ABSTRACT


Geoscience education researchers have recently recognized the importance and role of affect and self-regulation as critical mediators between course context and student learning outcomes (e.g., performance and persistence). Introductory physical geology students (n = 73; from 5 U.S. colleges and universities) were interviewed about their learning strategies and experience in their introductory geology course, including how they prepare for an exam. A grounded theory approach was used to analyze the interview data and create codebooks to characterize motivation and self-regulated learning as it was reported in interviews. All students report a performance component to their motivation, where a learning task is a means to an end, such as earning a grade. However, most high performing students (70%) also reported their motivation was also oriented towards a mastery goal, such as satisfying curiosity, more frequently than low performing students (18%). The majority of students (81%) also described an emotional component to their motivation. Contrary to existing models that emphasize the dominant role of positive emotions, most students indicated they were motivated to engage in exam preparation as a way to avoid experiencing negative emotions. In terms of self-regulation, high performers are more strategic in their planning and low performing students rely more on instructors for guidance when choosing strategies. Both high and low performers use a combination of shallow (e.g., rehearsal) and deep (e.g., elaboration and organization) learning strategies, but high performers are using deep strategies frequently more and in more advanced ways. High performers are using self-control strategies more often during the action phase of the SRL cycle. High performers are
more likely to consider the success of their learning process, yielding more evidence of regulation. From a synthesis of these findings, an applied model of self-regulated learning is presented in which high performing students begin the exam preparation process with reflection on their classwork. Results suggest that student outcomes would benefit from instructors explicitly incorporating aspects of this model into geoscience courses.
Why Do They Do That? An Analysis of Student Learning Processes and Perceptions in Introductory Geology Courses

by
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DEDICATION

I dedicate this to my brother, Doug.
Laura Lukes taught high school for 5 years before serving as an Albert Einstein Distinguished Educator Fellow at the National Science Foundation in the Office of Polar Programs (now the Division of Polar Programs). While there, she served as director of the Joint Science Education Program (JSEP). She has also taught at the community college level since 2006 and, as part of this program, at the university level since 2012. During her time at North Carolina State University, she served on the university’s teaching award committee and was selected to serve as a member of the Geological Society of America’s Education committee. She also served as co-chair of the Association of Polar Early Career Scientists (APECS)’s Nordic project workshop as part of the Arctic Science Summit Week in Helsinki.
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# TABLE OF CONTENTS

LIST OF TABLES ........................................................................................................... viii

LIST OF FIGURES ......................................................................................................... ix

CHAPTER 1-What motivates students to study for an exam? .........................1

ABSTRACT ....................................................................................................................... 2

INTRODUCTION ............................................................................................................. 3
  Why is it important to understand student motivation? ....................................... 4
  What do we already know about student motivation? ........................................ 5
  Research Question and Goals ............................................................................. 8

METHODS ....................................................................................................................... 9
  Data Collection ....................................................................................................... 9
  Participants ........................................................................................................... 10
  Qualitative analysis .......................................................................................... 11

RESULTS ....................................................................................................................... 13
  Achievement goal orientation ........................................................................... 13
  Emotion ............................................................................................................... 13

DISCUSSION ............................................................................................................... 14
  Performance vs. Mastery Goal Orientations ....................................................... 14
  Motivation-Emotion Connections ..................................................................... 17
  High Performing Students vs. Low Performing Students .................................. 18
  R1 Universities vs. Two-year Colleges .............................................................. 22
  Implications for Future Investigations and Improving Student Motivation ....... 23
  Limitations ........................................................................................................... 25

CONCLUSION .............................................................................................................. 27

ACKNOWLEDGEMENTS .............................................................................................. 28

REFERENCES ............................................................................................................ 29

Appendix A: Interview protocol .............................................................................. 45
CHAPTER 2-How students prepare for exams in college-level introductory geoscience courses: A qualitative analysis of 73 student interviews

ABSTRACT ......................................................................................................................... 47
INTRODUCTION ............................................................................................................. 47
  What is self-regulated learning? ................................................................................. 49
  Why is understanding student self-regulation important? ...................................... 52
  Research questions and goals .................................................................................. 53
METHODS ....................................................................................................................... 55
  Data collection ............................................................................................................ 55
  Participants .................................................................................................................. 56
  Methods of qualitative analysis .................................................................................. 57
RESULTS .......................................................................................................................... 58
  Planning ....................................................................................................................... 59
  Action (Using tactics) .................................................................................................. 61
  Reflecting ..................................................................................................................... 65
  Regulating .................................................................................................................... 67
DISCUSSION ..................................................................................................................... 69
  Implications for research ............................................................................................. 70
  Implications for practice ............................................................................................... 70
CONCLUSION ................................................................................................................... 77
ACKNOWLEDGEMENTS ................................................................................................. 77
REFERENCES .................................................................................................................. 79

CHAPTER 3-What’s the difference? Comparing the exam preparation strategies of high and low performing students in introductory geology courses

ABSTRACT ......................................................................................................................... 92
INTRODUCTION ............................................................................................................. 92
  What is self-regulated learning? ................................................................................. 93
  Research questions and goals .................................................................................. 94
METHODS ....................................................................................................................... 95
  Data collection ............................................................................................................ 95
Participants .......................................................................................................................... 96
Methods of qualitative analysis .......................................................................................... 97
Methods of quantitative analysis ......................................................................................... 99

RESULTS ............................................................................................................................ 100
Coding results ..................................................................................................................... 100
SRL model results ............................................................................................................... 100

DISCUSSION ....................................................................................................................... 101
Planning ............................................................................................................................... 101
Action ................................................................................................................................. 104
Reflection ............................................................................................................................ 110
Regulation ........................................................................................................................... 112
SRL as a process ................................................................................................................. 115
Limitations and strengths ................................................................................................. 118

CONCLUSION ..................................................................................................................... 120

ACKNOWLEDGEMENTS ................................................................................................. 120
LIST OF TABLES

CHAPTER 1

Table 1. Codebook: Motivation to Study................................................................. 41

CHAPTER 2

Table 1. SRL Codebook............................................................................................. 87

CHAPTER 3

Table 1. SRL Codebook............................................................................................. 128
Table 2. Coding Results (*=significant).................................................................. 132
LIST OF FIGURES

CHAPTER 1
Figure 1. Relationship between goal levels ................................................................. 34
Figure 2. Qualitative method process ............................................................................ 36
Figure 3. Comparison of goal orientation of high and low performers ......................... 37
Figure 4. Comparison of goal orientation of university and community college students .... 37
Figure 5. Comparison of emotion reported by high and low performers ....................... 39
Figure 6. Comparison of emotion reported by university and community college students .. 40

CHAPTER 2
Figure 1. Role of self-regulation and student outcomes ................................................... 84
Figure 2. General composite model of SRL ..................................................................... 85
Figure 3. Research methods ......................................................................................... 86

CHAPTER 3
Figure 1. General SRL model ....................................................................................... 125
Figure 2. Research methods ......................................................................................... 126
Figure 3. Emergent SRL model of high performing students preparing for an exam ....... 127
CHAPTER 1

What motivates introductory geology students to study for an exam?

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KEY WORDS

affect, motivation, undergraduates, learning strategies, community college, emotion, learning outcomes, self-regulated learning
ABSTRACT

There is a need to understand why some students succeed and persist in STEM fields and others do not. While numerous studies have focused on the positive results of using empirically-validated teaching methods in introductory science, technology, engineering, and math (STEM) courses, little data has been collected about the student experience in STEM courses. The aim of this study was to capture and characterize the student perception of their motivation to study for an exam in a geoscience class. Students enrolled in introductory physical geology courses (n=42) at 5 different institutions (7 instructors at 2 research universities and 3 community colleges) were interviewed using a semi-structured protocol. The interview data was analyzed using a grounded theory approach. The resulting emergent themes included goal orientation and emotion. All students report a performance component to their motivation, where a learning task is a means to an end, such as earning a grade. However, most high performing students (70%) also reported their motivation was also oriented towards a mastery goal, where a learning task itself serves as an end, such as satisfying curiosity, more frequently than low performing students (18%). The majority of students (81%) also described an emotional component to their motivation. Contrary to existing models, most students indicated they were motivated to engage in exam preparation as a way to avoid experiencing negative emotions. These resulting insights to student motivation have implications both for course design and instructional practices in similar introductory courses.
INTRODUCTION

The United States is facing a STEM (Science, Technology, Engineering, and Math) workforce shortage (President’s Council of Advisors on Science and Technology, PCAST, 2012). Nearly half of college-level STEM majors switch to non-majors within the first two years of their college experience (Strenta et al., 1994; Seymour & Hewitt, 1997). Much of this workforce demand can be met if we can reduce the STEM attrition rate by just 10% (PCAST, 2012). It is therefore important to understand why students are leaving STEM fields like geology, so that intentional changes can be made to improve retention.

Why are students leaving STEM? Many students identify dissatisfaction with their introductory STEM classes as a primary factor in their leaving STEM (Seymour & Hewitt, 1997; Tobias, 1990). In other words, if a student with a geology major takes an introductory geology course and has a negative experience, they are likely to change majors and leave STEM altogether. In addition, student experiences in introductory geology courses have been identified as critical gateway for attracting geology majors (Levine, 2008; Houlton, 2010; Wilson, 2013). Compared to other STEM fields, the student experience in college level introductory geology courses is doubly important, not only for retaining existing majors, but also for attracting new students to the discipline.

Before the student experience can be improved, we need to first establish a baseline for the features of that experience. There has been a notable body of work in discipline-based education research in the STEM fields over the last 30 years (National Research Council,
NRC, 2012) that has focused on student cognition (e.g., teaching practices and learning gains, metacognition) but less attention has been paid to student affect (NRC, 2012). Research on the affective domain of the student experience (e.g., emotions, attitudes, motivation, values) is gaining recognition for its critical role in student engagement and is emerging as a key area of interest in the field (van der Hoeven Kraft et al., 2011; NRC, 2012). This study is part of the large-scale collaborative efforts of the Geoscience Affective Research Network (GARNET), which aims to measure affect among students in introductory geology courses across the United States (Gilbert et al., 2012). We report the results of a series of student interviews that investigate some aspects of student motivation associated with exam preparation in introductory geology courses. Further, we discuss the importance of student emotion as an additional driver of study behaviors.

**Why is it important to understand student motivation?**

What do we mean by motivation? While there is much debate surrounding the definition and nature of motivation, here we define motivation as a “process whereby goal-directed activities are instigated and sustained” (Schunk, et al., 2013). In other words, motivation is an excited internal state that involves the beliefs and/or emotions that someone holds and results in strategy use and behaviors that aim to avoid or seek something. Some students may arrive at this state driven by factors such as an interest in the topic, by a sense of academic self-preservation, and/or through the encouragement of family, peers and/or the instructor. Others will struggle to develop motivation in some educational environments and this will
hamper their efforts to achieve learning goals. Whatever the cause, motivation, both in and out of the classroom, is critical to student learning in any domain including the geosciences (van der Hoeven Kraft et al., 2011). Models of student learning (e.g., Pintrich & Zusho, 2007) indicate that motivational processes drive student action, such as studying for an exam, and can positively mediate learning outcomes (e.g., achievement, persistence, effort; McConnell and van der Hoeven Kraft, 2011).

**What do we already know about student motivation?**

There are several theories and approaches linking student motivation and learning. The diversity in models speaks to the complexity of motivational processes. Data that emerged was consistent with one of these theoretical frameworks, achievement goal theory, which is discussed below. For a more thorough review of motivational theory, the reader is directed to Schunk et al. (2013), which provides a comprehensive discussion and analysis of motivational theory as applied to education research.

A student’s goal orientation refers to “an integrated pattern of beliefs, attributions, and affect that produces the intentions of behavior” (Weiner, 1986; Ames, 1992). In other words, goal orientations are the rationale for why a student pursues an achievement task (Schunk et al., 2013) rather than the performance objective a student has for an achievement task (e.g., earn a grade of X on an exam; Kaplan and Maehr, 2007). Goal orientation is expressed and observed in the different ways students approach, engage in, and respond to achievement tasks (Ames, 1992; Dweck & Leggett, 1998). While there are many different models of goal
orientation, there is general consensus in the literature (Schunk et al., 2013) that there are two main goal orientations: performance goal orientation and mastery goal orientation. A student with a performance orientation engages in learning activities with the purpose of demonstrating competence or ability, often in a context of how that achievement will be judged relative to others (Schunk et al., 2013). Engagement in a task is viewed as a means to an end such as rewards, which in academic settings are often (course) grades (Pintrich et al., 1993). In contrast, a student with a mastery goal orientation, sees the task as an end itself (Pintrich et al., 1993) and thus engages with the purpose of self-improvement by developing new skills, acquiring new knowledge, and/or improving competence by overcoming a challenge (Schunk et al., 2013). For example, a geology major might seek to be successful in a course to enhance their GPA so that s/he can earn a place in graduate school (performance orientation) but s/he can also recognize that they are developing a skill that will be applied in their career (mastery orientation). Some have suggested that students may toggle between multiple goals, each with their own type of orientation (Pintrich, 2000b).

Goal orientation is typically measured through self-report surveys, like the Motivated Strategies for Learning Questionnaire (MSLQ, Pintrich et al., 1993) in which students use a Likert scale (e.g., 1=strongly disagree to 7= strongly agree) to rate their reaction to a statement describing a manifestation of a person’s goal orientation (e.g., “I want to do well in this class because it is important to show my ability to my family, friends, employer, and others.” Or “I prefer course material that challenges me to learn new things.”). These ratings
for statements associated with each goal orientation (performance or mastery) are usually then averaged to create an overall goal orientation score (e.g., Gilbert et al., 2012).

Goal orientations have also been linked to emotion through correlational studies (Linnenbrink and Pintrich, 2002; Pekrun et al., 2002). Mastery goals have been reported to be predictors of enjoyment of learning, hope, and pride whereas performance-avoidance goals have been described as predictors of anxiety, hopelessness and shame (Pekrun, et al., 2006). These studies tend to view emotions as outcomes rather than part of the motivational process itself. For example, performance goal-oriented students feeling more anxiety and shame after poor performance and mastery goal-oriented students feeling more pride after achievement. These studies do not explicitly define the role emotions play in motivational processes as they are correlational in nature and causation cannot be established from the data.

It is important to remember that there are different levels of motivation when discussing motivation in a formal learning context such as an introductory geology course (Figure 1). A person may be motivated to engage at a global level such as engagement in school in general. They may be motivated at the discipline level, in this case their engagement in science. A student may be motivated at the course level as seen by their engagement in the geology course as a whole and/or at the class level such as their engagement in a specific day or week of class. Finally, a student can be motivated at the task level through their engagement in activities like responding to a clicker question, completing homework, or studying for an
exam. In addition to a student potentially alternating between multiple goals, they are likely to also be toggling between different levels of motivation. For example, in a geology class, a student’s motivation may be oriented towards performance because they want to earn a good grade on the exam (task-level) because they want to earn a good grade in the class (course-level), so that they will complete the credits necessary to earn a college degree (school-level; Figure 1). In research, therefore, it can be difficult to sort out those differences and influences. Self-report instruments such as the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1991) capture the course level motivation of a student, but may miss the day-to-day connection between student motivation and action. For the purposes of this study, we have chosen to focus on the task-level motivation of students, specifically their motivation to prepare, or study, for an exam. By asking students to reflect on their motivation to study for an exam rather than their motivation in the course as a whole, we can gain insights into how student motivation directly connects to specific choices and actions of students in an introductory geology course. These insights have the potential to inform instructor practice in terms of what resources and scaffolding methods would be most beneficial to students.

**Research Question and Goals**

This study sought to answer the question: what motivates students to study for an exam (task-level motivation)? Specifically, in this article, we seek to answer the following questions: Are there differences in the goal orientation of high and low performing students as they prepare for an exam? What role do emotions play in student motivation to study for an
exam? Are there any differences between research university and community college populations? In addition to addressing these questions, a broader goal of this study was to identify the implications of this motivation as it relates to instructor practice.

METHODS

Motivation is often inferred through the product of student actions rather than measured directly (e.g., if Sally earns an A, then Sally is said to be motivated). A better proxy for understanding motivation as a process is by asking students to reflect on the rationale behind their goals, choices, and actions. This study takes a qualitative approach to investigate student motivation through interviews that evoke student reflection. As a methodological framework, a qualitative approach yields richer descriptions and captures contextual relationships that are inherently omitted by quantitative methods (e.g., surveys).

Data Collection

A total of 73 students, from 2 research universities (R1) and 3 community colleges (2YC), volunteered to be interviewed as part of a larger study (e.g., Gilbert et al., 2012). The university classes typically enrolled 80-150 students each, whereas, the community college classes enrolled fewer than 50 students. University students were interviewed between weeks 10 and 12 of the semester (students had taken two exams prior to interview). All of the community college students were interviewed between week 8 and 9 of the semester after completing 1 or 2 exams with the exception of students from one community college class (which were interviewed during week 5—the week before their first exam).
Student interviews were conducted in person (by the first author) and lasted 15-75 minutes depending on the extent of student responses. During the interview, students were asked a consistent suite of questions about their experiences in their introductory geology course, with a particular focus on how students study for and prepare for an exam in the course through questions such as “What motivates you to do what you just described [about how you study for an exam]?” (The complete list of questions and interview protocol are described in Appendix A in the supplementary materials). Following a grounded theory approach to the study (Oktay, 2012; illustrated in Phase 1 shown in Figure 2), the interviews were semi-structured in nature, providing students with open ended questions that allowed student-identified themes to emerge and be further investigated by the interviewer with follow up questions. Interviews were digitally recorded and later transcribed. Upon completion of the interview, participants reviewed the interviewer’s notes to confirm accuracy. After the interview, the interviewer created memos: summarizing non-verbal observations of the students and interviewer reactions and impressions, identifying emerging ideas and themes, and comparing interview notes and memos to data in previous interviews and memos (the constant comparison component of grounded theory methods).

