>
<td>67.67</td>
<td>70.20***</td>
<td>68.84</td>
<td>72.40***</td>
</tr>
<tr>
<td>SRL Strategy Use</td>
<td>102.97</td>
<td>104.07</td>
<td>107.70</td>
<td>111.97***</td>
</tr>
</tbody>
</table>

***Note: \( p < .001 \), indicating the difference from pre- to post is statistically significant.

Research Question 3: Effect of Strategy Instruction on SRL Strategy Use

The third research question addressed whether or not the strategy instruction (treatment) increased students’ reported SRL strategy use. To address RQ3, a mixed-design ANOVA was utilized with time (pre/post) and condition (treatment/control) as the independent variables and SRSI-SR scores as the dependent variable.

It was hypothesized that students in the treatment condition would report increased SRL strategy use from pre- to post-surveys. Results from a mixed-design ANOVA supported this hypothesis (see Table 4-5). A statistically significant main effect for time \( (F_{(1, 138)} = 11.55, \ p = .001, \ \eta^2_p = .08) \) and condition \( (F_{(1, 138)} = 6.93, \ p = .009, \ \eta^2_p = .05) \) was present, and a statistically significant time x condition interaction was also present \( (F_{(1, 138)} = 4.04, \ p = .046, \ \eta^2_p = .03) \). Figure 4-2 illustrates these results. To properly interpret main effects in the presence of a significant interaction effect, simple main effects were ascertained by post-hoc comparisons of estimated marginal means. The results from these analyses indicated that the treatment group reported statistically significantly higher SRL strategy use at post-survey compared to pre-survey (mean difference = 4.28, \( p < .001 \), 95% CI = 2.21, 6.34) while the control group did not (mean
difference = 1.10, \( p = .36 \), 95\% CI = -1.25, 3.45). Further, the treatment group reported statistically significantly higher SRL strategy use than the control group at post-survey (mean difference = 7.91, \( p = .003 \), 95\% CI = 2.73, 13.09), but not at pre-survey (mean difference = 4.73, \( p = .054 \), 95\% CI = -0.07, 9.53).

Figure 4-2: Estimated marginal means for SRSI-SR pre/post survey scores. Min possible mean = 28, Max possible mean = 140.

**Research Question 4: Effect of Strategy Instruction on Academic Performance**

The last research question addressed whether or not strategy instruction (treatment) impacted students’ academic performance. Because academic performance was measured with two ordinal-level variables (students’ self-reported letter grade on Exam 4 and self-reported final letter grade for the course), a mixed-design ANOVA was inappropriate. Therefore, two Mann-Whitney U and two Wilcoxon Signed Rank tests were utilized to answer the research question. Since each of these individual procedures (e.g., the first Mann-Whitney U test) does not account
for the other variable (e.g., differences between pre/post-surveys), it cannot properly account for the same amount of variance that a mixed-design ANOVA can. Thus, the following results should be interpreted accordingly, with caution.

The assumptions of both Mann-Whitney U tests were met. Distributions of the self-reported Exam 4 and self-reported course grade for control and treatment were similar, as assessed by visual inspection (see Figures 4-3 and 4-4). Therefore, Mann-Whitney U tests could compare differences in median grades between the two conditions.

![Independent-Samples Mann-Whitney U Test](image)

**Figure 4-3:** Population pyramid comparing distributions of self-reported course grade between control and treatment conditions.
Figure 4-4: Population pyramid comparing distributions of self-reported course grade between control and treatment conditions.

The assumptions of the Wilcoxon Signed Rank test were also met for both conditions. Distributions of the difference scores between pre-test and post-test achievement measures were symmetrical for both treatment and control conditions (see Figures 4-5 and 4-6).

Figure 4-5: Distribution of the differences between pre- and post-survey achievement measures (control group).
Results from the first Mann-Whitney U test indicated no statistically significant difference between control and treatment with regards to prior knowledge (Exam 4 grades; Mann-Whitney U = 2,360.50, $p = .836$). Results from the two Wilcoxon Signed Ranks tests indicated that both the control group ($Z = -6.09, p < .001$) and the treatment group ($Z = -6.81, p < .001$) saw statistically significant increases in academic performance from pre- to post-survey. That is, the median of all participants’ pre- to post-survey differences in academic performance was not zero. Finally, the second Mann-Whitney U test indicated no statistically significant difference between control and treatment groups with regards to final course grade (Mann-Whitney U = 2,189.50, $p = .342$). Table 4-6 details these results.

