

THINKING ABOUT THINKING IN STUDY GROUPS

Thinking About Thinking in Study Groups: Studying Engineering Students' Use of  
Metacognition in Naturalistic Settings

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### ABSTRACT

Metacognition has been identified as a critical skill set for learning in problem solving, conceptual understanding, and studying, all of which are key in any undergraduate engineering curriculum. Though significant research has identified metacognition as critical in learning, most of this research has been conducted in experimental settings and has focused on individual engagement. While experimental settings provide evidence that metacognition is important to learning, these controlled studies do not tell us if students actually engage in metacognition in their own contexts. The purpose of this research study was to describe the metacognitive habits of engineering students in the naturalistic setting of study groups as well as contextual factors that supported this engagement. In order to accomplish this, I developed a methodological approach useful for identifying metacognitive engagement in naturalistic settings. In this ethnographically-inspired qualitative study, I used participant observations as my primary source of data and ethnographic interviews as supplemental data. Three study groups participated in this study and represented a diverse range of strategies for learning and studying.

In order to identify the metacognitive behaviors of the study participants, I developed the Naturalistic Observations of Metacognitive Engagement (NOME) coding strategy, a coding scheme that can be used to identify metacognitive engagement in naturalistic settings involving undergraduate engineering students. Through the use of the NOME for coding the observational transcripts, I found that undergraduate engineering students engage in metacognitive engagement in different ways and certain metacognitive behaviors are engaged in at a higher rate than others. From an analysis of the observational fieldnotes, I found that contextual factors such as learning environment, study group schedule, study group purpose, learning resources, and workload potentially impact the way in which engineering students engage in metacognitive practices. The findings of this study provide important implications for researchers in metacognition and engineering education, educational practitioners, students, and the research site and participants from which the data was collected.

## Dedication

To my Mom and Dad: I guess those ‘Unsatisfactory’ marks in conduct for excessive talking in kindergarten didn’t affect my trajectory too much...thanks for loving and believing in this kid that still talks a little too much!

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## 1 Chapter 1 Introduction

A significant goal of educators in the engineering disciplines is to prepare graduating students so they can apply the knowledge gained in their studies to solve problems, make improvements and design new technologies. However, there is increasing evidence that students are graduating from undergraduate institutions while still holding on to robust misconceptions in fundamental areas such as physics, electricity, statics, materials and thermodynamics (Krause, Kelly, Corkins, & Tasooji, 2009; Steif, Lobue, Kara, & Fay, 2010; Streveler, Litzinger, Miller, & Steif, 2008). To facilitate the learning of difficult engineering concepts, it is important that we identify skill sets that students need to regulate their own learning processes while engaging in their undergraduate education. One such skill set that has been identified to aid in the regulation of learning, and in particular conceptual learning, is metacognition (Case, Gunstone, & Lewis, 2001; Pintrich, 1993a; Rittle-Johnson, Siegler, & Alibali, 2001).

Metacognition refers to the knowledge and regulation of a student's learning processes (Brown, 1987; Flavell, 1979). Metacognition is typically broken into two components: metacognitive knowledge and metacognitive regulation. Metacognitive knowledge refers to what a student knows about his or her own cognitive processes (Brown, 1987; Flavell, 1979). Metacognitive regulation refers to the strategies used to oversee his or her own learning (Flavell, 1979). Both metacognitive knowledge and regulation have been identified as critical to the general activities of studying, problem solving, and repairing misconceptions (Case & Gunstone, 2002; Davidson & Sternberg, 1998; Grotzer & Mittlefehldt, 2012; Hennessey, 2003; Mayer, 1998; Pintrich, 1993a; Rittle-Johnson et al., 2001; Schoenfeld, 1992; Winne & Hadwin, 1998).

Significant research describes the benefits of engagement in metacognitive behaviors for learning. For example, Chi, Bassok, Lewis, Reimann, and Glaser (1989) found that students who

engaged in self-explanations, and thus engaged in more self-monitoring activities, tended to be better problem solvers. White and Frederiksen (1998) found that low achieving students showed learning gains when engaged in metacognitive reflection. Metacognition has also been identified as a critical component of self-regulated learning (Butler, Cartier, Schnellert, Gagnon, & Giammarino, 2011; Butler & Winne, 1995; Zimmerman & Schunk, 2011). While there is significant research that shows the importance of metacognitive engagement in learning, much of this research is conducted in experimental settings where variables and environments are controlled (e.g., (Lawanto, 2010; Litzinger et al., 2010; Veenman, Prins, & Verheij, 2003)). Little is known about how students actually engage in metacognition in naturalistic settings (Perry, 2002). Even further, there is minimal research that examines if students actually engage in metacognitive behaviors during self-directed learning activities, such as studying. In particular, little is known about how students engage in metacognitive behaviors in engineering and what contextual factors support engagement in metacognition.