**Participants**

A grounded theory approach is an iterative, recursive process that relies on constant comparison. Consequently, the interview protocol developed over time through 73 student interviews. To ensure consistency, the participants in this study, consist of the 42 students that were interviewed with the final version of the protocol. From the larger study survey
data, participants were nearly evenly split between sex (55% female) and between research university and community college (55% R1). In terms of diversity, 21% indicated they were of a background other than white (non-Hispanic) and 19% did not disclose ethnicity/race. More than two thirds (69%) indicated that were “very interested” or “somewhat interested” in science, but only 21% indicated that they were “very likely” or “somewhat likely” to be a science major. In terms of achievement, while 70% of students earned an A or a B in the class at the end of the semester, only 48% earned an A or B average on exams/quizzes.

**Qualitative analysis**

Following a standard grounded theory approach to analyzing the interview data (Charmaz & Belgrave, 2012; Figure 2), transcribed interviews were read in an iterative, recursive fashion, allowing the researcher to constantly compare data between interviews. Prior to coding, all 42 interviews and their corresponding memos were read by the primary investigator to identify recurring ideas and emergent themes. Interviews were then coded following common practices. First (Phase 2 in Figure 2), during open coding, 10 transcripts were dissected by the primary investigator and two other researchers (one involved in the larger GARNET investigation and one unfamiliar with the project) at the individual thought level, meaning that each separate thought a student had about a source of motivation was tagged. For example, “I want to pass…plus, I’m a science major, so I want to know this stuff.” would be split into two separate tagged items (“I want to pass” and “I’m a science major, so I want to know this stuff.”). Next, memos were created to identify recurring ideas and initial interpretations. From the memos, a list of open codes was compiled and revised in a
recursive manner as the interview transcripts were analyzed. The primary investigator coded and re-coded each interview 3 times in an effort to test-retest the codes to establish intra-coder reliability. The open codebooks, open coding results, and memos between researchers were compared to establish inter-rater reliability and validity through peer review. These emergent results were also compared to the dominant motivation in education literature to identify any overlap (Phase 3 in Figure 2). Consensus between researchers was reached on recurring ideas and themes for a final codebook (see Table 1) to be used for selective coding. Interview transcripts were recoded (Phase 4 in Figure 2) using the final codebook (each transcript recoded twice by the primary investigator to establish 100% intra-rater reliability). Inter-rater coding reliability (in this case, percent of agreement) was established through the co-coding methods of Gorden (1992). The two coders reached an initial average agreement of 92% (using 7 of the 10 interviews), reaching 100% consensus on all 7 interviews through discussion. The remaining interviews were then coded by the primary investigator. These selective coding results and resulting memos were synthesized to develop categories (performance goal orientation, mastery goal orientation, avoiding negative emotion(s) and approaching positive emotion(s)). Eventually, an emergent model of student motivation in studying for an exam in an introductory geology course resulted. While participants were unavailable to review and confirm the validity of final codes (member checks), participants reviewed and confirmed the interviewer's field notes (Phase 1 in Figure 2), establishing the validity of any interpretations or conclusions that closely follow the wording or sentiment of the field notes.
RESULTS

The overarching themes that emerged from the data included the achievement goal orientation of the student (consistent with performance and mastery goal orientations already identified in the literature) and the emotional goals of the student (engaging in studying with the goal of avoiding or approaching emotional states).

Achievement goal orientation

All of the students reported some form of performance goal orientation in which they view the task as a means to an end, such as an extrinsic reward like a grade, degree, or job (see Table 1, Code 1). Mastery goal orientation, in which they see the task as an end unto itself, such as desire to learn, interest, future use, etc. was reported by 43% of participants (18 students; see Table 1, Code 2). When the data were sorted into high performing (earned A or B average on exams) and low performing (earned an average of C or below on exams) subpopulations, 70% (14 of 20) of high performers and 18% (4 of 22) low performers reported a mastery goal orientation (Figure 3). When data were examined as 2YC and R1 university subpopulations, 53% (10 of 19) 2YC students and 35% (8 of 23) R1 university students reported aspects of mastery goal orientation (Figure 4).

Emotion

Eighty-one percent (34 of 42) of all students included emotion as part of their explanation of what motivated them to prepare for an exam (Table 1, Codes 3 and 4). This majority was consistent across gender (74% of males and 87% of females). These students can be further
separated into subgroups: 29% (12 of 42) reported avoiding negative emotions; 19% (8 of 42) reported approaching positive emotions only; and 33% (14/42) described both avoiding negative emotions and approaching positive emotions. High performing students were more likely to report they were avoiding negative emotions (80%, 16 of 20) than low performing students (46%, 10 of 22; Figure 5). This majority of high performers was consistent across gender (90% of females and 67% of males). Within the high performer population, 100% of students who earned an A average on exams/quizzes reported that they were avoiding negative emotion. A majority of high performers (60%; 12 of 20) and almost half of low performers (46%; 10 of 22) reported they were seeking positive emotions. This majority was inconsistent across gender (73% of high performing females and 44% of high performing males). Large majorities of both 2YC (95%, 18 of 19) and R1 students (70%, 16 of 23) reported emotional components to their motivation. Students were more likely to report avoiding negative emotions than approaching positive emotions at both types of institution (Figure 6). In each case, a larger proportion of 2YC students (compared to university students) noted they were avoiding negative emotions (79% vs. 48%) or approaching positive emotions (63% vs. 43%).

**DISCUSSION**

**Performance vs. Mastery Goal Orientations**

The data from this study provide a unique perspective on goal orientations because, unlike other studies that rely on survey data, goal orientations emerged from the student narratives, rather than the students evaluating themselves on pre-established statements of goal
orientation. Most survey-based studies focus on the correlation of these high/low average performance and mastery goal orientation scores with other factors (e.g., learning strategies). Such studies are focused on the degree to which a student expresses performance and mastery goal orientations rather than whether or not s/he expresses one or the other. By asking students to discuss what they see as important, we can reduce the tendency for researchers to preferentially select data that confirms their pre-existing beliefs (commonly called confirmation bias; Nickerson, 1998). This allows us to gain insights into whether students self-identify with one or both of the goal orientations. All students reported a performance goal orientation at the task level when preparing for an exam, with fewer reporting a mastery goal orientation. While students may identify with mastery goal orientations at a more global course level (see Gilbert et al., 2012), at the task level, performance goal orientation dominates their engagement.

Mastery goal orientation has been correlated with higher performance and the more effective use of self-regulated learning strategies. Self-regulated learning is “an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment” (Pintrich, 2000). The absence of a mastery orientation in most students could be interpreted to represent a corresponding deficit of self-regulated learning strategies in preparation for an exam. When we examine performance, we see that our results are consistent with the dominant literature indicating that high
performance levels correlate with mastery goal orientation (see comprehensive review of this
correlation in Meece et al., 2006).

Another advantage to using qualitative grounded theory methodology is that we can observe
how students interpret questions about their motivation in terms of goal level. Surveys like
the MSLQ, are assumed to represent course-level, but actually ask students to consider
multiple goal levels through prompts such as “in this class,” “when I take a test,” and “for
this course.” In this study, we explicitly asked students to discuss what motivated them to do
the tasks they described in preparing for an exam (task-level motivation). Despite this clear
task-level prompt, most student responses revealed a more complex relationship between
goal levels. For example, Cassandra (a R1 student) declares that she motivates herself to use
flashcards to prepare for an exam because she wants a good grade in the class (course-level).
The implication is that getting a good grade on the exam (task-level) will result in a good
grade in the class. When she is prompted about why she wants a good grade, she connects to
more global goals such as GPA and being able to transfer into a specific program in the
college (school-goal) which is linked to her broader career goals. Such data suggests
students are toggling between goal levels and/or framing their task-level motivation in more
global school and life goals. If we examine the codebook that emerged from student
responses (Table 1), we see that most instances of mastery orientation are more global in
nature, while performance orientation tends to be at the task level with connections to more
global goals. This apparent mixing of goal levels may be actually be evidence of a future
time perspective theory which focuses on the connection between beliefs and motivation
(Husman and Shell, 2008). More studies establishing a clear link between student strategies and their future goals are needed to clarify these relationships.

Motivation-Emotion Connections

Most students (81%) report an emotion component when they reflect on their motivation to prepare for an exam, suggesting that emotion plays a significant role in achievement motivation. Most emotion-achievement models predict that positive emotions (e.g., joy, pride) would be indicated by students who report higher levels of mastery goal orientation and negative emotions (e.g., shame, guilt) would be associated with performance-avoidance goal orientations. We do see some support of this in our results. For example, Faith says “If I get an A on the test I’d be like “Oh I want to get an A on the next test too.” I think it actually motivates me rather than getting a bad test. Not saying a bad test does not make me want to do better but…an extra motivat[or] I think if I receive a good grade first.” Faith wants to sustain the pride she is feeling and uses that emotion to drive her to action.

Unlike the predictions of most emotion-achievement models, our results show a high incidence of the avoidance of negative emotions by students who report mastery goal orientation. Some students appear to be using feelings of guilt and shame to engage in learning strategies. For example, Vanessa (R1) states she is "paying to come here, so [she] might as well make good grades…[she’s] capable of doing so, so why be lazy?” There is a sense of guilt for potentially wasting both money and her ability by doing poorly. By including laziness, she also equates effort/action with performance (good grades). She uses
this emotionally charged self-talk and self-instruction as a way to motivate and regulate her engagement. In this sense, Vanessa uses the anticipation of emotional responses to drive her to action. This is in direct contrast with model predictions and responses from other students like Faith (R1) who use retrospective emotions to drive action. This unexpected result suggests we need to examine how students are using emotions to engage in learning strategies.

**High Performing Students vs. Low Performing Students**

A clear majority (70%) of high performers (those who earn an A or B average on their exams in the class) report a mastery goal orientation in addition to their performance orientation compared to only 18% of low performers (those who earn a C average or below on their exams). If we separate the high performers even further, we find that 100% of those students who earned an A average on exams indicated a mastery goal orientation in addition to their performance goal orientation. These high performing students (both A and B averages) are motivated by their interest in the topic, learning in general, or how their learning process contributes to improving society in general. As Patrick, a R1 university student (STEM major) put it, “I was really intrigued by it.” He went on to explain that he put the effort and time into applying his study methods because he had an insatiable curiosity about the world. He didn’t want to just be able to repeat the answers the instructor was looking for, he wanted to understand why the answer was the way it was. While it seems logical that a geoscience or STEM major is motivated by mastery goals such as interest and value, it is important to note that 30% of the high performers are not geoscience or STEM majors. Non-STEM
related majors such as Staci (an arts major at a R1 university) echoed such curiosity as an inherent task value, indicating that she “would like to get the most as possible” out of her learning experience in class, viewing preparation for an exam as one of those tasks. Note the more global nature of her mastery orientation. This suggests that there may be a relationship between complex goal level patterns and performance.

If we examine the nature of these mastery goal orientations of high performing students, we can see that mastery goals correspond with deeper learning strategies such as elaboration (e.g., paraphrasing, creating analogies) and/or organization (e.g., creating outlines or concept maps). For example, if a student is driven to understand the “why” behind a concept, they will relate new concepts to pre-existing knowledge and find analogies and resources to construct new conceptual meaning. In this way, these results are consistent with previous reports that suggest that high performers are more intrinsically motivated individuals who value a task as a process in addition to the benefits of completing a task successfully (Pintrich, 2000).

But what of the low performers that indicated mastery goal orientations in addition to their performance goal orientation? Why were they not as successful? When we examine the student reflections on their motivation in the context of the geology study strategies they outlined during the interview, a clear distinction emerges between the high performing and low performing mastery goal-oriented students: a disconnect between their motivation and action. In other words, the sources students perceive as motivation to study action aren’t
actually resulting in study action. For example, Andre (a 2YC student), indicates an interest in geology as part of his motivation early in the interview, but goes on to explain that “…like it’s motivation of I want to do the stuff I like to do after, I basically say I have to do the work first…” When it comes down to the motivation behind his actual study actions, he is purely motivated by extrinsic rewards (getting to do what he really wants to do). Andre’s study strategies (chunking his time 1-2 days before a summative assessment by quizzing himself with flashcards containing general key concepts) focus on rehearsal strategies rather than elaboration and do little to satisfy his purported interest in geology. When we compare this to Patrick’s interest from earlier, we see that unlike Andre, Patrick’s interest and curiosity coincide with how Patrick studies. Unlike Andre, Patrick uses his curiosity to drive his effort levels and persistence at a study task: “[he’s] going to do this however long it takes.”

It is possible that the low performing mastery goal oriented students are inaccurate in their self-monitoring or are projecting an ideal version of themselves to the interviewer. Graham (a 2YC student in his seventh semester) indicates that “just learning is awesome,” but he also acknowledges that for geology, for some inexplicable (to him) reason he just “isn’t doing anything [to study] for [geology].” While he is self-reflective in his interview, unlike the high performing students, he has failed to fully evaluate his self-observations. He has yet to determine why he is motivated or not motivated to action and more importantly, he fails to enact strategies to regulate his motivation even when he recognizes that it is failing him. From these conflicting results, we can see that student self-report data on survey instruments measuring course level motivation can miss how motivation actually mediates student
learning processes and outcomes at the task level. A student, like Graham, may indicate a mastery goal orientation when reflecting on their motivation to engage in a task such as studying for an exam, but describe a performance goal orientation behind their actual study action.

The majority of high performers indicate discrete emotions (e.g., anxiety, guilt, self-disappointment, pride). If we further sort the A high performers from the B high performers, we see that all A students report they are avoiding negative emotions. We propose that this is evidence that high performers use emotions as motivational controls to regulate their engagement in self-regulated studying activities. Consider what Travis (2YC) tells us: “if that’s what I decided to do, then I’m going to give it my best efforts, otherwise it is a waste of time.” He will engage in his study strategies with clear purpose and high effort levels to avoid feeling guilt at wasting time. The conviction in his voice and his description of his study methods in another part of the interview appear in support of his claim of avoiding guilt.

When we examine the high and low performing populations in general, we observe that 2YC students are 35% of the high performing population and 59% of the low performing population. This appears to be related to the grade portfolio breakdown of 2YC courses. They tend to have less of the final course grade determined by performance on summative assessments (e.g., exams) than the R1 courses. When we further examine the high performing students who indicate an additional mastery goal orientation, we see that half of
these high performers with mastery goal orientation are from 2YC. In contrast, it is of interest to note that all (except one) of the low performing students with mastery goal orientation were 2YC students. This brings to light the question of differences in motivational needs and processes between the R1 and 2YC populations.

**R1 Universities vs. Two-year Colleges**

On first glance, R1 and 2YC appear similar in that all students report performance goal orientation and fewer students indicate mastery goal orientation. Upon closer examination, we see that a higher percentage of 2YC students report a mastery goal orientation compared to R1 students. We also see that a higher percentage of 2YC students report an emotional component to their motivation, suggesting that 2YC students do in fact have higher affective loads and potential affective obstacles to their learning. Several 2YC students described their motivation with more emotional urgency due to personal context than university students with comments like “I’m picking my college career off the ground…that was a dark time” (Randy, 2YC). Consider Sienna, she studies to perform well “to make [her] dad proud” which by itself is perhaps unremarkable, but she follows with “…making him proud is always hard,” adding a deeper emotional tone evoking questions of self-esteem to this need for external validation. Additionally, she also indicates she is studying to perform well so she could someday “figure out and prevent other people” from having the same geologically-related health concern her mother did. If she fails, she faces rejection from her father and a sense of guilt and shame for not metaphorically helping her mother. In other words, there is a lot more emotionally riding on her performance than is expressed by the typical R1 student,
like Jason, who tries really hard in geology to perform well because he “want[s] to have that understanding that [he] may need in the future [for his career plans].” All three (Randy, Jason and Sienna) want to perform well and they all want to use the geology content understanding for their future career plans, but Sienna has several emotional components to her motivation portrait. This high affective load (emotional demands on brain processing) has the potential to interfere with her intentions because she is focused on her feelings instead of the cognitive task itself.