Figure 4-6: Distribution of the differences between pre- and post-survey achievement measures (treatment group).
Table 4-6: Median differences pertaining to RQ4.

<table>
<thead>
<tr>
<th></th>
<th>Median Difference (Treatment – Control)</th>
<th>Median Difference (Course Grade – Exam 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exam 4</td>
<td>0.00</td>
<td>-</td>
</tr>
<tr>
<td>Course Grade</td>
<td>0.00</td>
<td>-</td>
</tr>
<tr>
<td>Treatment</td>
<td>-</td>
<td>3.00***</td>
</tr>
<tr>
<td>Control</td>
<td>-</td>
<td>3.00***</td>
</tr>
</tbody>
</table>

***p < .001

Note: 1 = F, 2 = D, 3 = C, 4 = C+, 5 = B-, 6 = B, 7 = B+, 8 = A-, 9 = A
Chapter 5

Discussion and Conclusions

Intervention Participants are Similar to Control Participants

The first research question addressed whether or not students who elected to attend the strategy instruction intervention differed from those who did not in terms of their metacognitive awareness, self-efficacy, and SRL strategy use. It was hypothesized that students who elected to attend the intervention would have higher self-efficacy on average than those who did not attend. There were no accompanying hypotheses for the first and third research questions.

The results indicated that students who voluntarily participated in the intervention were no different than the control group participants in terms of reported metacognitive awareness, self-efficacy, or reported SRL strategy use. Perhaps metacognitive awareness has little impact on students’ decision to attend an SRL strategy intervention. Or, since the Jr. MAI was intended to be used with middle school students (Sperling et al., 2002), its utility with undergraduate students may be reduced. A third possibility is that of sampling bias. Perhaps the sample that was drawn from the biology course was simply too homogenous regarding metacognitive awareness.

Additionally, students who participated in any part of the study (i.e., control or treatment group) appeared not to differ in self-efficacy for performance in their biology course. While it was hypothesized that students with higher self-efficacy would choose to participate in the intervention, the relatively high pre-survey response rate (79% of the entire class) may indicate that all students in the class were sufficiently motivated by the prospect of late-semester extra credit, such that any potential differences in self-efficacy between the treatment and control groups were masked. Indeed, students may be very motivated by “surprise” extra-credit
opportunities toward the end of the semester, as their final course grade becomes more solidified. If this be the case, any changes in the intervention outcomes (e.g., reported SRL strategy use or academic achievement) can be more safely attributed to the intervention, and not simply differences in motivation.

Finally, the finding that treatment and control participants were similar regarding reported SRL strategy use prior to the intervention is also important to note when interpreting other results. When implementing a voluntary learning strategies intervention, it could be argued that students who already use learning strategies regularly may wish to attend because they understand the utility of using strategies. Conversely, it could be argued that students who use learning strategies regularly may decide not to attend a learning strategies intervention because they do not feel the need to add additional strategies to their repertoire. The results of this study appear to support an intermediate argument, since the two conditions were not significantly different in their reported strategy use. However, the strict inclusion criteria for this study resulted in only including 140 participants out of the 324 who began the study. Thus, the inclusion criteria may have masked any true differences in strategy use between the two conditions. Still, the apparent similarity at pre-survey between the two conditions is a strength for this study, as any post-survey differences may then be more confidently attributed to the intervention.

**Findings Supporting Intervention Effectiveness**

It was hypothesized that students in the treatment condition would exhibit increased SRL strategy use from pre- to post-surveys. Results from a mixed-design ANOVA supported this hypothesis with a medium effect size ($\eta_p^2 = .05$). The effect size is perhaps not surprising, given the intervention focused solely on two cognitive learning strategies, and the SRSI-SR addresses students’ use of 28 different learning strategies (not all of which are cognitive). When translated
to Cohen’s $d$, the effect size for condition is 0.46 and is close to the average effect size found by Ragosta (2010) for similar interventions. Ragosta’s meta-analysis reports that the average effect size for SRL strategy interventions using standardized SRL strategy measures is 0.32 (SE = 0.20). The presence of a simple main effect for condition at post-survey implicates the intervention as a possible cause for the significant difference in students’ reported strategy use by condition. That is, since students reported equal levels of SRL strategy use at pre-survey but the treatment group reported higher levels of SRL strategy use at post-survey, it can be inferred that the intervention positively impacted students’ self-reported SRL strategy use.