In examining learning in engineering, it is important to consider that many learning activities, both in and out of the classroom, happen in groups. In a recent study on the fidelity of implementation of research based instructional strategies, Borrego, Cutler, Prince, Henderson, and Froyd (2013) found that between 60% and 96% of instructors who participated in the study engaged their students in some sort of collaborative learning activities. Research has shown the positive impacts of collaboration on learning outcomes (Prince, 2004; K. A. Smith, Sheppard, Johnson, & Johnson, 2005). Collaborative work with peers has been shown to meet students' needs for relatedness (Wentzel, 1997), diminish feelings of inadequacy (Hickey, 1997), and benefit cognitive engagement through engaging students in explanation, clarification, debate and the critique of the work of others (Yackel, Cobb, & Wood, 1991). Though positive benefits have

been shown from collaborative work inside the classroom, little is known about whether these positive benefits translate to collaborative work outside of the classroom. Due to the significant push for collaborative learning in engineering education and the limited understanding of collaborative engagement in metacognition, this work was bounded to examine metacognitive engagement in study groups.

Limitations in available methods for studying metacognition contribute to the knowledge gap. The most widely used methodological approaches for studying metacognition in education are self-report measures, think-aloud protocols, and interviews (Baker & Cerro, 2000). Though these methods are popular, they are only appropriate for certain inquiries of study. For example, self-report methods are popular because they can be used to collect a large amount of data in a short amount of time. But self-reports methods can only be used as an off-line method, or a method in which data is collected at a separate time from the learning event, for studying metacognition (Baker & Cerro, 2000). In a similar fashion, interviews can also only be used to study metacognition off-line. Further, there is a continuing debate in the study of metacognition as to whether engagement in metacognition is a conscious or nonconscious process (Hacker, Dunlosky, & Graesser, 1998). If facets of metacognitive engagement are nonconscious, then self-report measures provide little valuable data. Further, more intrusive ‘online’ methods of data collection that ask participants to perform certain tasks do not give an accurate picture of what participants do under their own volition. Due to the limitations in current methodological approaches, it was first necessary to focus on developing an approach for studying metacognition in a naturalistic setting where participants would engage with one another without requiring the researcher to interfere.

The purpose of this research study was to understand how engineering students were engaging in metacognition in naturalistic settings. In order to achieve this aim, I had three main objectives for this study. The first objective was to develop an appropriate methodological approach for studying metacognition in naturalistic settings. Specifically, I developed an observational coding strategy that identified metacognitive engagement through the use of participant observations. The second objective of this study was to provide a rich description of what metacognitive engagement looks like for engineering students in a naturalistic setting, specifically in a study group environment. The third objective was to provide a discussion of contextual factors that are potentially linked to differences in metacognitive engagement.

This chapter provides information on the needs and benefits as well as the stakeholders of this study. After a discussion of the purpose, benefits and stakeholders, a brief description of the study design is provided along with a definition of the scope and limitations of the study. However, before moving forward, it is important to define key terms that are useful in understanding this study.

### 1.1 Definitions

Because words can have different meanings in different contexts and different bodies of literature, I supplied the definitions that guided my work. The definitions provide information as to the assumptions I have made when using certain words.

- **Metacognition** is defined as knowledge and regulation of one's learning processes (Brown, 1987; Flavell, 1979). Metacognition is typically broken into two main components.
  - **Metacognitive knowledge** is defined as the insight that the learner has about his own cognitive processes (Brown, 1987; Flavell, 1979).

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- **Metacognitive regulation** refers to the activities that a learner uses to oversee his learning (Brown, 1987)
- A **naturalistic setting** is a setting that focuses on “individuals acting within psychological, disciplinary, social, and cultural contexts” (Perry, 2002, p. 1). In this study, the naturalistic setting is defined as a research setting that is natural to the participant and is not set up or manipulated by the researcher. The study groups that were observed as part of this study were naturally formed groups that were not set up by the researcher. The time and location of each study were dictated by the study group and were not set up or influenced by the researcher.
- A **study group** is defined as a group of two or more students that meet together with the goal of studying some aspect of engineering content. This studying may include working on homework, working on a project or lab as well as studying for a quiz, test or exam.
- A **problem solving course** is defined as any course that requires students to solve open-ended problems as part of the course work. Problem solving is defined as “goal-oriented activity where the path or means to the goal is at least somewhat uncertain” (Dominowski, 1998, p. 25). Thus, problem solving courses typically focus on engaging students in ill-structured problems. Courses like statics, dynamics and thermodynamics are considered problem solving courses in engineering.
- **Context** is defined as the set of circumstances that surround a certain event or activity. For this study, context can include, but is not limited to, the settings in which students attend classes and study outside of class time, the way in which a particular course is structured, how students interact with one another in their study group sessions, and how the university is structured to support students in their academic progress.