**Implications for Future Investigations and Improving Student Motivation**

The results of this study suggest caution should be used when interpreting course level motivation survey or interview data, as students may conflate their more global course level motivation with their task level motivation sources or express relationships between them that are difficult to parse out. By giving students a specific scenario in their course to reflect on when discussing their motivation to study for an exam (e.g., “Walk me through a typical week or two before an exam, how do you prepare?”), the responses are more likely to be a valid representation of what students actually do in geology class, rather than a global interpretation of “studying” in general. In other words, this specificity reduces the number of potential memory data points a participant is referencing when formulating their responses. They are primed to think about geology class and not math class, for example. If students digressed into how they studied for other courses, they were redirected and asked about other courses and learning in general near the end of the interview.
This study examines student motivation for the task of studying for an exam. Other tasks, such as note taking, clicker questions, small group work, class discussions, and active listening may involve different motivation. These tasks need to be explicitly examined in a similar manner to identify what motivates students to engage in different task-specific learning processes in these different tasks and to delineate where motivational processes break down for students to facilitate instructor intervention. If students are inaccurately identifying their task level motivation, a strategy for instructors could be to include opportunities for students to reflect on their learning and study strategies, including motivation.

The results suggest that most students have a high affective load (emotional demands on brain processing). The results also suggest that high performing students use this high affective load to drive their engagement in learning processes. While it is tempting to portray the results as implying that instructors should intervene to increase or decrease student affective load, we argue the results instead suggest instructors should focus their efforts on preparing class materials and reference materials to be aligned with class assessments (e.g., exam) so that when students are motivated to engage, they have effective resources that will efficiently lead them to success. All students exhibit a performance orientation and most have emotional drives that motivate them to prepare for exams. Our job as instructors should be to clarify the processes necessary for success on exams. For example, by providing explicit learning objectives that are tied to the assessments, students can focus their efforts on strategies to learn the concepts rather than trying to figure out what they need to learn.
Limitations

The strength of this study lies in using the student voice to characterize a model for motivation and emotion, rather asking students how they compare to an existing model for motivation. However, even when students are explicitly asked about their task level goals, they frequently discuss them in terms of more global goals. This tendency to discuss multiple goals and levels simultaneously presents a challenge for anyone seeking to account for the principle mediators of student outcomes. Future studies could include follow up questions in the interview protocol that explicitly prompt students to differentiate between the task level and global level more accurately to establish the relative significance of each.

While the participant demographics of this population were consistent with the larger study population (see methods section), the participant population selection process presents a few noteworthy limitations to consider. First, participants were limited to R1 and 2YC institutions. Future studies could include other populations such as private liberal arts colleges. Second, participants were volunteers and were offered a $20 gift card for participating. Such incentives (financial and social) potentially bias the sample towards individuals that have similar motivations for participating like the goal of getting a gift card. While a few participants divulged post interview that they were motivated primarily by the gift card, the majority of participants indicated they were interested in sharing their experience in geology. The average time of the interviews (~45 minutes) suggests that the majority of participants were genuinely considering the questions, rather than rushing through to get done. Third, the sample population of this study reported disproportionately
higher levels of interest in science compared to the larger study population. However, like the larger population, participants were predominately non-STEM majors. Finally, the majority of the participant population earned an A or B in the course, suggesting there may be some unaccounted for motivation bias in our population selection. We reduced this bias, however, by using exam grade averages in lieu of final course grade. When these exam averages were sorted by high and low performance, the population was no longer skewed towards high performers. While it would have been more ideal to select a population randomly from the larger study or, in keeping with grounded theory methods, select a population based on emerging ideas, it wasn’t practical due to the logistical requirements of one researchers interviewing participants at multiple institutions across the U.S. For example, limited funding only allowed the interviewer to be on campus for 2-3 days. If a student was unable to interview during that window due to their schedule, they were not included in the study. Related to this scheduling conflict is the role interview timing may have played in student responses. Institutions have similar calendar schedules, preventing the researcher to interview students at the exact same time in the semester. Every effort was made to schedule the interviews around similar points in each institution’s course schedule so that students had at least two exams in geology as reference points, with one exception (see methods section). Despite the limitations discussed here, the advantages and insights from including the student voice provide new data to the discussion of student learning in the geosciences that has been previously unknown.
CONCLUSION

Through our analysis of student interviews, we present a new dataset and key findings for the geoscience community. Assessment drives student actions and learning gains. All students are motivated to study to obtain extrinsic rewards (e.g., grade, degree) and the tasks that determine the majority of grade (often exams) will likely drive student focus and action. The majority of students describe an emotional component to their motivation. Course structure can be used as a tool by students to reach emotional goals that are tied to performance. Therefore, modifying course structure to provide students with opportunities that explicitly model the processes necessary to be successful on an exam is likely to be beneficial to student outcomes.

Students indicate that mastery goal orientations in addition to performance goal orientations mediate higher performance outcomes (A or B average on exams). As mastery goal orientations are related to study strategy use (Pintrich, 2000; Elliot et al., 2011), instructors should encourage the development of student mastery goals. This can be accomplished by directing student attention to learning objectives, aligning assessments with objectives, assessing students using evaluation/analysis level questions (that require deeper study strategies), explicitly describing study strategies, and providing opportunities for students to reflect and self-evaluate performance and strategies.
ACKNOWLEDGEMENTS

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REFERENCES


Tobias, S. 1990. They’re not dumb, they’re different: stalking the second tier. Tucson, AZ: Research Corp.


FIGURE LIST

Figure 1. Relationship between goal levels

Figure 2. Qualitative method process

Figure 3. Comparison of goal orientation of high and low performers. Percent of high performers (earned A or B average on exams; n=20) and low performers (earned a C or below average on exams; n=22) who reported aspects of performance (e.g., extrinsic rewards like grades and what grades could get them like degree, job, etc.) and mastery (e.g., desire to learn, interest, future value, etc.) goal orientations.

Figure 4. Comparison of goal orientation of university and community college students. Percent of R1 and 2YC participants who reported performance and mastery goal orientations.

Figure 5. Comparison of emotion reported by high and low performers. Percent of high and low performers who report they are motivated to avoid negative emotions (e.g., anxiety, shame, guilt, self-disappointment). Percent of high and low performers that report they are motivated to approach positive emotions (e.g., pride, joy) are also illustrated.
Figure 6. Comparison of emotion reported by university and community college students.

Percent of R1 and 2YC students who reported avoiding negative emotions and approaching positive emotions.
Figure 1. Relationship between goal levels
Figure 2. Qualitative method process
Figure 3. Comparison of goal orientation of high and low performers
Figure 4. Comparison of goal orientation of university and community college students
Figure 5. Comparison of emotion reported by high and low performers
Figure 6. Comparison of emotion reported by university and community college students
Table 1. Codebook: Motivation to Study

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Subcode</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Performance</td>
<td>“…engaging in a learning task is the means to an end. The main concern the</td>
<td>1.1 Grade</td>
<td>Student engages to earn a “good” grade, to pass the class, or to improve</td>
<td>“Because I want to have a good GPA…” Shawn [G2]</td>
</tr>
<tr>
<td>goal orientation</td>
<td>student has is related to issues that are not directly related to participating in the task itself (such as grades, rewards, comparing one’s performance to that of others)…” (Pintrich et al., 1991 MSLQ manual)</td>
<td>reward</td>
<td>GPA.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2 Future</td>
<td>Student engages because the results will result in earning a degree,</td>
<td>“…get a good grade and be able to pass the course so I can get a good job.” Annabelle [N2]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reward</td>
<td>graduation, transfer to another school or program, entrance to graduate school, an internship, or a job.</td>
<td></td>
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<tr>
<td></td>
<td>1.3 Secure resources</td>
<td></td>
<td>Student engages because the results will allow them to keep financial aid resources.</td>
<td>“Well, since I am an athlete, I have to make a certain grade point average to stay at the university.” Gina [G2]</td>
</tr>
</tbody>
</table>
### Table 1. Continued

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Subcode</th>
<th>Description</th>
<th>Examples</th>
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<tbody>
<tr>
<td>2. Mastery goal</td>
<td>“…concerns the degree to which the student perceived herself to be participating in a task for reasons such as challenge, curiosity, mastery. Having an intrinsic goal orientation towards an academic task indicates that the student’s participation in the task is an end all to itself, rather than participation being a means to an end…” (Pintrich et al., 1991 MSLQ manual)</td>
<td>2.1 Desire to learn</td>
<td>Student engages because they want to learn something and/or value the process of learning.</td>
<td>“Then I realized as I came to college that I really just want to learn for myself and do well for myself.” Megan [G2]</td>
</tr>
<tr>
<td>orientation</td>
<td></td>
<td>2.2 Interest in topic</td>
<td>Student engages because they are curious or have an interest in the topic.</td>
<td>“I particularly have recently have found an appreciation for natural sciences because it’s the laws of the natural world we live in I think it’s very, it particularly strikes a chord with me and I find it fascinating.” Travis [H3]</td>
</tr>
<tr>
<td>2.2 Mastery for future use</td>
<td></td>
<td>2.3 Mastery for future use</td>
<td>Student engages because they value the skills/content they are learning to understand it so that they will be able to use in the future.</td>
<td>“…classes such as like geology or, you know, my major classes like thermodynamics and stuff, I'll, I try really hard because I want to have that understanding that I may need in the future.” Jason [N2]</td>
</tr>
<tr>
<td>2.4 Mastery for contributing to society</td>
<td></td>
<td>2.4 Mastery for contributing to society</td>
<td>Student engages because the process of engagement helps society improve.</td>
<td>“The most helpful you can be is to be good at what you are doing. Like if you go through college and get C’s in everything, you still get a degree, but you’re still the least helpful person on the team… you won’t help to solve the problem because you don’t know enough.” Katrina [G2]</td>
</tr>
</tbody>
</table>
Table 1. Continued

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
<th>Subcode</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Avoid negative (activating) emotion</td>
<td>Students explicitly indicate a desire to reduce or avoid negative emotions as a result of their engagement.</td>
<td>3.1 anxiety</td>
<td>Is about prospective fear of performance</td>
<td>“I need to prep for tests or I’ll just freak out.” Hannah [G2]</td>
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<tr>
<td></td>
<td></td>
<td>3.2 guilt</td>
<td>Is about having done something for which one may deserve consequences (retrospective)</td>
<td>“I’m paying to come here, so I might as well make good grades.” Vanessa [S2]</td>
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<td></td>
<td></td>
<td>3.3 shame</td>
<td>Is about believing one is flawed and therefore unworthy of social acceptance and belonging</td>
<td>“…the pressure of graduating, getting good grades…[from] myself and parents and seeing other students like brothers and sisters getting top honors…” [Sal [B2]</td>
</tr>
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<td></td>
<td></td>
<td>3.4 self-disappointment</td>
<td>Is about believing that one has not lived up to potential</td>
<td>“…fear of failure…I want to be back in the realm of intellectual intelligence…it’s just demoralizing…” Valarie [N2]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.5 general</td>
<td>Is about avoiding a negative emotion, but it is unclear which one</td>
<td>“that was a dark time…[now] it’s I have to!…That’s my personal goal.”</td>
</tr>
<tr>
<td>4. Seek positive (activating) emotion</td>
<td>Students explicitly discuss a desire to feel a positive emotion as a result of their engagement.</td>
<td>4.1 pride from achievement</td>
<td>Is about believing one is worthy in this case because of accomplishment in performance</td>
<td>“It feels good to achieve a goal of seeing an A on a report card.” Patrick [N2]</td>
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<td></td>
<td></td>
<td>4.2 pride from doing a task well</td>
<td>Is about believing one is worthy in this case because of accomplishment in process (putting in full effort, doing it well)</td>
<td>“It’s a commitment. If it’s worth my time and effort, I should put my best effort forward…If I’m going to do something, I’m going to do it well.” Travis [H3]</td>
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<td></td>
<td></td>
<td>4.3 joy from fun</td>
<td>Is about having a pleasant experience</td>
<td>“It’s a fun thing to do too.” Tina [H3]</td>
</tr>
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# Appendix A: Interview protocol

<table>
<thead>
<tr>
<th>Question</th>
<th>Prompts</th>
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<tbody>
<tr>
<td>Tell me about yourself.</td>
<td>Major? Interests?</td>
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<tr>
<td>How would you characterize yourself as a student?</td>
<td>Have to get an A/B or best that you can or pass to get credit?</td>
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<tr>
<td>Walk me through a typical week before an exam, how do you prepare?</td>
<td>Resources?</td>
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<tr>
<td>(calendar visual provided)</td>
<td>Methods (What does X look like, describe it)?</td>
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<tr>
<td></td>
<td>How often do you do X?</td>
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<td></td>
<td>How do you motivate yourself to do (method X) and then motivate</td>
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<tr>
<td></td>
<td>yourself to stay on task?</td>
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<td></td>
<td>What are you trying to do?</td>
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<td>What is your goal in doing (method X)?</td>
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<td>How do you know if you successfully learned the appropriate material</td>
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<td>after you do (method X)?</td>
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<td></td>
<td>What kind of an environment do you do (method X)?</td>
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<td>You mentioned (method X) does it involve others, or do you do it</td>
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<td>independently?</td>
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<td>If your instructor asked for evidence that you studied, what would you</td>
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<td></td>
<td>show them (if anything)?</td>
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<td></td>
<td>Do you study differently for exams vs. quizzes? How?</td>
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<td>Briefly describe your class to me.</td>
<td>What’s instructor like?</td>
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<td>How do they teach/present?</td>
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<td></td>
<td>Types of work I can expect to do?</td>
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<td></td>
<td>Resources available to study?</td>
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<td>Group work?</td>
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<td>Grading?</td>
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<td>Grade mostly determined by?</td>
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<td>Know grade now?</td>
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<td>Describe a typical HW assignment in your class and your strategies for</td>
<td>If that doesn’t work?</td>
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<tr>
<td>doing HW.</td>
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<tr>
<td>Let’s pretend your instructor gives you an assignment and you find</td>
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<td>yourself more challenged by the assignment than you thought.</td>
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<td>What do you do?</td>
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<tr>
<td>If someone walked into a typical class and observed you “learning”,</td>
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<tr>
<td>what would they see you doing?</td>
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<td>How often do you reflect on how you are learning or how effectively</td>
<td>Does your instructor have you do this?</td>
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<tr>
<td>you learn?</td>
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<td>When did you first have to “study” for any subject in school?</td>
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<td></td>
<td>Why then?</td>
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<td></td>
<td>Science?</td>
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<tr>
<td>You mentioned (methods XYZ). How did you come up with these strategies?</td>
<td>Have your strategies changed over time since you first started studying or</td>
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<tr>
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<td>have they stayed the same?</td>
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<td></td>
<td>Do you use different strategies in different classes?</td>
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<td>What helps you learn?</td>
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<td>What hinders your learning?</td>
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<tr>
<td>Role of student?</td>
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<td>Role of instructor?</td>
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<tr>
<td>Other?</td>
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CHAPTER 2

How students prepare for exams in college-level introductory geoscience courses:

A qualitative analysis of self-regulated learning in 73 student interviews

Submitted to *Journal of Geoscience Education*.

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KEY WORDS

Self-regulation, motivation, undergraduates, learning strategies, metacognition
ABSTRACT

Geoscience education researchers have recently recognized the importance and role of affect and self-regulation as critical mediators between course context and student learning outcomes (e.g., performance and persistence). Introductory physical geology students (n = 73; from 5 U.S. colleges and universities) were interviewed about their learning strategies and experience in their introductory geology course, including how they prepare for an exam. We used a grounded theory approach to analyze the interview data and create a codebook to characterize self-regulated learning as it was reported in interviews. We present an applied model of self-regulated learning and propose that student outcomes would benefit from instructors explicitly incorporating aspects of this model into geoscience courses.

INTRODUCTION

The National Research Council (NRC, 2012) and others have recently called for discipline-based education researchers to recognize the interdependence of affective and cognitive processes in student learning. In a study of geoscience classes, McConnell and van der Hoeven Kraft (2011) examined this in a geoscience context. They identified the critical role affect and self-regulated learning processes play in students’ use of effective cognitive strategies to encode information when learning geoscience. However, self-regulated models of learning have not been investigated in geoscience classrooms. A self-regulated learning model offers researchers and instructors a conceptual framework for understanding student learning in a way that bridges affective, cognitive, and metacognitive domains. Instructors can use a self-regulated learning framework to identify student approaches to class
assignments and help students adopt effective learning strategies and tactics that will improve learning. But what is the specific nature of self-regulated learning in a typical geoscience classroom setting? How can instructors influence these student self-regulatory processes? To facilitate a broader discussion of these issues, this paper provides a brief overview of current models of self-regulated learning (SRL), describes baseline data characterizing SRL by students in introductory geology courses, and discusses how SRL can be used in a geosciences context to improve student learning outcomes.

In a learning environment, such as a geoscience course, there are many variables. There are differences between students such as age, gender, and previous experience. There are also many course context factors such as types of academic tasks, setting, class demographics, and instructional methods including reward structures. Self-regulatory models of learning seek to explain why some students are successful and others are not. In these models of learning, self-regulation and motivation are thought to mediate the relationships between individuals, the classroom context, and student learning outcomes (Pintrich, 2000; Pintrich and Zusho, 2007; Winne and Hadwin, 2008; see Figure 1). In other words, the effects of differences between students and classroom environments they experience may influence outcomes, but may not have a direct causal relationship. Instead, differences in personal characteristics and classroom contexts influence student motivation as well as how they plan and implement learning strategies (self-regulation), which in turn influences outcomes. So, any observed differences in student outcomes by age, gender, instructional methods, etc. are the result of the motivational and self-regulatory strategies and processes a student employs (Figure 1). Therefore, the more we can shape the learning
environment to help students become better self-regulators, the more likely it is that students will learn more in our classes and become more skillful learners.