However, these results could be explained by way of social desirability. That is, students in the intervention may have realized that the researcher perhaps wanted to see gains in the SRSI-SR scores, and thus responded accordingly on the post-survey to please the researcher. The researcher attempted to mitigate this potential limitation by indicating to the participants on the pre- and post-surveys that no right or wrong answers existed and to simply be honest. Despite this potential limitation, cautious optimism is warranted from these findings; the intervention appears successful.

**Findings Not Supporting Intervention Effectiveness**

It was hypothesized that students’ metacognitive awareness would be positively impacted by the treatment due to the embedded support for metacognitive conditional knowledge in the intervention worksheets. Support for this hypothesis was not found. Although students’ reported metacognitive awareness was higher at post-survey than at pre-survey, there was no difference between conditions. Thus, it cannot be concluded that the treatment alone had any effect on metacognitive awareness. This is not necessarily surprising since the treatment focused on cognitive learning strategies—not metacognitive strategies. While these two types of strategies
may interact and positively relate to each other (Dinsmore & Zoellner, 2018), they do remain conceptually distinct. Since all participants (control and treatment) saw increases in their reported metacognitive awareness, it is possible that the act of completing the measure positively impacted their metacognitive awareness. That is, all students’ metacognitive awareness and behavior may have been positively impacted simply because the pre-survey reminded them of good metacognitive behaviors that they then began to implement. An additional possibility is that students become more metacognitively aware as the semester comes to an end. Students may become more concerned with their course grade (which will be finalized soon) as the semester closes. Thus, they may enact more metacognitive regulation strategies in an attempt to boost performance on the final opportunities to impact their course grade.

Support for the hypothesis that strategy instruction delivered via LAs will increase students’ academic performance was not found. There are several possible reasons why the hypothesis was not supported. One reason is that the intervention was simply implemented too late in the semester. Most of the available points for the course had already been “spoken for” by the time the intervention took place—only the final exam was left. Thus, the potential for students to increase their academic performance and have it show in their course grades was quite limited. A related possibility is that students may not have had enough time left to substantively make use of the strategies that were taught. The intervention concluded only one week prior to the Final Exam, thereby restricting the amount of time students had to use the strategies in the authentic class context. Finally, participants self-reported their academic performance on an ordinal scale which limited the statistical analyses available for use. The non-parametric analyses that were used as a substitute for a mixed-design ANOVA could have masked any true effects of the intervention.
**Limitations and Conclusions**

There were several limitations to this study. First, there was variance in the nature of how academic performance was measured—Exam 4 performance was used as a pre-measure and overall course grade as a post measure. Although these scores were significantly correlated, future research would benefit from more similarly structured measures. Second, as noted, the intervention was implemented quite late in the semester—concluding about one week prior to the Final Exam. By that time in the semester, students had already completed most of the course, and thus most course points that had potential to impact their overall course grade were already accounted for, likely affecting their motivation to attend the session and to apply the strategies. Future studies will embed the intervention earlier and revisit more often as is recommended by strategy instruction intervention research (e.g., Pressley, Gaskins, Solic, & Collins, 2006). Third, the study relies on self-report measures of strategy use which is likely strongly influenced by recent attendance in a strategy use intervention. Future studies should delay the time of self-report to examine if students’ reports decrease over time or sustain reported use. The larger concern is the well documented limitations of using self-report measures in SRL research (e.g., Winne, 2010). The accuracy and validity of self-report measures has been questioned for a long time; social-desirability bias can influence self-reports as can flaws in recall (Winne & Perry, 2000), and this study is not an exception to those possibilities. Future research should employ multiple methods to measure SRL constructs. Finally, only the treatment group participants had the opportunity to sign a grade-release form; the control group participants did not. Thus, only the treatment group participants’ actual course grades could be linked with their other data. Future research should obtain grade-release consent from all participants—not just the treatment group.