**What is self-regulated learning?**

Despite some structural differences between commonly used models of SRL (e.g., Pintrich, 2000; Winne & Hadwin, 1998, 2008; Zimmerman, 2000), there is consensus on the underlying assumptions that define the nature of self-regulated learning (see Pintrich, 2000). First, self-regulated learning (SRL) is an active, constructive process. Students are agents, taking ownership of the learning process and making meaning of themselves and their environments. Second, students set goals for their learning, so that learning is a goal-driven process. Third, students attempt to manage their thinking (cognition), motivation, emotions, and behavior through a series of monitoring and control processes, as dictated by their goals and the learning environment (Pintrich, 2000). Self-regulated learners think about how they process information and how their learning directs their engagement. In other words, they are metacognitively aware of their learning processes. That awareness allows them to reflect on how their learning outcomes compare to internal and external standards. For example, when reading a page in a textbook, a student who is metacognitively aware recognizes when they do not understand the text they are reading by comparing their perceived performance to internal standards. They also recognize when they do not understand the specific concepts in the reading that will be on the test by comparing their perceived performance to external, instructor-provided standards of the test such as a practice test or list of learning objectives. Any discrepancies between these standards and their learning outcomes prompt students to
reflect, evaluating the effectiveness of their learning strategies, and perhaps to identify alternative strategies (Winne and Hadwin, 1998). Ideally, the results of these self-evaluations lead to regulation and/or control. Regulation is the change and the adoption of more successful learning strategies and tactics, while control refers to attempts to focus effort and attention to more successfully implement learning strategies and tactics. If there are no discrepancies, students confirm the usefulness of their strategies and tactics and plan to continue to use them. For a more thorough explanation of the role of standards in student self-assessment, see Winne and Hadwin (1998).

The three principal assumptions outlined above can be structurally organized into a general, composite model of SRL (Figure 2). SRL is depicted as a recursive loop that links the commonly accepted macro-level student processes as phases: planning, action, reflection, and regulation (e.g., Greene and Azevedo, 2009). In the planning phase, students define the learning tasks, establish goals, and choose strategies and tactics to achieve those goals. These (and their variations) are examples of micro-level SRL processes. For example, they decide that they need to know how to calculate the age of a rock sample using known ratios of parent and daughter isotopes so they can meet their goal of earning an A on the exam. They choose to accomplish this goal by selecting the tactic of re-reading their notes. In the second phase of SRL, students take action by employing their strategies and corresponding tactics (e.g., re-reading notes, choosing a quiet location so they can focus while reading). In the third phase, which may occur in tandem with the second phase, students reflect on their actions.

Reflection includes three components: monitoring, evaluation, and analysis. Monitoring involves comparing what is being done to a standard or criterion. A student may
monitor thoughts, feelings, and/or behavior, but often may not realize when they do, as this process often occurs covertly. For example, a student who looks at a rock cycle diagram may finish examining it and determine that they didn’t process the information they just read. This realization, which can be a feeling of knowing or judgment of learning, is a product of the monitoring process. Evaluation occurs when a student compares monitoring results to learning goals. The student who read the diagram decided they did not meet their goal to be able to explain the parts of the rock cycle. Analysis then occurs when the student examines the monitoring/evaluation results to either affirm the usefulness of current tactics or determine if modifications and/or alternatives are needed. In this case, the student may analyze the situation and conclude that they did not meet their goal to understand the rock cycle because they were going through the physical motions of implementing the reading strategy, like eyes scanning the words, but did not attach meaning to the words. The realization that their learning goals have not been met may trigger the regulation phase in which the student seeks to improve future outcomes by changing their cognitive and affective tactics and/or adding control tactics to support their current learning strategies. For our example, the student may choose to change cognitive strategies and use a new tactic, such as recreating the diagram of the rock cycle on their own paper. Or, the student may continue to re-read the rock cycle diagram, but add a control tactic, such as reading the diagram labels aloud to help them to focus and process information more effectively.

The composite model of SRL presented in Figure 2 is not meant to be inclusive of all the micro-level SRL processes. Nor is the model meant to imply that SRL is a strictly sequential
pattern. Rather, the model is meant to emphasize that self-regulation is an iterative, recursive process and that “closing the loop” through regulation is key to achieve effective student learning.

**Why is understanding student self-regulation important?**

More expert learners may cycle through the macro-level phases of SRL faster or more effectively than others. Some students may have greater metacognitive awareness and knowledge of SRL than others. Regardless of whether students are metacognitively aware and recognize the process, all students engage in some aspect of self-regulation. Presumably, when completing a task such as studying for an exam, most students go through multiple SRL cycles, until, through reflection, they decide they have met their goals. At the course level, over a semester in a single course, students engage in multiple “units” of task-level SRL cycles as they receive instructor-provided feedback about their class activities, homework, and exam results. Students incorporate these external evaluations into their self-reflections to improve their learning strategies through adaptation. Unfortunately, students have preconceptions and may rely on faulty pre-existing beliefs about learning strategies and tactics. Failure to correctly define the task initially, poor strategy choice, inaccurate reflections, and/or gaps in SRL cycles, can lead to poor student outcomes (Figure 1). Instructors can introduce activities into classes that scaffold the self-regulation skills students need to complete these SRL cycles and perform successfully.

Knowledge of SRL and a delineated SRL model (Figure 2) can help researchers and instructors identify key measurable macro-level components (planning, action, reflection,
regulation) in student learning. By targeting and measuring specific components of SRL, critical weak points for students in the SRL cycle can be identified. Once identified, faculty can select appropriate intervention strategies to implement. Additionally, by physically mapping out student strategies in a SRL cycle format, students and instructors can examine a more holistic picture of individual student learning processes. The cycle format allows students and instructors to get a better idea of why or how learning is or is not occurring. Instructors can use the SRL model (Figure 2) as an academic counselling tool when working with struggling students. By providing a concrete visual (Figure 2) for the abstract conceptual model of the SRL process, students can have an opportunity to increase their metacognitive awareness of their learning processes. By raising student awareness, instructors can help students better understand and monitor their own learning processes.

**Research questions and goals**

The composite model presented in Figure 2 provides a framework for thinking about how students regulate their learning. However, within each of the macro-level processes (planning, action, reflection, and regulation), students engage in micro-level activities and processes. Some researchers have made efforts to identify and characterize the micro-level processes. For example, Greene and Azevedo (2009) investigated SRL in middle and high school students pulled from (unspecified) science classes. Yet, because of limited studies, it is unclear whether these catalogues of SRL micro-processes are global in nature or vary across disciplines. By identifying and examining these micro-level subcomponents of the planning, action, reflection, and regulation phases, researchers and instructors will be able to
examine specific aspects of SRL and may be able to compare SRL processes of high and low performing students, leading to the development of best practices that improve learning. The SLR process, and how to use it to promote better learning, can only be understood if the smaller detailed components are understood. Therefore, this paper focuses on some key questions about student learning in a geosciences context:

- What do the micro-level processes of planning, action, reflection, and regulation look like in practice when students engage in learning tasks such as studying for an exam?
- How does class structure and instructor behavior influence these SRL processes?
- Are students using a unique portfolio of micro-level processes in introductory geology courses?

The overall objective of this study was to collect a baseline assessment of the four phases of the self-regulated learning experience of students in introductory geology courses as they prepare for a performance evaluation (exam). To accomplish this, we developed a qualitative tool for characterizing SRL using grounded theory methods. With this tool, future geoscience SRL investigations will be grounded in the student perspective and voice when conceptually modeling the ways in which students actively manage their learning in geology. Grounded theory methods derive concepts, properties, and dimensions of SRL from the data collected, rather than measuring the data using previously established catalogues. As it is unclear how SRL processes and skills transfer across disciplines, we can more accurately represent what processes occur specifically in the context of a geoscience course by using a grounded theory approach that allows the SRL model to emerge from the data.
METHODS

Data collection

A total of 73 students, in introductory physical geology courses from 2 research universities and 3 community colleges, volunteered to be interviewed as part of a larger study (Gilbert et al., 2012, Lukes and McConnell, *in prep*). Participants were offered a nominal gift card for participating in the interview. The university classes typically consisted of 80-150 students each; the community college classes consisted of fewer than 50 students. University students were interviewed between weeks 10 and 12 of the semester; the students had taken 2 exams prior to interview. All of the community college students were interviewed between week 8 and 9 of the semester after completing 1 or 2 exams, with the exception of students from 1 community college class. In that class, students were interviewed during week 5 -- the week before their first exam. All courses provided students with a textbook or an online reading resource with a suggested or assigned reading schedule.

All instructors required students to complete homework and in-class activities; the type of activities varied and included online practice quizzes, reading reflections, short research topics, and practice problems. All courses (except one) had 3-4 exams during the semester. Exams in five of those courses were comprised primarily of multiple choice questions, but also included 2-3 short answer questions. In one class, the exams consisted entirely of multiple choice questions. One course did not have exams, but instead had shorter, more frequent quizzes that were similar to the larger, less frequent exams in the other courses.
Data collection methods are outlined in the top box (Phase 1) of Figure 3. Student interviews were conducted in person by the first author and lasted 15-75 minutes depending on student responses. The complete list of questions and interview protocol are described in Lukes and McConnell, *in prep.*, but in essence, students were asked to “walk [the interviewer] through a typical week or two before an exam [in geology], how do you prepare?” Following a grounded theory approach to the study (Oktay, 2012), the interviews were semi-structured in nature, providing students with open ended questions that allowed student-identified themes to emerge. The themes and recurring ideas could be further investigated by the interviewer with follow up questions. Interviews were digitally recorded and later transcribed. Upon completion of the interview, participants reviewed the interviewer’s notes to confirm accuracy. Participant confidentiality was maintained by assigning each participant a pseudonym and by removing identifiers from transcripts (including reference to geographic locations, institution, other students’, and instructors’ names).

**Participants**

Participants were nearly evenly split between female (49%) and male. Participants were also about half from research universities (47%) and community colleges. 22% of the participants reported they were of an ethnicity other than white (non-Hispanic) and 12% did not disclose ethnicity/race. The majority of students were traditional college age (57% reporting age of 18-21), with 10% reporting ages 22-24 and 16% reporting 25 or older (17% did not disclose their age). Most (83%) indicated that were “very interested” or “somewhat interested” in science, but only 22% indicated that they were “very likely” or “somewhat likely” to be a
science major (37% did not disclose their major intent). 75% of students earned an A or a B in the class at the end of the semester, but only 43% had earned an A or B average on exams.

Methods of qualitative analysis

Memos are reflective notes qualitative researchers make, documenting their thought process about what they are learning about concepts and relationships from the data during analysis. Memos are a critical part of qualitative research process, as they lend credibility and trustworthiness to meanings derived from the data. For this study, after the interview, the interviewer created memos that summarized non-verbal observations of the students and interviewer reactions and impressions, identified emerging ideas and themes, and compared interview notes and memos to data in previous interviews and memos. The memos facilitated the constant comparison component of grounded theory methods (Phase 1 in Figure 3). Excerpts from the interviews that pertained to student explanations of how they study for an exam were first isolated from the rest of the transcript. Then, the excerpts were reviewed multiple times, and dissected by the primary investigator at the individual thought level (all 73 interviews; Phase 2 in Figure 3). Subsequently, memos were created to identify recurring ideas and make initial interpretations and models. From the memos, a list of open codes was compiled and revised in a recursive manner as the interview transcripts were analyzed, also resulting in revisions of the visual analysis models in memos. To establish the trustworthiness of the primary investigator’s interpretations, 3 randomly picked transcript excerpts were tagged and initially coded thought-by-thought by two other researchers, who were otherwise not involved in the study, to identify specific activities students engaged in.
and the purpose behind their engagement. Upon discussion, 100% agreement was found between investigators using the methods of Gorden (1992), establishing validity and reliability of emergent codes.

These initial recurring ideas and open codes were compared to existing SRL model components and products previously discussed in the SRL literature. From this and recursive reflection by the primary researcher, selective codes were identified to create a codebook (Table 1). The codebook was benchmarked (expert review to support credibility) by two educational psychologists and four geoscience education researchers. This codebook was then used by the three researchers to co-code five interviews. There was 96% agreement between the three coders, so the reliability of the codebook was established and the codebook was used by the primary researcher to code the remaining interviews.

RESULTS

Overall, at the macro-level, the SRL relationships identified in this study (Table 1) match those in existing SRL models. Students reported aspects of planning, using tactics (action), reflecting, and regulating. However, students mostly reported these macro-levels implicitly through the reporting of micro-level tactics. These micro-level results are organized by macro-level SRL phases and presented using student data identified using pseudonyms. The emergent codebook adds to existing general SRL models by distinguishing between the use of cognitive and control strategies during the acting and regulating phases. Further, we place the use of these strategies in the context of exam preparation in the authentic setting of an
introductory geoscience course. We offer some suggestions for instructors seeking to have their students become more intentional about their learning process.

**Planning**

Planning emerged at the macro-level as a process in which a student indicated they were making a decision prior to engaging in an action to process information. Planning involved defining the task, choosing goals, identifying and choosing strategies and tactics. At the micro-level, students defined the task in a variety of ways. Some students identified the instructor as the critical gatekeeper to their preparation efforts. For example, Ray indicated he uses role playing, pretending he is the instructor: “I put myself as teacher. What would I ask?” Some students, like Dylan, indicated they heavily relied on perceived instructor cues during class to identify what they needed to study. “Most teachers have a way of implying to their students what they want you to do and what exactly [they] want you to know. [laughs] And one of my skills in school is that game, to be able to pick up on that, so that way I can save time studying.” So, if Dylan didn’t perceive a concept as being implicitly “flagged” by the instructor, he didn’t review it when preparing for an exam. The instructor behavior directly influences what content he plans to study.

Other students viewed the course materials as a map or guide to their preparation efforts. For example, Cassandra used the instructor-provided class notes and reading assignment to systematically identify key items to learn or review. Like many students, Cassandra relies on course resources like her textbook. However, unlike students such as Dylan and Ray,
Cassandra primarily relied on her internal criteria and judgments of what’s important to know in those provided resources rather than trying to take the instructor’s perspective of what’s important.

Some students did not report any clear task definition or lacked a systematic approach. For example, Amy reported she re-read all the notes and completed all the homework assignments, without identifying any overt list of key concepts to prepare. In other words, she was learning for the first time or reviewing everything that was covered or talked about in class. Others, like Elissa, saw the instructor-provided notes (PowerPoint slides) as pre-defined lists of what to study during her exam preparation because “…[notes have] most of the information that’ll be on the test…”

While students immediately started describing their exam preparation strategies and tactics during the interviews, student articulation of how they identified and chose strategies/tactics to meet their learning goals was largely absent. There were instances, however, when students explained that they relied on previous beliefs about learning/studying. For example, after describing her tactics to embed information into her memory, Alison declared, “I’ve always done that just to remember anything!” There were also instances where students were explicitly instructed to use particular strategies by an instructor. For example, Dylan used distributed, or spaced timing cognitive and control tactics because “[instructor] says to do it, to do practice quiz right after I get out of class, then do it again a few days later.” Similarly, Claire said that she re-wrote information rather than re-reading because she “heard from
another professor that if you write when you are studying, then you’ll remember it better.” In both these cases, the students do not communicate a metacognitive conditional knowledge of why they are using these methods. In other words, they do not appear to understand why the strategy is useful, how it helps them learn, nor why it would be appropriate to use in this situation. Instead, they are relying on the instructor’s perceived authority and choice to share this technique with them.

The majority of micro-level tactics in planning, appear to be directly connected to the use of course resources (e.g., study guides, learning objectives, practice problems, assigned reading) or stem from student interpretations of the instructor actions and curriculum choices. Many students noted the instructor’s verbal emphasis during lecture, explicit instruction on study strategies, or their emphasis of assigned topics or pages in the textbook. However, many students appear to fail to assess the specifics of the context of their course and rely on “tried and true” tactics by default. Or their default strategies proved to yield the desired results at the time of the interview, reaffirming the strategy and tactic choices students made. As Dylan put it, “so far this technique has gotten me good results. It’s gotten me A’s on both my tests.”

**Action (Using tactics)**

Since the goal is ultimately learning, actions are the attempts student make to cognitively process, or encode, information. Two major sets of micro-level processes emerged from the interview data: cognitive tactics and control tactics (Table 1). Students reported a variety of
cognitive tactics that they used to process, or encode, information. Many students reported shallow cognitive learning strategies that encode information into the short term memory, such as passive rehearsal tactics in which repetition is the end process (Weinstein & Jung, 2010). Students reported passive rehearsal strategies like re-reading or re-writing notes, as well as drill exercises for memory. For example, Walt reported, “the main thing that I do is just go through those [online multiple choice reading] quizzes as many times as I can.” He explains his purpose is to not identify the ones he is having difficulty with (which would be a monitoring process), but to encode the answers into his memory. The implication is that he believes that the online quiz questions are representative or likely to be on the exam. Walt and other students also reported more active rehearsal tactics, such as highlighting or starring key items in notes or the textbook. In active rehearsal strategies, students engage in repetition activities as a way to hold onto information so that it can be further processed (Weinstein and Jung, 2010).

Some students reported deeper cognitive learning tactics. Students use deeper tactics to transform or translate information in order to make connections between what the they are trying to learn and their prior knowledge, experience, attitudes, and beliefs (Weinstein and Jung, 2010). Students reported basic elaboration tactics such as paraphrasing instructor-provided notes or the textbook and seeking help from peers, instructor, and/or webpages with the purpose of clarification. For example, aside from just re-reading their books, Hannah reported that she “takes notes as [she] reads” and Alison reported that she will elaborate by creating mnemonic associations to help her remember facts or concepts because “it really
helps to associate with the things I know.” Students also reported a variety of what Weinstein and Jung (2010) define as advanced elaboration tactics, such as visualization, trying to teach someone else, creating and responding to questions about the material to be studied, creating analogies, perspective taking, and using everyday experience to try to understand a concept. For example, Ruth discussed how she related what she was learning in geology to concepts she was learning in her other courses.

Another category of deeper cognitive learning strategies are organization tactics. Organization tactics, in contrast with elaboration tactics, focus on reconfiguring information. Through organization tactics, a student creates a new scheme to structure information into a new meaningful way to facilitate meaningful encoding of concepts into memory (Weinstein and Jung, 2010). For example, Albert, used the instructor-provided summary slides to reorganize all of the previous class notes he has taken. As he explained, “I print [a] copy of that and put all my notes on that to understand how all the pieces fit together.” He is not just passively re-writing the notes, he is identifying connections, and the instructor-provided re-organized structure helps him similarly re-organize the concepts in his mind.

Students also reported a variety of control tactics to support their choice of cognitive strategies described above. For example, Marty used a portfolio of control tactics when preparing for an exam. He reported, “I motivate myself just by trying to throw myself into a sort of panic, by imagining that it’s due sooner than it is. It usually helps because necessity forces me to do a lot of things.” In other words, he creates fake deadlines to evoke emotions.
that motivate him to focus his attention and efforts on engaging in exam preparation activities. He goes on to explain that he “need[s] to have all the materials done like studying by the [day of the exam] so [he] can rest easy on [the exam day].” In this way, he engages in emotional control strategies to plan his ability to focus the day of the exam. He also uses micro-level tactics to keep his attention on processing information when studying. Like other students such as Tracey who studies in her bedroom away from her roommate because “she always talks and it’s distracting,” Marty also chooses an environment that has the least audible distractions. He does this to focus his attention on cognitive actions like recalling as many details and facts associated with an instructor-provided learning objective. Similarly, several students reported efforts to control their attention and frequently identified re-writing notes or purposely writing out answers as an intentional choice to force themselves to focus and think about the material. Others describe efforts to manage time in order to control attention, motivation, and/or emotion. For example, Ellen chooses to cram a day or two before the exam (a massed, rather than distributed, timeline for exam preparation) because as she reasons, “I feel like if I do it too soon or too early, I’m going to forget all the information.” Within that larger chunk of time, however, she takes break to control her attention and stay focused on the task. In contrast to Ellen, Ethan, plans his time to control his emotional state, as evidenced by his statement, “I try to stop studying the last day or two before an exam. I mean I don’t like to overload and get stressed out. I like to go into it nice and calm and relaxed.”
Reflecting

Reflection emerged as a collection of metacognitive processes that led to new decisions. The reflection process includes monitoring, evaluation, and analysis. This can often occur in conjunction with action or immediately after acting. During the reflection process, a student’s metacognitive skills are put to the test. At the micro-level, students primarily report using some form of self-testing to predict and simulate the exam performance, as well as to monitor and evaluate their progress towards their performance goals. All students who reported self-testing view their self-testing results as representative of how they will do on the exam, regardless of whether their self-testing relies on internal or external standards for monitoring and evaluation. The difference between students emerges when we examine what they are monitoring. Different students monitor different things: learning process, memory, and/or comprehension.

The majority of students report that they are monitoring and evaluating memory. For example, George uses course resources to monitor his memory. He re-takes online multiple choice reading quizzes (students are allowed unlimited submissions) to identify which questions/answers he can’t remember. He uses this information to create flashcards with those specific questions/answers and drills until he remembers the answers. Campbell, relies on more internal standards to monitor. She monitors her memory by “just tell[ing] it to [herself] without looking at the book.” She doesn’t go back and check the book to determine if she accurately remembered the information, instead she relies on her feelings of remembering the material. Similarly, Alison reported, “I’ll write it down and then like write
it down again and make sure I know it.” Others, like Cassandra, rely on a mix of internal and external standards by combining instructor-provided self-testing materials (e.g., study guide, online quizzes) and their own notes to create their own question and answer flashcards.

Other students explicitly indicate they are monitoring and evaluating comprehension, not just memory. For example, Albert reported “when I can visualize it without having to be what a written word said [visually paraphrasing], but when …I have a feel for it.” He distinguishes between remembering the words and understanding it as part of his mental models. Similarly, Ruth creates a list of key things to know, and then evaluates her understanding by making judgments about her feelings of knowing when she reviews the list. “If I feel confident about it,” she said, “I typically know that I understand it.”

Lastly, many students also report the use of this self-testing micro-level tactic (monitoring and evaluation) as a pre-planning tool. For example, to identify what she needs to study (the task), Kendra monitors and evaluates her understanding of the instructor-provided learning objectives. Jefferson completes an instructor-provided online practice exam to determine which concepts he needs to study. Others use instructor-provided study guides to self-test and identify the topics they don’t understand or remember.

Like choosing strategies, analyzing self-evaluations is often a covert process. Few students explicitly described a step-by-step analysis process. For example, Lexi re-reads the instructor-provided notes during the early stages of her exam preparation and “if I’m in the
notes and I don’t understand something, I would go back to the book.” In other words, she monitors her reading comprehension and made some covert analysis to decide to change her tactic from re-reading the notes to seek help from alternative resources (in this case, her textbook). However, some students do report evidence suggesting an analysis process. For example, Doris explains “depending how good I feel about how well I know that information…If I don’t know it or there is a lot of terminology, I’ll go through and I’ll write everything down again, just as a visual learning aide. The pictures, it’s easy for me to put it together if I have that visual aide.” She monitors and evaluates, as evidenced by reporting feelings of knowing, but she also explicitly links the resulting self-evaluations to her next steps. If she judges that there are things she does not know, she chooses the tactics of passive rehearsal and organization because she has determined that these will help her fill knowledge gaps and be successful.

Regulating

Regulating emerges as re-actions that occur after a reflection event as the result of a decision made during reflection. These re-actions may involve changes in aspects of planning, action, and/or reflection. Regulation can also be the continuation of tactics in use prior to reflection. Continuing a tactic is the result of deciding that the tactic was successful and is “working”, but may need more time and/or repetitions.

Most students defined their task to be learning the material they perceived as likely to be on the exam. As such, many students re-defined the task over time by refining the perceived list
of concepts they need to learn. For example, Walt re-reads his homework assignments and identifies the specific topics he “was way off on.” His exam preparation task at that point changes and is no longer just re-reading all of the homework assignments. Instead, he uses the homework assignments to serve as an external task standard to monitor his learning and he targets his learning to “make sure [he] hits that [topic] over and over again.” Many students reported a similar process of re-defining the task while also choosing new cognitive tactics. Walt doesn’t “hit that topic over and over again” by simply re-reading the homework responses. Instead, he practices recall through self-testing drills. Another student, Daniella, after self-testing with the instructor-provided learning objectives on flashcards, creates her own study guide packets that are “only on the stuff I have a hard time with, not like everything.” She has already monitored and analyzed her progress in understanding the material and so can re-define the task as learning those items she perceives as difficult. In other words, she used the reflection results to change her tactic from passive rehearsal (flashcards) to deeper tactics including organization and elaboration (creating the detailed study guide).

Some students, however, did not change tactics, continuing with the same cognitive strategy, but with a different target list of concepts. For example, Ethan reported, “I read [notes] over once and then I’ll look at the practice questions and from there if I don’t know how to answer the practice questions I’ll go back [and re-read notes].” Ethan revises his concept list, but applies the same passive rehearsal strategy by continuing to use the micro-level tactic of re-reading his notes.
Students also report the use of new control strategies to keep motivation. Daniella, who, when she feels she isn’t getting anywhere by her studying (whether using her flashcards or self-authored study guides), changes her focus to study items she perceives as easier to keep herself motivated. She also controls her motivation and focus by making the guides colorful and “pretty” to evoke positive feelings.

**DISCUSSION**

Despite the limitations noted by others of using self-report data to assess self-regulated learning (e.g., Winne and Jamieson-Noel, 2002), qualitative methods provide a rich insight to student rationales that quantitative methods cannot address. The codebook reported here presents SRL as it is measured in a classroom, rather than experimental setting. Because the codebook is grounded in student data from such a course context, it also provides a robust application to pedagogy and student learning. Grounded theory studies typically consider 20-30 interviews as sufficient to reach saturation for emergent themes to establish validity. This study presents qualitative data based on more than twice that number of interviews (n=73) and the population’s demographic data is representative of the entire population (>3,000; Gilbert et al, 2012). Consequently, the model presented here has greater strength and applicability beyond the course context of the specific participating students.

Additionally, identifying the micro-level processes that students report may provide insights for researchers and future studies attempting to explain the relationships between specific self-regulatory processes and student outcomes.
**Implications for research**

The results from this study illustrate the value of engaging in qualitative research methods. Compared to quantitative attempts to characterize SRL in geoscience courses (Gilbert et al, 2012), qualitative methods generate more detailed student explanations. Additionally, qualitative methods provide previously uncaptured insights to the relationships between self-regulatory processes, student outcomes, and student characteristics in specific educational settings (the connecting arrows in Figure 1). Additionally, the qualitative research tool (codebook) created as the result of this study can be used by future researchers to measure self-regulatory processes. If future studies identify and measure micro-level self-regulatory tactics in student populations, they can potentially identify relationships between self-regulatory processes, student outcomes, and student characteristics (Figure 1). For example, data about the self-regulatory tactics and student approaches to using course resources and instructor cues can be used to identify and examine any learning outcome differences due to gender, age, high vs. low performing students, etc. Alternatively, researchers can use the same tool to document and understand how students approach their learning tasks in general in a geoscience course.

**Implications for practice**

**Planning**

While instructors are unlikely to influence the personal goals of a student, instructors have the potential to influence other aspects of planning. For a novice with little previous knowledge of geosciences, the task of sorting out key ideas and details can be a challenge.
As Ethan explained, “it just helps you know how to focus your energies studying. Cause I mean without the study guides or what not, I could be reading anything, something that possibly isn’t relevant.” If a student, like Ethan, incorrectly identifies the learning task, their later employment of cognitive strategies in the action phase of SRL may be inappropriate and have little impact on their exam performance. Instructors can help students like Ethan learn to better identify/define their learning task by providing clear and explicit learning objectives.

Instructors can also potentially help students to choose more appropriate cognitive learning strategies and tactics. Students come to an introductory college course with a set of strategies and tactics that have worked for them in the past and they will choose from these pre-existing strategies and tactics to study for geoscience courses and tasks. When making the choice, they use their interpretation of the task at hand to identify and choose appropriate strategies and tactics. Previous studies (e.g., Karpicke, Butler, & Roediger, 2009) have shown that many students use learning strategies that result in surficial understanding (e.g., rehearsal strategies such as using flashcards with the purpose of memorizing). These strategies are not as effective, in terms of performance, compared to deeper strategies (e.g., creating an outline or concept map) that require them to organize and recall information. Consequently, metacognitive gaps (not knowing about the effectiveness of different learning strategies) may result in poor student performance. These gaps can potentially be reduced if an instructor explicitly describes the strengths and weaknesses of different learning strategies and explains how to use the appropriate learning tactics step-by-step in a geoscience class context. For
example, an instructor could have students read a short article on learning to learn or
describing specific study strategies (e.g., Weinstein & Jung, 2010) and could model how to
use sample strategies in class by thinking aloud through an example with the class.

**Action**

Reading about effective strategies and seeing strategies being used by others may not be
sufficient to cause some students to change their behavior and use effective strategies and
tactics when studying for an exam. However, instructors can require students to use known
strategies and tactics as part of their course design. Consider Ethan, who reported re-reading
his notes and then self-testing himself with the instructor-provided [optional] study guide
questions. When he was asked what he would have done to prepare if his instructor hadn’t
provided the list of study guide questions, he responded, “there’s a lot of material. I’d
probably go over the readings a couple times more.” In other words, he would have
defaulted to spending more time using his less effective passive rehearsal strategy rather than
seeking and employing a new strategy or tactic. Assigning students tasks that require deeper
learning strategies forces students to use more effective learning tactics outside of class. For
example, in-class activities or homework assignments that require students to summarize,
create outlines, apply concepts to new scenarios, or create visualizations for concepts will
give students opportunities to practice these more effective methods. Requiring students to
take inquiry-based labs as a co-requisite with a lecture class may also help supports students
develop learning skills. For example, Ruth described the lab as helping her prepare for the
exam, “the geology lab helps you put it into real life terms…actually putting stuff to use.”
With continued practice, these models of learning tactics may become embedded as part of a student’s learning strategy in geoscience.

Instructors can also promote the use of strategies that helps students in focusing attention and effort (known as control strategies). For example, a student may apply time management strategies to study in spaced (e.g., 15 minutes every day) or massed (e.g., 3 hour block day before the exam) units of time. Yet, research indicates that spaced timing produces better memory retention (Son & Simon, 2012). So, instructors can structure a class such that students have frequent assignments, such as practice questions or quizzes each class or week, rather than having only 2-3 exams over the semester. Assignments which are collected and/or assessed regularly as part of the course will help students use (and ideally internalize) effective cognitive and control strategies. Technologies, such as class management systems (e.g., Moodle, Blackboard), that provide delivery of short, self-graded quizzes, allow students to reflect and self-assess learning without requiring instructor time.

**Reflection**

For effective learning, through monitoring and evaluation, students must be able to decide whether they are on task and whether that can recall and understand the material they planned to learn. In order to decide, a student has to first be self-aware. Without self-awareness and self-monitoring skills, the reflection phase of SRL may be a critical failure point for low performing students. Metacognitive skills, such as self-monitoring, have been linked to better performance (Thiede, et al., 2003). Instructors can facilitate this monitoring process by having students make formal judgments about their learning. Summative
assessments, such as online practice quizzes with unlimited opportunities to retake, or formative assessments, such as Conceptests, think-pair-share activities, and exam wrappers (pre-post exam reflections), can be effective. Without an opportunity for self-assessment, students may enter an exam unaware of gaps in their understanding, or with “illusions of competence” (Karpicke, Butler, & Roediger, 2009).

During analysis, a student has to decide why their strategy didn’t produce the desired results. For productive and successful analysis, students must be honest with themselves. To be honest, they must have knowledge of how strategies and tactics work to improve learning and a metacognitive awareness about their actions when implementing tactics. They have to be able to decide if they did or did not perform the strategy correctly. They also have to be able to decide if the strategy appropriately matched the task conditions. Students may make incorrect assessments and have inaccurate beliefs about their own studying behavior and knowledge of cognitive strategies (Karpicke, Butler, & Roediger, 2009). Overcoming student beliefs can be challenging (Strike & Posner, 1992; Pintrich, Marx, and Boyle, 1993). If a student fails an exam, but believes that their pre-existing, long-used strategy for learning was appropriate and works, they are likely to attribute their failure to non-strategy related factors such as internal sources (e.g., not enough time/effort on strategy) or external sources (e.g., the questions were poorly worded). This misattribution may prevent them from identifying and engaging in different activities that will more effectively regulate their learning and lead to better outcomes. Instructors can help students hone their reflective analysis skills by having students reflect on the adequacy and appropriateness of their study strategies, as well as formalize their new plans for the next exam (regulation) through
activities such as exam wrappers (Thompson, 2012). Instructors can also emphasize the importance and value of reflection by reviewing sample exam questions in class, both prior to an exam and after an exam. A think aloud method could be used to explain different strategies a student could use or could have used to prepare for a specific exam question. This modeling process is especially useful for students who come into a course with a deficient knowledge of cognitive strategies and tactics.

**Regulation**

Regulation occurs as the result of reflection; therefore, reflection is a critical precursor to student implementation of regulation and control. Instructors help students improve regulation by promoting the reflection process, as discussed previously, by including overt reflection exercises as a regular part of coursework. For example, exam wrappers ask students to explicitly identify the changes they will make when they do future tasks and subsequently to consider the effectiveness of the changes they have made. Reflection activities make students accountable for monitoring and assessing their regulation, and can help them determine if their regulation is adequate. Instructors can quickly identify those students who are inaccurate in their self-monitoring by scanning these reflections and can help those students regulate, or “close the learning loop,” by providing instructor observations. Additionally, instructors can provide students with a SRL model to use as an external standard in their self-monitoring of their SRL processes. If students are given a visual model for SRL, such as the one presented here (Figure 2 or Table 1), students will be
able to more readily self-identify which part they need to improve. This may give them a way to communicate their needs and seek help more regularly.