The results, interpretations, and limitations of this study help inform the SRL literature about the viability of cognitive strategy interventions that teach two strategies and utilize LAs as
intervention leaders. Taken together, students appear to make gains in their SRL strategy use after participating in direct SRL strategy instruction led by a course LA. Although the design of this study was such that the effect on academic performance could not be ascertained clearly, the self-reported increase in SRL strategy use is perhaps foreshadowing of later academic gains for the treatment group. Future investigation is warranted to examine if students’ use of generative strategies persists and transfers to other course contexts.

Future research should further investigate the potential effect that simply responding to metacognitive awareness self-report measures has on reported metacognitive awareness. Further, it is notable that students who elect to attend SRL strategy interventions do not tend to be more self-efficacious than those who do not. This finding has implications for practitioners and researchers alike, as it shows the potential effect that late-semester extra credit opportunities has on motivation to participate in studies—extra-credit may serve as an effective motivator for all students, not just highly self-efficacious students. Given that the current study showed increases in reported metacognitive awareness from pre- to post-survey regardless of condition, future research should investigate this finding further to see if it persists, and attempt to attribute a cause to it (e.g., timing in the semester, expectancy effects, or testing effects).

Succinctly, the conclusions that follow from this study are cloudy. Students who elect to attend interventions tend not to be any more metacognitively aware, self-efficacious, or report using more SRL learning strategies than those who do not, but several causes of these findings could be at play. SRL/generative learning strategy instruction delivered via course LAs appears to increase self-reported use of SRL strategies, but its effects on reported metacognitive awareness and academic performance appear null. More research is warranted to further uncover the relationships between these constructs. For example, does the quality of students’ strategy use differentially impact student outcomes such as metacognitive awareness, strategy use, or academic performance? Does the amount of outside help the student receives (e.g., private
tutoring, study group attendance) impact their decision to attend or not? And does students’ self-efficacy increase after being exposed to strategy instruction from their LAs or otherwise? These and other questions require the attention of future work. Hopefully, this study has helped lay a foundation for such work.
References


Donker, A. S., de Boer, H., Kostons, D., Dignath van Ewijk, C. C., & van der Werf, M. P. C. (2014). Effectiveness of learning strategy instruction on academic performance: A meta-


structure of the 18-item version of the junior metacognitive awareness inventory.


doi:10.1080/07481756.2017.1326751


doi:10.1016/j.chb.2007.01.025


doi:10.1037%2fmot0000076


Teacher, 31(8), 901–908.


Directions for Teaching and Learning, (45), 15–26.


Zimmerman, B. J. (1986). Becoming a self-regulated learner: Which are the key subprocesses?


Appendix A

Intervention Worksheets

Worksheet 1

Name: ___________________________  PSU ID (e.g., xyz123):

Elaborative Interrogation

Have you ever had the experience where you think you know something, and then on the test you realize you don’t really? This is very common for students in biology. One possible cause is that you learned the material on a shallow level instead of on a deep level. One example of the differences between these types of learning is the difference between being able to recite Newton’s third law of motion, and being able to use that law to solve a problem. Generative Learning will help you learn at a deep level so that you will be able to use and apply what you learn.

Your brain is a model builder. When it tries to comprehend something, it creates a model for how things should work. This model is informed by experiences, prior knowledge, new information, and your own world view. The concepts and connections between concepts that make up our models represent knowledge. They are what we know. Sometimes, however, these models can be incomplete or incorrect. In order to build accurate and complete knowledge models, we have to generate meaning from new information. Meaning is generated by creating two types of relationships:

1. Relationships between your own knowledge/experience and the to-be-learned information
2. Relationships among the parts of the to-be-learned information.

We can generate these two types of relationships in several ways, but one very effective and research-supported strategy includes elaborative interrogation (EI).

Elaborative interrogation is a well-supported strategy that students use to generate meaning. We can do this by making connections among parts of the new information, and by making connections between the new information and our prior knowledge. Simply put, EI involves asking yourself “why” questions. The strategy gets its name from the elaboration one engages in while generating answers to interrogations (questions) that assess your deep understanding (your brain’s models).

For example, students learning about the physics of light may ask themselves “Why are most plants green? What does that tell me about the type of light that most plants are least able to use?” In this case, the students could either generate their answers from their own prior knowledge, or seek out these answers, and discover that most plants are green because green light is reflected by most plants, indicating that the green frequency of light is not very useful to plants.