**Limitations and future work**

When discussing their planning processes, few students reported their strategy and tactic selection process. This, and other apparent omissions by students, is not unexpected because strategy identification and selection tend to be covert processes. In other words, students started describing their tactics without explicitly explaining why they had chosen those tactics. The apparent omissions could also be due to the nature of the interview protocol. Most students were prompted later in the interview to explain how their preparation plan varied across courses and time. Students tended to explain their rationale for choosing strategies in geology when they were comparing geology to other courses like Math or English. While it would have been useful to include the student responses to this later interview protocol question in this study’s analysis, these responses were not included because not all of the students were asked this question.

Another limitation is the variation of the conduct of student interviews. Because the primary investigator could only be in one place at a time and had other obligations, interviews were conducted at different weeks in the students’ semesters (between weeks 5 and 12). The iterative, recursive nature of SRL suggests student strategy use would change over a semester as they have opportunities to reflect and internalize results from multiple exams. However, the purpose of this study was to characterize SRL as reported by students, rather than
document changes in SRL patterns over time. Using a dataset of variable timing is reasonable to accomplish this goal. Future studies could address the issue of change in SRL over time. Similarly, the purpose of this study was not to investigate relationships between SRL tactics and student characteristic variables such as previous academic experience, age, and gender or student outcomes such as average exam grade. Future studies could examine the relationships between these variables and the micro-tactics reported by participants.

CONCLUSION

The applied SRL model we present here can be used by researchers to identify specific areas of the learning process to target to study the impact of interventions. Instructors can use the model to inform their course design to facilitate student self-regulatory processes to positively impact student outcomes. Additionally, the model has the potential to be used by students as a reflection tool to improve their performance. Future studies can use the presented codebook to examine relationships between student characteristics (e.g., gender), SRL processes, and outcomes (e.g., high performance).

ACKNOWLEDGEMENTS

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REFERENCES


Figure captions

Figure 1. Role of SR processes and student outcomes (based on Pintrich and Zusho, 2007)
Student outcomes like performance and interest may correlate with differences in student characteristics and course contexts, but that difference is mediated by differences in the variations in student motivational and self-regulatory processes.

Figure 2. General composite model of self-regulated learning (SRL)
When a student learns, they go through macro-level phases of planning, action, reflection, and regulation. Planning, action, and reflection are depicted as boxes because each phase includes a unique set of subcomponents. Planning includes identifying/defining the task, goal setting, and identifying/choosing strategies. Action includes cognitive and control strategies. Reflection includes monitoring, evaluation, and analysis. Regulation, on the other hand is the “closing of the loop” in the learning process. Regulation, unlike the three other phases, is not comprised of a unique set of micro-level components of its own. Instead, regulation is the enactment of the decision made during reflection phase to continue or change the strategies and tactics being used by a student. Since regulation is primarily a continuation or modification of micro-level components in planning and action phases, it is depicted as two arrows connecting to planning and action. This general model is not to be interpreted as being inclusive of all processes associated with SRL or as a strict time sequence process.
Figure 3. Research methods

The qualitative methods used in this study can be divided into four phases. Phase 1 describes the data collection process. Phase 2 describes how the codes for the codebook were developed. Phase 3 describes how the codebook was validated externally. Phase 4 describes how the codebook was internally validated and used to analyze the interviews.
Figure 1. Role of self-regulation and student outcomes
Figure 2. General composite model of SRL

*Reflection includes monitoring (keeping track of thoughts, feelings, and behavior), evaluation (comparing results to goals), and analysis (deciding if the approach used is effective and appropriate).
Figure 3. Research methods
**Table 1 SRL Codebook**

<table>
<thead>
<tr>
<th>1. Planning - Student making decisions prior to engaging in action.</th>
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<tbody>
<tr>
<td><strong>1.1 Identifying / defining the task</strong></td>
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<tr>
<td><strong>1.2. Choosing goals</strong></td>
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<td><strong>1.3. Identifying &amp; choosing strategies</strong></td>
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<tr>
<th>2. Acting - Student attempting to encode information or support efforts to encode information.</th>
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<tr>
<td><strong>2.1 Cognitive tactics - Actions to encode the information into their memory (whether short term or long term).</strong></td>
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<td><strong>2.1.1 Surface learning</strong></td>
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<td><strong>2.1.2 Deep learning</strong></td>
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</table>
| 2.2 Control tactics: Actions to support the effective completion of cognitive strategy. | 2.2.1. Affect (motivation, emotion) | Student manipulates emotion/motivation to evoke desired behavior  
• self-talk remind oneself about personal goals (e.g., perform well for future goals)  
• make themselves feel guilty or stressed to evoke desired behavior |
| 2.2.2. Time | Student manipulates time on task and intentionally chooses a time schedule to evoke desired behavior.  
• schedule time after each class to study  
• only study day or two before exam so can remember information |
| 2.2.3. Environment | Student manipulates physical and social environment to reduce distractions and increase focus on task.  
• choosing a quiet location to work  
• choosing to work alone  
• choosing to work with others who are motivated  
• collecting resources |
| 2.2.4. Metacognitive awareness | Student manipulates cognitive behaviors through overt self-awareness and process monitoring.  
• Consciously thinking about how focused/how much attention you are paying  
• using self-talk to redirect focus, actively thinking about meaning |
### 3. Reflecting - Students engaging in metacognitive processes to make new decisions or affirm existing strategy choices.

<table>
<thead>
<tr>
<th>3.1 Monitoring &amp; Evaluating - comparing performance to a standard whether it is an external standard or an internal one.</th>
<th>3.1.1. for process</th>
<th>Student is determining if control and metacognitive strategies were implemented properly according to their standards.</th>
</tr>
</thead>
</table>
| | 3.1.2. for memory | The goal is to see if that accessible memory encoding has been established (may include many of the strategies discussed under elaboration, but purpose is different).  
- using flash cards to quiz your ability to remember answer  
- covering up your notes and recalling what was written on them  
- using practice questions with answer keys to recall correct answer |
| | 3.1.3. for understanding | The goal is to see if that accessible understanding has been established (may include many of the strategies discussed under elaboration, but purpose is different).  
- using questions or key terms as cues to recall everything they know about a topic and then checking for gaps in understanding or confusing parts  
- explaining a concept to someone else, while identifying confusing parts or inability to answer follow up questions from other person  
- reading a passage or listening to someone explain it and identifying gaps in understanding or confusing parts |
| | 3.1.4 unclear purpose - Monitoring/evaluation is described, but the purpose is unclear. |

| 3.2 Analyzing - Students make inferences and draw conclusions from monitoring data. |  | identifying where/why things went wrong  
confirming that their strategy/tactic works  
identifying need for new strategies/tactics |
<table>
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<tr>
<th>4. Regulating: Students re-acting (occur AFTER reflection event as the result of reflection).</th>
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<tbody>
<tr>
<td><strong>4.1 Redefining the task</strong> - Student changes their beliefs about the task itself.</td>
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<tr>
<td>- If student’s task was to initially learn the material by reading, they may change the task to be identifying and learning the study guide items they don't know.</td>
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<tr>
<td><strong>4.2 Choosing new goals</strong> - Student changes targets from what s/he started with.</td>
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<tr>
<td>- Student changes target from remembering all of the vocabulary term definitions to remembering at least 70% of them.</td>
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<tr>
<td><strong>4.3 Identifying and choosing new cognitive strategies/tactics</strong> - Student changes initial or earlier cognitive strategy/tactic to replace or supplement initial strategy.</td>
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<td>- replacing an earlier cognitive strategy/tactic with a new one</td>
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<tr>
<td>- adding a cognitive new strategy/tactic</td>
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<tr>
<td>- stopping an earlier strategy/tactic</td>
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<tr>
<td>- A student who was rereading notes (rehearsal) decides to create an outline from reading (organization).</td>
</tr>
<tr>
<td><strong>4.4 Identifying and choosing new control strategies/tactics</strong> - Student changes initial or earlier control strategy/tactic to replace or supplement initial strategy.</td>
</tr>
<tr>
<td>- replacing an earlier control strategy/tactic with a new one</td>
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<tr>
<td>- adding a control new strategy/tactic</td>
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<tr>
<td>- stopping an earlier strategy/tactic</td>
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<tr>
<td>- A student was studying with another student and decides s/he is off task and chooses to study alone instead.</td>
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CHAPTER 3

What’s the difference? Comparing the exam preparation approaches of high and low performing students in introductory geology courses

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Self-regulation, motivation, undergraduates, learning strategies, metacognition
ABSTRACT

Geoscience education researchers have recently recognized the importance and role of affect and self-regulation as critical mediators between course context and student learning outcomes (e.g., performance and persistence). Introductory physical geology students (n = 73; from 5 U.S. colleges and universities) were interviewed about their learning strategies and experience in geology, including how they prepare for an exam. We used a mixed methods approach to analyze the interview data to characterize self-regulated learning as it was reported in interviews. We present an applied model of self-regulated learning and propose that student outcomes would benefit from instructors explicitly incorporating aspects of this model into geoscience courses.

INTRODUCTION

There are many variables that impact student learning in a geoscience course. There are differences between students such as age, gender, and previous experience. There are also many situational factors for a given course such as types of academic tasks, online or in person setting, class size, content, and instructional methods, including reward structures. These situational factors are essentially controlled for in a given course section as students receive the same instructor-provided resources and assignments. Despite these similar “learning experiences,” some students perform well on course exams and others do not. Self-regulated models of learning seek to explain some of these discrepancies in performance.
Self-regulation and motivation are thought to mediate the relationships between individuals, the classroom context, and student learning outcomes (Pintrich, 2000; Pintrich and Zusho, 2007; Winne and Hadwin, 2008). In other words, differences in personal characteristics and situational factors influence student motivation as well as how they plan and implement learning strategies (self-regulation), which in turn influences outcomes. We seek to analyze the strategies and tactics used by high and low performing students to characterize their learning processes in an effort to explain differences in performance and build a learning model to improve student success. We can shape the learning environment to facilitate student success if we can identify the strategies and tactics used by high performing students and uncover the barriers that impede low performing students.

What is self-regulated learning?

Self-regulated learning (SRL) refers to a broad process in which students learn by setting goals and actively managing their thinking (cognition), motivation, and behaviors through a series of monitoring and control processes (Pintrich, 2000). Students are aware of their information learning processes and behaviors (metacognition). That awareness allows them to choose to reflect on how their learning outcomes compare to internal and external standards. The results of this comparison are used to inform and revise internal decisions about strategy and tactic use in an effort to meet learning goals. This process is often represented in a general four stage or phase model (Figure 1) involving planning, action, reflection, and regulation. This model of SRL is not meant to be interpreted as a strictly sequential process. Rather, some phases may overlap.
For example, consider an introductory class in which an instructor teaches about karst topography. A student adopts the instructor’s presented learning objective for an exam and sets a goal to explain how sinkholes form in Florida. The student plans by choosing the tactic of reading their textbook pages on sinkhole formation. The student enters the action phase when they begin reading a page in a textbook. A student who is aware of their learning process (metacognition) enters the reflection phase during or following the action phase when they may recognize that they do not understand the concepts discussed in the text. This is often accomplished by developing a feeling of knowing, or in this case, not knowing. The student then analyzes the situation, deciding that reading isn’t working to help them accomplish their goal of explaining how sinkholes form. They choose to re-read the textbook passage, but add a new tactic of creating a labelled drawing of the process of sinkhole formation. This return to the reading action and change in tactic choice represents the regulation phase. The student completes the learning process when, upon subsequent reflection, they believe that they understand the concept of sinkhole formation. Students can go through this “cycle” once or multiple times to complete the process for each learning task.

**Research questions and goals**

This study aims to examine the self-regulated learning strategies and tactics students use in introductory geology courses to prepare for an exam. More specifically, we aim to compare the self-regulation strategies and tactics of high and low performers to identify those strategies and tactics that mediate and impede higher performance. By understanding these
differences, we can develop a model to help all students prepare more effectively by presenting them with successful strategies and tactics. Key questions include:

- What tactics do high and low performers use?
- Do high and low performers use different or similar tactics?
- Do high and low performers apply tactics in similar or different ways?

METHODS

Data collection

A total of 73 students, in introductory physical geology courses from 2 research universities and 3 community colleges, volunteered to be interviewed as part of a larger study (Gilbert et al., 2012, Lukes and McConnell, submitted). The university classes typically consisted of 80-150 students each; the community college classes consisted of fewer than 50 students. Students were interviewed at similar points in the semester and courses had comparable situational factors such as textbook or an online reading resource with a suggested or assigned reading schedule, assigned homework, and in-class activities (e.g., online practice quizzes, reading reflections, short research topics, and practice problems), and multiple exams. For a more detailed description of courses, see Lukes and McConnell (submitted).

Data collection methods are outlined in the top box (Phase 1) of Figure 2. Student interviews were conducted in person by the first author and lasted 15-75 minutes depending on student responses. The complete list of questions and interview protocol are described in Lukes and McConnell, in prep., but in essence, students were asked to “walk [the interviewer] through a
A typical week or two before an exam [in geology], how do you prepare?” Following a grounded theory approach to the study (Oktay, 2012), the interviews were semi-structured in nature, providing students with open ended questions that allowed student-identified themes to emerge. The themes and recurring ideas could be further investigated by the interviewer with follow up questions. Interviews were digitally recorded and later transcribed. Upon completion of the interview, participants reviewed the interviewer’s notes to confirm accuracy. Participant confidentiality was maintained by assigning each participant a pseudonym and by removing identifiers from transcripts (including reference to geographic locations, institution, other students’, and instructors’ names).

**Participants**

Participants were nearly evenly split between female (49%) and male and between research universities (47%) and community colleges. Less than a quarter (22%) of the participants reported they were of an ethnicity other than white (non-Hispanic) and 12% did not disclose ethnicity/race. The majority (67%) of students were traditional college age (18-24) and 17% did not disclose their age. Less than a quarter (22%) indicated that they were “very likely” or “somewhat likely” to be a science major and 37% did not disclose their major intent. A majority (75%) of students earned an A or a B in the class at the end of the semester, but only 43% earned an A or B average on exams. Students who earned an A or B average on exams (80% and above) were designated as “high performers” for the purpose of this study. Students who earned less than 80% were designated as “low performers.” For a more detailed description of the participant characteristics, see Lukes and McConnell (submitted).
Methods of qualitative analysis

Memos are reflective notes qualitative researchers make, documenting their thought process about what they are learning about concepts and relationships from the data during analysis. Memos are a critical part of qualitative research process, as they lend credibility and trustworthiness to meanings derived from the data. For this study, the interviewer created memos that summarized non-verbal observations of the students and interviewer reactions and impressions, identified emerging ideas and themes, and compared interview notes and memos to data in previous interviews and memos. The memos facilitated the constant comparison component of grounded theory methods (Phase 1 in Figure 2).

Interviews were reviewed multiple times, and dissected by the primary investigator at the individual thought level (all 73 interviews; Phase 2 in Figure 2). Subsequently, memos were created to identify recurring ideas, make initial interpretations, and develop visual step-by-step study process sequence models (similar to decision trees described in Gladwin, 1989). From the memos, a list of open codes was compiled and revised in a recursive manner as the interview transcripts were analyzed, also resulting in revisions of the visual analysis models in memos. To establish the trustworthiness of the primary investigator’s interpretations, 3 randomly picked transcript excerpts were tagged and initially coded thought-by-thought by two other researchers, who were otherwise not involved in the study, to identify specific activities students engaged in and the purpose behind their engagement. Upon discussion, 100% agreement was found between investigators using the methods of Gorden (1992), establishing validity and reliability of emergent codes and the generalized visual model (Figure 3).
These initial recurring ideas, open codes, and visual models were compared to existing SRL model components and products previously discussed in the SRL literature. From this and recursive reflection by the primary researcher, selective codes were identified to create a codebook (Table 1). The codebook was benchmarked (expert review to support credibility) by two educational psychologists and four geoscience education researchers (Phase 3 in Figure 2). This codebook was then used by the three researchers to co-code five interviews (Phase 4 in Figure 2). There was 96% agreement between the three coders, establishing the reliability of the codebook. Excerpts from the interviews that pertained to student explanations of how they study for an exam were isolated from the rest of the transcript to reduce bias from variations in interview protocol (follow-up questions based on student volunteered information) that may have occurred after the initial “tell me how you prepare” questions. Then, the codebook was used by the primary researcher to code all of the interview excerpts. This means that some of the codes that emerged and were included in the codebook may not be expressed in the interview excerpts portions analyzed in this study.

Coding results were then organized to determine the number of high and low performers that reported a given code for quantitative analysis purposes. Then the coding results were examined to determine the number of unique code incidents reported within the high and low performing student populations because students may report using multiple strategies of the same nature. For example, a low performing student may report using two different surface learning strategies (Code 2.1.1. on Table 2): repeatedly re-writing notes and drilling with automatically graded online practice quizzes. This student would count as one student towards the total number of students that reported 2.1.1., but would count as two
incidents of surface learning. The primary author examined all incidents reported for each code to identify themes for discussion purposes (Phase 5 in Figure 2). The themes were used to characterize the way in which students reported using the strategies and tactics for discussion purposes.