Elaborative interrogation is very useful when reading your textbook, however, the strategy can also be used while studying notes or attending lectures, too. Use EI when you read or hear a fact about something, are presented with a general “truth” regarding a relationship, or discover an unexpected result/outcome. If you ever catch yourself saying “huh, that’s weird” or “Ok, that must be a fact I should know,” then it is a good time to use EI. Practice answering some elaborative interrogation questions below, and then practice generating your own questions, and answering them.

1. We know that erythrocytes (red blood cells) carry oxygen from the lungs to the tissues. We also know that erythrocytes produce the energy for themselves anaerobically. Why?
2. While glucose is the starting point for glycolysis in respiration in both plants and animals, sucrose is the main form of sugar transported around the plant. Why?

3. Now you try. Start with some facts, concepts, processes, or procedures that you learned, generate a “why” question, and then answer it. Try to generate a question for which you do not already have an answer.

4. Why does your professor point out that plants also need to produce energy through aerobic cellular respiration when they use light energy to produce ATP in the chloroplasts?

5. Oxygen is essential in aerobic cellular respiration. Why is this true?
Worksheet 2

Name: 

PSU ID (e.g., xyz123):

Creating Analogies

Have you ever had the experience where you think you know something, and then on the test you realize you don’t really? This is very common for students in biology. One possible cause is that you learned the material on a shallow level instead of on a deep level. One example of the differences between these types of learning is the difference between being able to recite Newton’s third law of motion, and being able to use that law to solve a problem. Generative Learning will help you learn at a deep level so that you will be able to use and apply what you learn.

Your brain is a model builder. When it tries to comprehend something, it creates a model for how things should work. This model is informed by experiences, prior knowledge, new information, and your own world view. The concepts and connections between concepts that make up our models represent knowledge. They are what we know. Sometimes, however, these models can be incomplete or incorrect. In order to build accurate and complete knowledge models, we have to generate meaning from new information. Meaning is generated by creating two types of relationships:

1. Relationships between your own knowledge/experience and the to-be-learned information

and

2. Relationships among the parts of the to-be-learned information.
We can generate these two types of relationships in several ways, but one very effective and research-supported strategy includes creating analogies.

Analogies are a type of comparison between two things. Generally, analogies demonstrate similarities between two seemingly unlike things. In order to create an effective analogy, the “deep structure” of the relationship between the two things being compared must be identified. “Surface details” are not important, and will likely differ. Thus,

- The deep structure of a relationship is what makes two seemingly unrelated things, related.
- Surface features are what make two seemingly unrelated things seem unrelated.

An example follows.

_A wolf is to pack in the same way that a lion is to ____[pride]._

Here, the deep structure of the analogy is that the first terms (wolf and lion) are both members of a large group (pack and pride). This is the relationship that makes this analogy meaningful. A wolf _is a member of_ a pack, in the same way that a lion _is a member of_ a pride.

The surface features, which do not give meaning to the analogy are things like:

- A wolf is a K-9, and a lion is a feline
- Lions have retractable claws, but wolves do not
- Lions hunt on the savannah, but wolves typically do not

These features do not help us make meaning from the analogy.

Now, try creating some of your own analogies using content from your biology class. Can you draw an analogy between something you learned last week and something you learned this week? How about an analogy between something you learned in this class and something you already know about?
1. How are animal hormones and plant hormones related to each other?

2. When insulin binds to an insulin receptor on your cells, it allows the opening of a glucose transporter and glucose can enter the cell. Can you think of something else that acts similarly?

3. How do the functions of gibbelling and abscisic acid act like a tug-of-war regarding seed germination?

4. Now you try: How is _____ [new concept] related to what you already know about _____ [experiences with something involving this concept]?