The step-by-step study process described by each student was summarized in memos as a sequence of events list. These event lists were compared to examine holistic SRL process patterns (e.g., timing of code items, frequency of individual code items, non-coded processes). They were also mapped directly onto the emergent visual model (Figure 3). This allowed the primary author to make holistic SRL comparisons within and between high and low performing student groups.

**Methods of quantitative analysis**

For each codebook item, a Chi square test was performed to determine the significance of differences in code report totals between high and low performing student populations. Only p values less than 0.05 were considered significant. These calculations add strength to the qualitative analysis interpretations.
RESULTS

Coding results

The greatest differences between high and low performers were reported across the reflection phase, but there were significant differences between groups in aspects of all phases. Coding results are summarized in Table 2. Three of the code items (1.2 choosing goals; 2.2.4. metacognitive awareness; 4.2 choosing new goals; see Table 1) were not observed in any of the interview excerpts used for this study. A larger proportion of A/B exam average students (high performers) described using 13 of the 19 SRL code items compared to C and below exam average students (low performers). However, only 5 of these were found to be statistically significant: 1.1 defining the task (p<0.01); 2.2.2. controlling time (p<0.05); 3.1.3. monitoring for understanding (p<0.01); 3.1.4. analyzing monitoring results (p<0.01); and 4.5 reaffirming strategy and tactic use (p<0.01). A larger percent of low performers were observed for two of the codes: 3.1.2., the reported use of monitoring for memory tactics and 3.1.4., the reported use of monitoring for an unclear purpose. Both of these were found to be significant (p<0.05 and p<0.01 respectively).

SRL model results

The visual step-by-step study process sequence for most students was consistent with the general SRL model (Figure 1). However, high performers, in general, linked this recursive exam preparation SRL model with a broader SRL cycle within the course. The majority of high performers discussed classwork as exam preparation, contrary to majority of low performing students. When preparing for an exam, high performers discussed using
reflection as a transition between the “normal” learning/preparation efforts of classwork with the more targeted “repair” strategies associated with preparing for an exam event. Reflection, in other words, emerged as critical phase that acted as connector between classwork, exam preparation efforts, and the exam for high performers. The general SRL model (Figure 1) was modified to reflect the relationship between classwork, studying, and exam events (Figure 3).

**DISCUSSION**

**Planning**

A substantial majority of high performers (94%) reported that they actively identified and defined the learning task (Code 1.1, Tables 1 and 2), which in the case of preparing for an exam, is to learn the content covered by the exam. Fewer of the low performers (67%) explicitly reported having defined the task, rather moving ahead to describe their action phase of SRL. The differences between the numbers of high and low performers was significant (p<0.01). This suggests that some low performance could be due to a general lack of a clear understanding of the task at hand. While absence of reporting doesn’t necessarily equate to negative data, the clear communication of this aspect of planning by high performers suggests that they are consciously aware of the role task definition plays in their learning.

High performers used a variety of resources to define the specifics of this learning task including assigned reading, instructor-provided sample questions, class notes, but relied
primarily on instructor-provided study guides/list of learning objectives (25% of the 48 incidents reported by high performers) and explicit or perceived instructor cues about what would be on the exam during class (21% of high performer incidents). For example, Staci reports “there are things that [instructor] said a hundred times in class. I figure those will probably be on the exam. Also, [instructor] hands out the study guide, which is just basically a list of everything [needed for exam].” Similarly, Miranda reports that she is looking for cues from the instructor: “[instructor]’ll say it multiple times or write it on the board. [Instructor] won’t go out and say ‘oh you should remember this’ but you just kinda know, like can tell.” Like the high performing students, low performing students relied primarily on instructor-provided study guides/list of learning objectives (31% of 45 reported low performing incidents) and explicit or perceived instructor cues (22% of incidents). However, many low performers indicated that the task was to learn everything (18% of the reported low performer incidents). Students who reported their task was to learn everything tended to also discuss running out of time when studying, suggesting that low performing students would benefit from targeting their study efforts. Both high and low performing students are relying on the instructor-provided learning objectives, suggesting that importance of correlating learning objectives and assessment. While both groups reported using learning objectives, the low performing students may not necessarily know how to use these resources as effectively as high performing students.

About half of both the high and low performing student groups reported their process for identifying and choosing learning strategies (Code 1.3, Tables 1 and 2). This is often
considered a covert process, so observing it at such a high level is of note. Asking students to reflect on their exam preparation strategies during the interview could prompt awareness that would otherwise be covert or absent. However, the high, across the board representation suggests that these students are likely to be introspective and metacognitively aware (Schraw and Dennison, 1994), possessing both knowledge of what learning strategies and tactics are (declarative metacognitive knowledge) and in which conditions to use them (conditional metacognitive knowledge). The 18 high performers that reported identifying and choosing strategies reported 21 incidents of this, while the 22 low performers reported 42 incidents of identifying and choosing strategies. Interestingly, the high performers reported choosing strategies primarily because they believed they were effective cognitive strategies that had worked in the past (53% of high performer incidents). For example, Rowen reported that “this has usually worked for me…on most tests I’ve taken thus far, so I kinda just continue doing that.” Or high performers chose strategies that were necessary to control their focus (33%). For example, Shaun said “I’m not trying to jam my brain and get all stressed out. That’s why I try to space it out.” He chooses a distributed study schedule to reduce his stress levels because stress keeps him from effectively focusing on and learning the material. Low performers, similarly choose strategies because they are effective and have worked in past (33%). For example, Tony reported the rationale behind his choice to re-write information: “writing it down definitely helps big time and to be focused. To write something down and to copy it is one thing, but to write something down and know what you are writing is [another].” However, low performers were more likely to emphasize that they chose a strategy because an instructor or parent had explicitly told them to use it (30% of the low
performer incidents). For example, Sienna reported “my mom’s a teacher, so she makes me do all of this [her strategies].” Sheri, on the other hand relies on what the instructor tells her to do: “[instructor] says you should study in different places, so I take notes to the gym.” This suggests that low performers rely more than high performers on instructor guidance on exam preparation strategies.

**Action**

Both cognitive and control tactics were reported by high and low performers (Table 2). There was no significant difference between the use of surface level strategies between high and low performers (Code 2.1.1., Tables 1 and 2). The majority of both groups (68% and 62% respectively) reported that they use surface learning rehearsal methods such as rewriting notes or highlighting text (Table 1) that aim to encode information through repetition (Weinstein and Jung, 2010). However, low performing students reported a higher number of incidents relative to the number of people reporting (21 high performers reported 27 incidents, while 26 low performers reported 48 unique incidents). This suggests that low performers are more likely to adopt shallow learning strategies as a primary learning strategy, which is consistent with the results of other studies (Karpicke, Butler, & Roediger, 2009).

The majority of the reported incidents by both high (59% of 27 incidents) and low performers (52% of 48 incidents) consisted of passive rehearsal by re-reading course materials. Low performers are not utilizing the textbook as a resource as much as high performing students. High performers relied equally on re-reading the textbook and the
instructor provided notes, while low performers relied almost exclusively on the instructor’s notes. Instructors should be aware of the reliance of students on their notes as a primary resource. A subset of high performers also reported (15% of 27 incidents) using active rehearsal techniques that require more intentional focus, such as highlighting/starring key information, while reading; more than low performing students (4% of 48 incidents). This suggests that while high performing students may be rehearsing by re-reading, they are strategic in their reading by identifying important information and planning to return to it. Low performing students focused on less relevant information as indicated by a higher number of incidents (15% of 48 incidents) of drilling using provided quiz/test questions with instructor provided answers or using vocabulary term-definition flashcards. Some low performers reported that they even repeated the instructor wording in their head or aloud (4%), further reiterating such a reliance on the instructor. Both populations also reported that they spent time re-writing notes or lines from the book verbatim (15% high performers; 17% low performers), which was frequently identified as being used because as a tactic, they believe it works. As Mary reported, “I feel like if I write it, then it sticks with me more.” Students also frequently identified re-writing as being used because they have been instructed to use it as learning method. For example, Claire reported how she re-writes notes because “I heard that from another professor, that if you write when you are studying, then you’ll remember it better, so I do.” This copying of text is in contrast to deeper learning elaboration strategies where writing is used to paraphrase or summarize text.
The majority of both high (65%) and low performers (52%) reported that they use deep learning elaboration strategies (Code 2.1.2., Tables 1 and 2) that require them transform information into a more meaningful structure that can readily be retrieved (Weinstein and Jung, 2010). The majority of the incidents reported by both groups (36% of 34 incidents high performers; 40% of 32 incidents low performers) involved some form of retrieval exercise in which students were answering open ended questions. Some used existing questions embedded in instructor provided materials (e.g., study guides, homework assignments or class activities with practice problems) or used instructor provided materials to make their own questions, like Jonah. He reported “I go through the [instructor posted PowerPoint] slides and the book and get important concepts out and write them down and make possible test questions.” Some reported practicing retrieval by using visualization exercises to recall the conceptual narrative the instructor presented, as evidenced by Sienna’s statement, “…[instructor] adds a little bit more to [PowerPoint slides] or gives us related life stories that help us understand the PowerPoints. When I look at the PowerPoints [when studying] I just kinda remember—I visualize the story with the PowerPoint.” Others reported recalling as much as they could using a word prompt. For example, Daniella reported “before a test I will just grab one of my friends and rant everything I know at them. …I say ‘oh, do you want to know the difference between a shield volcano and composite volcano? Oh, well, I’ll tell you.’ I always tell them everything about it.”

Both high and low performers also reported similar amounts of basic elaboration in which they paraphrased content into their own words (12% high performer incidents; 13% of low
performer incidents). The difference between these groups emerges when we examine which micro-level tactics they are using. High performers reported more advanced methods of elaboration in which they make conceptual connections (27% of high performing incidents compared to 12% of low performing incidents). Some students reported making connections between content items. For example, Walt reported connecting bigger concepts with smaller details: “so a subduction zone, like if I know that’s going to be on a test, then on my sheet I’ll have subduction zone and then stemming out from that I’ll have some things like oceanic plate goes under the continental plate, and so forth. I’ll have all those little concepts.” Others made conceptual connections between content items and items outside of class. For example, Albert goes into the lab full of rock and mineral samples to “mess around and try to identify [samples]” so he can “go out in the real world and pick up a rock and be able to identify it.” Similarly, Ruth connects what she is doing in lecture to her lab course, “I think the geology lab helps you put it into real life terms, like it helps you understand it better.”

High performers also report using organization tactics more than low performers (24% and 13% of incidents respectively) in which they rearrange content in their own outlines and concept maps to help them process and recall information. This suggests that high performers are more frequently translating and learning information at a deeper level when they are preparing for an exam.

The majority of high performers (52%) and some low performers (31%) reported using strategies and tactics to control aspects of their affect, or motivation and emotion (Code 2.2.1, Tables 1 and 2). This was almost statistically significant (p=0.075). High performers
either took actions to reduce their stress levels (50% of 18 incidents) or to induce stress to motivate themselves (50% of 18 incidents). For example, Walt reported “I don’t cram right up to the test because that stresses me out and I feel I do worse on tests that I cram right up until the test.” He spaces his actions over several days so he can control his focus by reducing emotional distractions. Valarie on the other hand, reported “that last-minute panic mode, that’s really most effective…the studying happens when [I] procrastinate.” She intentionally stresses herself out to control her focus, so that she can prepare for the exam. While some low performers reported similar actions (27% and 33% of 15 incidents respectively), they were more likely to use (40% of incidents) reward or punishment actions to control their motivation to engage in study activities. For example, both Gina and Waldo will “get in trouble” with someone else (coach/tutor and wife respectively) if they don’t study. Scott reported using food as a reward, “do this…and then you can go eat whatever you want.” This suggests that high performers are more aware of the role their emotions play in their motivational schemes and actively use this knowledge to control their actions. This was reiterated in later portions of the interview when students were explicitly asked about their motivation (see Lukes and McConnell, in prep (#1) for full details of this analysis).

Different proportions of high and low performers reported that they actively managed when and for how long they studied (45% and 21% respectively; p<0.05; Code 2.2.2, Tables 1 and 2). Low performers (50% of 10 incidents) tended to describe the choice to cram in a massed block of time as a way to control focus to study. For example, Sienna reported “I do also cram a lot at once because I feel it is easier. I feel like the more I looked at it, I feel like it’s
fresher in my mind that day, the exam day. I’ll study a good four or five hours, just to make sure that I have everything down.” Most high performers (67% of 18 incidents) actively chose to space their study events for focus and to ensure enough time to complete task. As Peter explained, “I try to take off little chunks. I don’t have the energy to cram. It just doesn’t work…I’ve had to do it and I didn’t like it and my performance suffered, so it doesn’t work…[instead] I’ll try to take a little bit at a time.” Similarly, Randy reported “I’ve learned the best way for me to study is not necessarily to cram, but a bit at a time and spend a couple weeks doing it.” High performers are actively using a spaced timing method that has been shown to be more effective at retaining information in a person’s memory (Son and Simon, 2012).

Students were directly asked about the type of environment they study in, so it is not surprising that the majority of students indicated that they took actions to control their environment (58% high performers and 60% low performers; Code 2.2.3, Tables 1 and 2). High performers and some low performers choose quiet environments (56% of 18 incidents for high performers and 33% of 33 incidents for low performers) and to work alone (28% of incidents for high performers and 12% for low performers). Despite these similarities, there is a clear difference between high and low performers in terms of how they choose to control their environments. Low performers, unlike any high performers, described intentionally choosing to work in environments with noise or music playing to help keep them focused (36% of 33 incidents). For example, George reports that “[music] helps me concentrate” and Anthony explains “I feel like I use the rhythm of the music to memorize stuff that I’m
reading.” Some, like Graham, were adamant in their need for music to focus, who reported “I have to listen to music when I study. I have to.” Low performers (12% of incidents) also identified writing strategies as helping them stay focused on processing information when they study (as Tony explained in his earlier planning phase when he was choosing his tactics).

Reflection

High performers reported using tactics to monitor their memory less (35%) than did low performing students (60%; p<0.05; Code 3.1.2, Tables 1 and 2). High performing students (55%) on the other hand, reported using tactics to monitor their comprehension, or understanding of content more than low performing students (24%; p<0.01; Code 3.1.3, Tables 1 and 2). This suggests that high performing students are not just processing information at a deeper level, but evaluating themselves and their learning at a deeper level (beyond memory recall) than low performing students. Low performing students often express a belief that remembering is equivalent to understanding. For example, Sienna explains how she identifies concepts she is having a hard time with, suggesting she doesn’t understand them. But then when later asked what her goal is when doing different strategies, she declares emphatically “well, memorize it of course for the test.” The difficulty she referred to earlier was difficulty remembering the information, rather than difficulty understanding it. This discrepancy likely explains the “illusions of competence” (Karpicke, Butler, & Roediger, 2009) that students may have when preparing and taking an exam. Low performing students may believe that they are well prepared for an exam because they can
recall the information in their notes, even though they may be unable to explain what it means.

In addition to these, there were many additional incidents reported by both groups that were determined to be monitoring tactics, but it was unclear if the purpose of these activities was for memory or understanding (55% of high performing students and 83% of low performing students reported such incidents; p<0.01; Code 3.1.4., Tables 1 and 2). This suggests that either these students did not know which aspect (memory or comprehension) they were monitoring (no clear plan), or they were not communicating their rationale. For example, Valarie explained how she used the questions embedded in the textbook to monitor, “this textbook has these little things at the bottom corner that say ‘before you leave this page, you should be able to blah, blah, blah’ and it has a list of things you should be able to do. And so I look at those and I try to think in my head if I can do those things.” It’s unclear whether she means she can remember the content answers or if she understands the content. Either way, she is relying on her internal feelings of knowing rather than checking herself against an external, more objective standard like Amy does. Amy reported “I will close the book and try to remember all of the things I read in my mind and if I can recall all of the points, I write them on a paper and then open the textbook to compare them.” In future studies, this could be clarified with a follow up question by the interviewer. Regardless of why they are monitoring, however, it is clear that monitoring is a key part of the exam preparation process.
High performers (39%) also reported analyzing their monitoring results more than low performers (12%; p<0.01; Code 3.2, Tables 1 and 2). Analysis is a key event in the SRL process that must take place before effective regulation can occur. This suggests that high performers are metacognitively processing their monitoring results to inform their next exam preparation steps. Some students reported evaluating the effectiveness of their process, finding it satisfactory. For example, Travis reflected that “as I get further down the road and concepts become more and more involved and detailed oriented, I’ll adapt in that way [use different tactics], but for now, this works pretty well for me.” Others, like Jason, monitor their understanding and identify new strategies and tactics to use to repair knowledge gaps. For example Jason reported when he re-reads his instructor provided PowerPoint notes to prepare for the exam that “If there’s a clicker question, I’ll cover it up and then…if I don’t understand that question very well, I’ll go back through those [instructor-provided PowerPoint] slides and try to see if the answer is embedded within one of those slides.” Jason monitored his understanding of the concept and clearly identifies a new tactic (help seeking with the purpose of clarifying) to use if the results of his monitoring process are negative. In this way, high performers are actively refining their learning process.