5. How is electron transport in the mitochondria membrane the same as electron transport in the thylakoid membrane?
Worksheet 3

Name: 

PSU ID (e.g., xyz123):

Practice: Pick Your Own Strategy

By now you have been exposed to two effective, research-supported strategies that help students truly learn biology. Remember, your brain is a model builder. The models that it builds represent knowledge. Models are made by making connections among parts of new information, and making connections between new information and prior knowledge or experience. Sometimes, however, these models can be incomplete or incorrect. In order to build accurate and complete knowledge models, we have to generate meaning from new information. Meaning is generated by creating two types of relationships:

1. Relationships between your own knowledge/experience and the information you want to learn

   and

2. Relationships among the parts of the information you want to learn.

We can generate these two types of relationships in several ways, but two very effective and research-supported strategies include making analogies and using elaborative interrogation (EI).

Think about the content that you are studying right now in BIOL240. Use the space below as an area to practice using one or both of the two strategies you learned, or another strategy that works for you. Try to come up with some questions that are similar in form to (but not the same as) those that you were exposed to on the previous two worksheets. Then try to answer them. It’s ok if you come up with questions you cannot answer.
## Appendix B

### Types of Peer Teaching

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer Tutoring</td>
<td>The recruitment of one student to provide one-on-one instruction for another student, accompanied by explicit assignment of participants to &quot;tutor&quot; and &quot;tutee&quot; roles; usually focused on course content.</td>
<td>(Roscoe &amp; Chi, 2007; Zamberlan &amp; Wilson, 2015)</td>
</tr>
<tr>
<td>Reciprocal peer tutoring (RPT)</td>
<td>RPT is characterized by the structured switching of tutor-tutee roles at strategic moments during peer learning.</td>
<td>(De Backer, Van Keer, &amp; Valcke, 2012; Topping, 2005)</td>
</tr>
<tr>
<td>Supplemental Instruction (SI)</td>
<td>Supplemental instruction (SI) is an academic support program that employs successful later-year tertiary students to facilitate peer-learning sessions mostly attached to high-risk courses; focuses on study skills and guiding learners—not reteaching</td>
<td>(Dawson, van der Meer, Skalicky, &amp; Cowley, 2014)</td>
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<tr>
<td>Peer assisted study sessions (PASS)</td>
<td>PASS is a structured peer-led study group where students collectively share knowledge and solve course-related tasks.</td>
<td>(Spedding, Hawkes, &amp; Burgess, 2017)</td>
</tr>
<tr>
<td>Peer assisted learning (PAL)</td>
<td>PAL is considered an umbrella concept by some, comprised of a group of strategies that involve the active and interactive mediation of learning through other learners who are not professional teachers</td>
<td>(Berghmans, Neckebroecck, Dochy, &amp; Struyven, 2013)</td>
</tr>
<tr>
<td>Peer mentoring</td>
<td>Peer teaching programs in which the focus is on socialization, and not necessarily course content</td>
<td>(Zamberlan &amp; Wilson, 2015)</td>
</tr>
</tbody>
</table>
Appendix C

Pre- and Post-Survey

Demographics

1. What is your first name?
2. What is your last name?
3. Please enter your access ID:
4. Please select your gender:
   a. Male
   b. Female
   c. Prefer not to say
   d. Other
5. Which of the following describes you?
   a. Hispanic/Latino
   b. White
   c. Black or African American
   d. Asian
   e. American Indian or Alaska Native
   f. Native Hawaiian or Other Pacific Islander
   g. Other
6. Please select your current academic standing:
   a. First year
   b. Second year
   c. Third year
   d. Fourth year
   e. Fifth year or above
7. What is your age? (Please enter a number): 
8. Please report your current, overall GPA:
9. Please report your current grade in [this course]:
   a. A
   b. A-
   c. B+
   d. B
   e. B-
   f. C+
   g. C
   h. C-
   i. D+
   j. D
   k. D-
   l. F
   m. I don’t know
10. What grade do you expect to earn in [this course]? 
   a. A
   b. A-
c. B+
d. B
e. B-
f. C+
g. C
h. C-
i. D+
j. D
k. D-
l. F
m. I don’t know

11. What grade did you earn on the most recent exam?
12. What grade do you expect to earn on the next exam?
13. What course section do you attend most regularly?
   a. Morning section
   b. Evening section

14. How often do you attend regularly-scheduled lectures for [this course]?
   a. Every lecture
   b. Only missed 1 or 2
   c. Only missed 3 or 4
   d. Only missed 5 or 6
   e. Missed 7 or more

15. Do you receive outside help for [this course] outside of regularly-scheduled lectures? (e.g., tutoring, regular office hour visits, study groups with friends).
   a. Yes
   b. Maybe
   c. No

16. [If the student said “yes” or “maybe” to the above question, the following was displayed]: What type of extra help are you receiving?
   a. Tutoring on campus
   b. Tutoring off campus
   c. I regularly attend office hours
   d. I have a study group with other students that meets regularly
   e. I ask a friend or friends for help, but not regularly
   f. Online forum or blog (e.g., Piazza, Yahoo answers)
   g. Online videos (e.g., YouTube, Khan Academy)
   h. Other (please specify)

17. Have you been explicitly taught learning strategies before? Example learning strategies may include: making a concept map, planning out your study time, drawing a picture, creating practice quizzes, drawing analogies, self-explaining, etc.
   a. Yes
   b. Maybe
   c. No

18. [If the student said “yes” or “maybe” to the above question, the following was displayed]: How many different strategies were you taught?
   a. 1-2 (1)
   b. 3-4 (2)
c. 5-6 (3)
d. 7 or more (4)
e. I can't remember

19. How long did you spend learning specific learning strategies?
   a. 1 class or session
   b. 2 classes or sessions
   c. 3 classes or sessions
   d. 4 classes or sessions
   e. 5 or more classes or sessions
   f. The whole semester
   g. Other (please describe)

Jr. MAI version B

1. I know when I understand something.
2. I can make myself learn when I need to.
3. I try to use ways of studying that have worked for me before
4. I know what the teacher expects me to learn.
5. I learn best when I already know something about the topic.
6. I draw pictures or diagrams to help me understand while learning.
7. When I am done with my schoolwork, I ask myself if I learned what I wanted to learn.
8. I think of several ways to solve a problem and then choose the best one.
9. I think about what I need to learn before I start working.
10. I ask myself how well I am doing while I am learning something new.
11. I really pay attention to important information.
12. I learn more when I am interested in the topic.
13. I use my learning strength to make up for my weaknesses.
14. I use different learning strategies depending on the task.
15. I occasionally check to make sure I’ll get my work done on time.
16. I sometimes use learning strategies without thinking.
17. I ask myself if there was an easier way to do things after I finish a task.
18. I decide what I need to get done before I start a task.

SRSI-SR

Managing Behavior and Environment:
1. I make sure no one disturbs me when I study.
2. I make a schedule to help me organize my study time.
3. I finish all of my studying before I play video games or with my friends.
4. I try to study in a quiet place.
5. I think about how best to study before I begin studying.
6. I try to study in a place that has no distractions (e.g., noise, people talking).
7. I quiz myself to see how much I am learning during studying.
8. I study hard even when there are more fun things to do at home.
9. I tell myself to keep trying when I can’t learn a topic of idea.
10. I use binders or folders to organize my biology study materials.
11. I tell myself exactly what I want to accomplish during studying.
12. I carefully organize my study materials so I don’t lose them.
Seeking and Learning Information
13. I ask my teacher questions when I do not understand something.
14. I try to see how my notes from biology class relate to things I already know.
15. I make pictures or drawings to help me learn biology concepts.
16. I look over my homework assignments if I don’t understand something.
17. I think about the types of questions that might be on a test.
18. I ask my biology professor about the topics that will be on upcoming tests.
19. I rely on my biology class notes to study.
20. I try to identify the format of upcoming biology tests.

Maladaptive Regulatory Behavior
21. I forget to bring home my biology materials when I need to study.
22. I avoid going to extra-help sessions in biology.
23. I lose important biology dittos or materials.
24. I give up or quit when I do not understand something.
25. I let my friends interrupt me when I am studying.
26. I avoid asking questions in class about things I don’t understand.
27. I wait to the last minute to study for biology tests.
28. I try to forget about the topics that I have trouble learning.

MSLQ Self-efficacy Subscale
1. I believe I will receive an excellent grade in this class.
2. I’m certain I can understand the most difficult material presented in the readings for this course.
3. I’m confident I can understand the basic concepts taught in this course.
4. I’m confident I can understand the most complex material presented by the instructor in this course.
5. I’m confident I can do an excellent job on the assignments and tests in this course.
6. I expect to do well in this class.
7. I’m certain I can master the skills being taught in this class.
8. Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.