**Regulation**

Both high and low performers reported redefining the task (42% and 31% respectively; Code 4.1, Tables 1 and 2) to focus on those items they discovered through monitoring as being challenging. For example, Faith reported using the online practice quizzes to monitor her understanding and redefine the topics she needs to learn for the exam, “That way I know
what I know and everything. Then from there I can see what I need to work on or what I should look over more.” While this is less than the majority of either group, this does not mean that that more students aren’t doing this. It could be that they are doing this, but not reporting it because they viewed it as implicit or they were not explicitly aware that they were doing this.

Many high (48%) and low (31%) performing students choose new cognitive strategies after monitoring (Code 4.3, Tables 1 and 2). However high performers reported more incidents of choosing new cognitive strategies (26 compared to 15 for low performers). Both high and low performing students reported a shift to using passive rehearsal methods to drill their memory (42% of 26 incidents and 40% of 15 incidents respectively). For high performers the shift tended to be connected to previous deeper strategies. For example, Max may be drilling his memory but “it’s not just memorizing definitions and being able to say it. It’s memorizing, a rock will melt, it will solidify, it’s magma…It’s not just this is what a metamorphic rock is, this is what a sedimentary rock is, it’s more memorizing the process.” Max uses passive rehearsal strategies to repeat information until he remembers it, but he is memorizing the elaboration results he did previously to explain and process the concept of the rock cycle. For low performers, on the other hand, the shift was typically a continuation of the same tactic (rehearsal), but using a different tool. For example, Mary focuses on vocabulary and “[I] just write them down on a sheet of paper and re-read them and re-type them on my computer.” High performers continued to report that they were using advanced elaboration strategies more than low performers, even in regulation (24% of high performer
incidents and 13% of low performer incidents). Both groups reported using basic elaboration strategies in regulation, which primarily took the form of help seeking with the purpose of clarification. For example, Annabelle seeks help from others in her class and the internet, “If I have something to ask, I might ask her [student in class] or I might Google it and see if I can find additional information.”

The majority (55%) of high performers reaffirmed the merits of their strategy and tactic selection and use through the exam preparation process (Code 4.5; p<0.01, Tables 1 and 2). Low performers (21%) were much less likely to make statements supporting the efficacy of their process. When it was referred to, it tended to be implied. For example, Doris reported that re-reads her notes as her primary strategy and then later stated “I’ll glance over it and repeat a couple of things that I might feel are kind of hazy, especially I do a lot of repeating.” She implies that she chooses to repeat reading information and over and over because it works, but she doesn’t explicitly state this. High performers, on the other hand, were more articulate and were able to make a connection between their monitoring results and their strategy use. For example, Marilyn explained that “If I can’t answer what’s on the study guide from my class notes, that’s when I go and do research...I try not to memorize because I have a bad memory. What I try to do is make more and more connections to the material so that I kind of own it and that way it comes a little more natural to me.” She understands that trying to memorize will not give her good monitoring results and that she needs to use an elaboration strategy in which she relates content to make her own personal connections with it. This suggests again that high performers have better metacognitive skills and that low
performing students would benefit from instructors who incorporate self-reflection exercises into their assignments. Other studies have also shown that students benefit from being instructed to think aloud, using a verbalization method, when reflecting (Bannert and Mengelkamp, 2008).

**SRL as a process**

We can make several observations about the differences between high and low performing students:

- High performers are more strategic in their planning and low performing students rely more on instructors for guidance when choosing strategies.
- Both high and low performers use a combination of shallow and deep learning strategies, but high performers are using deep strategies more and in more advanced ways.
- High performers are using self-control strategies more during the action phase of the SRL cycle.
- High performers are more likely to consider the success of their learning process, yielding more evidence of regulation.

However, these observations do not explain how these reported elements of SRL (planning, action, reflection, and regulation) fit together in an applied setting to form an individual’s holistic learning process. While most students reported some form of SRL as illustrated in the theoretical model presented in Figure 1, some low performers did not. A time sequence map for each student’s exam preparation process was constructed so that processes could be
compared directly across students to look for differences between high and low performers. For example, Patrick begins his exam preparation by re-reading instructor-provided notes to both memorize (Action: passive rehearsal) and check his understanding of the material that is going to be on the test (Reflection: monitoring for comprehension). He then creates a key concept list of items using the notes (Regulation: Re-defining the task and choosing a new strategy of organization). Then he covers his list to self-test himself (Reflection: Monitoring memory), re-reading the items he misses (Regulation: Reaffirming tactic of re-reading).

In situating high performing student exam preparation event sequences, it emerged that high performers reported their preparation in context of their classwork (92% of A students and 53% of B students). These students viewed classwork as studying and learning. For example, Shaun reported, “Most of the time in geology, I’m keeping up with all the readings and doing all the reading reflections. So I’m studying just about every day in that sense, doing the reading reflections and homeworks.” The majority of low performers, on the other hand, did not reference classwork when discussing exam preparation (79%). For those that did (21%), they tended to discuss classwork and exam preparation as unrelated. For example, Kendra reported that she does her homework assignments “most of the time the day they are due,” but she “does them because I have to do them” rather than seeing them as a learning tool and part of her exam preparation.

Because high performers were in the middle of learning when they start preparing for an exam, they often started with the reflection phase, using some tool/resource to monitor their
learning so far. For example, Megan reported “I would review all the materials and see if I know the terms, see if I understand the concepts. Then I would have another study session and review those concepts that are the least familiar to me.” She starts to prepare for the exam by first assessing what she doesn’t know through a reflection process. This is depicted in Figure 3 by the arrow connecting “classwork” SRL cycle with the reflection phase of the “studying” SRL cycle (rather than having that arrow connecting to the planning phase of the “studying” cycle). High performers used this information to target their efforts in exam preparation. For example, Katrina identifies the items she doesn’t know then re-reads the pages on that topic in her textbook and if she re-monitors and still doesn’t understand it, she seeks help from “someone else who does understand it to explain it to me.”

Instructors may include a knowledge survey activity in which they make judgments of knowing (e.g., Bell and Volckmann, 2011) to prompt reflection among low performing students. High performing students are more accurate in their judgments of learning but low performers can show improvement in these judgments when they are explicitly asked to reflect (Nietfeld et al., 2006) and are incentivized to improve the accuracy of their judgments of knowing (Hacker et al., 2008).

Many low performers described effective strategy selection, but reported running out of time or motivation. For example, Scott reported time management issues when he said “so there was really no time for me to study.” But he also reported motivation issues when he said “It’s difficult. I have to make myself do it [studying]…I get distracted easily…and just
procrastinating a lot.” Similarly, Claire reported that “I had to stop like halfway [through finding and writing answers to the study guide] cause it’s really long.” Several openly discussed how they should do X, but chose Y anyway. For example, Campbell reported “[instructor] wants us to do this retrieval process where you draw it [rock cycle] out…but that never really worked for me even though it’s, there’s some study [instructor] has on it that it’s supposed to be really good. But I’m like, I don’t, no, I’ll just read over it.” Instructors may also have regular assignment due dates to ensure that low performing students are staying engaged with the learning process, rather than waiting until a few days before the exam to “learn” the material.

**Limitations and strengths**

Despite the limitations noted by others of using self-report data to assess self-regulated learning (e.g., Winne and Jamieson-Noel, 2002), qualitative methods provide a rich insight to student rationales that quantitative methods cannot address. Because the codebook is grounded in student data from a course context, it also provides a robust application to pedagogy and student learning. Grounded theory studies typically consider 20-30 interviews as sufficient to reach saturation for emergent themes to establish validity. This study presents qualitative data based on more than twice that number of interviews (n=73) and the population’s demographic data is representative of the entire population of introductory geology students (>3,000; Gilbert et al, 2012). Consequently, the model presented here has greater strength and applicability beyond the course context of the specific participating students.
Three of the codes had no coded incidents in the interview excerpt data: the planning process of choosing goals (Table 1, code 1.2); the action strategy of metacognitive awareness (Table 1, code 2.2.4.); and the regulating process of choosing new goals (Table 1, code 4.2.). Two of the codes had a negligible number of coded incidents: the reflection phase of monitoring learning process (Table 1, 3.1.1.) and the regulation process of identifying and choosing new control strategies (Table 1, 4.3.). This apparent gap in the data is likely due to the interview protocol and data selection methods of this study. For example, students were explicitly asked about their motivation and goals at a different point in the interview that was not included in this study’s analysis. This portion was excluded from this study to reduce bias from interviewer inconsistencies with the protocol as it evolved through the grounded theory process.

What is not captured by the coding process is the role of timing of monitoring in the exam preparation process. Researchers using a coding scheme should be cautious when interpreting coding results. As discussed with the emergent model, it is critical to map a time sequence of a student’s SRL process, not just identify the tactics they use. Without the holistic view of their SRL process, it is difficult to draw meaningful conclusions. This study uses a mixed methods approach that presents a holistic understanding of student SRL through combining model mapping and coding results.
CONCLUSION

The interview results presented here suggest that while high and low performing students may report similar strategy and tactic use on surveys, it is clear through their interview responses that they are using these strategies and tactics in different ways. High performers are using reflection in the form of monitoring processes to plan and target their study efforts. They plan and use more control strategies than low performing students. They also use deeper learning and monitoring strategies. Understanding the timing and types of micro-level tactics that high performing students are using, can provide guidance for students struggling to be successful in introductory geoscience courses. Additionally, instructors may include resources and activities to facilitate and support the strategies and tactics that high performers are using (Lukes and McConnell, submitted). For example, instructors could provide clear learning objectives and/or study guides, and incorporate activities such as knowledge surveys and exam wrappers that require students to reflect on their learning before and after an exam. Instructor provided resources like PowerPoint slide notes could include high order thinking examples and practice questions.

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REFERENCES


Figure 1. General SRL model

*Reflection includes monitoring (keeping track of thoughts, feelings, and behavior), evaluation (comparing results to goals), and analysis (deciding if the approach used is effective and appropriate).
Figure 2. Research methods
Figure 3. Emergent SRL model of high performing students preparing for an exam
### Table 1 SRL Codebook

<table>
<thead>
<tr>
<th>1. Planning- Student making decisions prior to engaging in action.</th>
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<tbody>
<tr>
<td><strong>1.1 Identifying / defining the task</strong></td>
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<tr>
<td>Student describes strategies to discern the content covered</td>
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<tr>
<td>and format of the task</td>
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<tr>
<td>• perspective taking (e.g., pretending they are the teacher)</td>
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<tr>
<td>• reading instructor-provided study guide</td>
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<tr>
<td><strong>1.2. Choosing goals</strong></td>
</tr>
<tr>
<td>Student describes goals for learning process</td>
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<tr>
<td>• “earn an A on exam”</td>
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<tr>
<td>• “remember this list of terms”</td>
</tr>
<tr>
<td><strong>1.3. Identifying &amp; choosing strategies</strong></td>
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<tr>
<td>Student describes, discusses, and/or indicates an intentional</td>
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<tr>
<td>strategy choice. There may or may not be evidence of</td>
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<tr>
<td>rationale behind choice.</td>
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<tr>
<td>• “That’s always worked for me in the past.”</td>
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<tr>
<td>• “It’s science, so I use flashcards because need to learn</td>
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<tr>
<td>terms.”</td>
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<tr>
<td>• “Instructor said this technique works better.”</td>
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<p>| 2. Acting- Student attempting to encode information or support |</p>
<table>
<thead>
<tr>
<th>efforts to encode information.</th>
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<tbody>
<tr>
<td><strong>2.1 Cognitive tactics-</strong></td>
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<tr>
<td>Actions to encode the information into their memory (whether</td>
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<tr>
<td>short term or long term).</td>
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<tr>
<td><strong>2.1.1 Surface learning</strong></td>
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<tr>
<td>Rehearsal strategies (involve repetition) and can be either</td>
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<tr>
<td>passive or active.</td>
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<tr>
<td>• passive rehearsal tactics (e.g., flashcards with purpose of</td>
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<tr>
<td>repetition, rewriting notes without reorganizing) or use of</td>
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<tr>
<td>other memory aids like mnemonics.</td>
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<td>• active rehearsal tactics in which repetition is used a tool</td>
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<tr>
<td>to hold onto information so that it can be further processed</td>
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<tr>
<td>(e.g., highlighting/ starring important information and</td>
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<tr>
<td>reviewing highlighted material at a future time)</td>
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<tr>
<td><strong>2.1.2 Deep learning</strong></td>
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<tr>
<td>Strategies that seek to transform information so it is</td>
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<tr>
<td>structured more meaningfully.</td>
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<tr>
<td>• basic elaboration (e.g., paraphrasing, summarizing, and</td>
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<tr>
<td>help seeking with the purpose of clarification</td>
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<td>• advanced elaboration (e.g., applying what a student is</td>
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<tr>
<td>learning to new and diverse tasks, trying to teach the</td>
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<tr>
<td>material to someone else, perspective taking, visualization,</td>
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<tr>
<td>using a problem-solving strategy in a new context, creating</td>
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<tr>
<td>analogies, using compare and contrast methods, and creating</td>
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<td>and responding to questions, help seeking if the help sought</td>
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<tr>
<td>supports one of the items above)</td>
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<tr>
<td>• Organization (e.g., creating outlines, concept maps, and</td>
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<tr>
<td>concept matrices)</td>
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</table>
| 2.2 Control tactics-Actions to support the effective completion of cognitive strategy. | 2.2.1. Affect (motivation, emotion) | Student manipulates emotion/motivation to evoke desired behavior
- self-talk remind oneself about personal goals (e.g., perform well for future goals)
- make themselves feel guilty or stressed to evoke desired behavior |
|---|---|---|
| 2.2.2. Time | Student manipulates time on task and intentionally chooses a time schedule to evoke desired behavior.
- schedule time after each class to study
- only study day or two before exam so can remember information |
| 2.2.3. Environment | Student manipulates physical and social environment to reduce distractions and increase focus on task.
- choosing a quiet location to work
- choosing to work alone
- choosing to work with others who are motivated
- collecting resources |
| 2.2.4. Metacognitive awareness | Student manipulates cognitive behaviors through overt self-awareness and process monitoring.
- Consciously thinking about how focused/how much attention you are paying
- using self-talk to redirect focus, actively thinking about meaning |
<table>
<thead>
<tr>
<th><strong>3. Reflecting</strong>— Students engaging in metacognitive processes to make new decisions or affirm existing strategy choices.</th>
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<tbody>
<tr>
<td><strong>3.1 Monitoring &amp; Evaluating</strong>— comparing performance to a standard whether it is an external standard or an internal one.</td>
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<tr>
<td><strong>3.1.1. for process</strong></td>
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| **3.1.2. for memory** | The goal is to see if that accessible memory encoding has been established (may include many of the strategies discussed under elaboration, but purpose is different).
- using flash cards to quiz your ability to remember answer
- covering up your notes and recalling what was written on them
- using practice questions with answer keys to recall correct answer |
| **3.1.3. for understanding** | The goal is to see if that accessible understanding has been established (may include many of the strategies discussed under elaboration, but purpose is different).
- using questions or key terms as cues to recall everything they know about a topic and then checking for gaps in understanding or confusing parts
- explaining a concept to someone else, while identifying confusing parts or inability to answer follow up questions from other person
- reading a passage or listening to someone explain it and identifying gaps in understanding or confusing parts |
| **3.1.4 unclear purpose**— Monitoring/evaluation is described, but the purpose is unclear. |
| **3.2 Analyzing**— Students make inferences and draw conclusions from monitoring data. |
| | • identifying where/why things went wrong
| | • confirming that their strategy/tactic works
<p>| | • identifying need for new strategies/tactics |</p>
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<thead>
<tr>
<th>4. Regulating - Students re-acting (occur AFTER reflection event as the result of reflection).</th>
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<tbody>
<tr>
<td><strong>4.1 Redefining the task</strong> - Student changes their beliefs about the task itself.</td>
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<tr>
<td>• If student’s task was to initially learn the material by reading, they may change the task to be identifying and learning the study guide items they don't know.</td>
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<td><strong>4.2 Choosing new goals</strong> - Student changes targets from what s/he started with.</td>
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<tr>
<td>• Student changes target from remembering all of the vocabulary term definitions to remembering at least 70% of them.</td>
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<td><strong>4.3 Identifying and choosing new cognitive strategies /tactics</strong> - Student changes initial or earlier cognitive strategy / tactic to replace or supplement initial strategy.</td>
</tr>
<tr>
<td>• replacing an earlier cognitive strategy / tactic with a new one</td>
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<tr>
<td>• adding a cognitive new strategy/ tactic</td>
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<tr>
<td>• stopping an earlier strategy / tactic</td>
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<tr>
<td>• A student who was rereading notes (rehearsal) decides to create an outline from reading (organization).</td>
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<tr>
<td><strong>4.4 Identifying and choosing new control strategies / tactics</strong> - Student changes initial or earlier control strategy / tactic to replace or supplement initial strategy.</td>
</tr>
<tr>
<td>• replacing an earlier control strategy / tactic with a new one</td>
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<tr>
<td>• adding a control new strategy / tactic</td>
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<tr>
<td>• stopping an earlier strategy / tactic.</td>
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<tr>
<td>• A student was studying with another student and decides s/he is off task and chooses to study alone instead.</td>
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<td><strong>4.5 Reaffirming strategies</strong></td>
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<tr>
<td>• Deciding to continue using a tactic because it works</td>
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<td>SRL Phase</td>
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