- **Domain-specific** means that the metacognitive skills selected for use by a student in a particular domain, such as a specific subject, are a function of the domain (Veenman, 2011), used in one domain only, and would not be transferable to another domain.
- **Domain-general** means that the metacognitive skills utilized are common to many domains and are thus transferable between different domains (Veenman, 2011).
- A **task** is defined as a piece of work that must be undertaken. Flavell (1979) also describes a task as a “cognitive enterprise” (p. 907).
- A **strategy** is defined as a set of procedures or steps selected in order to accomplish the goals associated with a particular task (Flavell, 1979).

### 1.2 Statement of the Problem

Despite the importance of both metacognition and study groups to students’ learning, little is known about how engineering students engage in metacognitive behaviors as they study collaboratively in groups. If we want to develop curriculum that is meant to support metacognition in engineering, we must first understand if and how students are engaging in metacognitive behaviors and what contextual factors impact that engagement when they work and study on their own. By understanding the baseline level of metacognitive engagement, we can develop specific pedagogical interventions that target weak metacognitive skills and continue to build stronger metacognitive skills. We can use the understanding of how different contextual factors impact engagement in metacognitive behaviors to emphasize the positive factors while minimizing the negative factors in curriculum development. With the push for collaborative learning at a heightened state in engineering education, it is further important that we understand how students engage in metacognition in collaborative settings. Our understanding of metacognition is further hampered by the fact that current methodological

approaches for studying metacognition are not appropriate for identifying metacognitive engagement in naturalistic settings, such as study groups. To develop a picture of what students are doing metacognitively in order to support future pedagogy development, we must first develop appropriate methods to study metacognition in naturalistic settings.

### **1.3 Purpose of the Study**

The purpose of this study involved understanding the current metacognitive behaviors of engineering students as well as how the context impacted engagement in those behaviors. To meet this purpose, it was first necessary to develop research methods appropriate for identifying metacognition in naturalistic settings. This results in three specific purposes.

The first purpose of this study was to develop appropriate methods for identifying metacognition in naturalistic settings. Historical assessment methods for metacognition included self-report measures and think-aloud protocols. These methods do not allow for the identification of metacognitive engagement in naturalistic settings, such as student study groups. Therefore, a significant portion of this study was focused on the development of research methodology appropriate for identifying metacognitive engagement in naturalistic settings.

The second purpose of this study was to understand what metacognitive behaviors students engage in when studying together in a group. Closely associated with this, the third purpose of this study was to understand how the context impacted students' willingness and ability to engage in metacognitive practices. While significant research effort has shown the importance of metacognitive engagement in areas like problem solving, studying, and conceptual learning, little has been done to understand what engineering students are actually doing in regards to metacognition when studying in natural settings. In order to move forward in designing curriculum that develops and supports metacognitive behaviors in engineering

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undergraduate students, it is important to first know what students are doing and how the current context impacts their metacognitive engagement, as a baseline. In order to accomplish these three purposes, one overarching research question was developed and broken into three research sub-questions. Table 1 displays each of the three research sub-questions, as well as how and what data was collected and analyzed at each step and the outcomes for each research question.

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Table 1 Research Plan and Outcomes for Metacognition Study				
<i>Overarching Research Question: How are engineering students engaging in metacognition when they are studying together in study groups?</i>				
#	Research Question	Data Collection	Analysis	Outcomes
1	How can students' use of metacognitive behaviors be identified in naturalistic settings (study groups)?	Nine participant observations (video and audio recorded); Eleven participant interviews for self-reported metacognitive behavior	1) Inductive and deductive coding of selected episodes for metacognitive engagement; 2) intercoder agreement for reliability measures; 3) comparison of observed versus self-reported behaviors for support in use of observational methods	Development of Naturalistic Observations of Metacognition in Engineering (NOME) coding strategy
2	What metacognitive behaviors are students engaging in when studying engineering content in groups?	Nine participant observations (video and audio recorded)	Observations coded using NOME coding strategy	1) Qualitative and quantitative descriptions of overall metacognitive behaviors; 2) In-depth descriptions of specific metacognitive behaviors
3	What contextual factors contribute to engagement in metacognitive behaviors while studying engineering content in groups?	Nine participant observations (extensive fieldnotes)	Inductive and thematic coding of fieldnotes	Identification of contextual factors that connect with patterns in metacognitive engagement: 1) learning environment; 2) learning resources; 3) study group purpose; 4) study group schedule; and 5) workload

To answer these questions, ethnographically-informed qualitative methods, including participant observations and interviews, were used to better understand how students are engaging in metacognition and how context impacts engagement. A series of eighteen participant observations were conducted with three participant groups as they studied engineering content in a naturally formed study group. Nine observations were selected for further analysis as they represented a range of events of interest over the duration of data collection. In order to develop an appropriate method for identifying metacognitive engagement in these observations, this study utilized the model of metacognition developed by Whitebread et al. (2009) when studying children's metacognitive abilities. This model was used as a starting point for the development of the Naturalistic Observations of Metacognition in Engineering (NOME) coding strategy. The nine observations were coded using the NOME coding strategy to identify what metacognitive engagement looked like over the data collection period. Extensive fieldnotes from the observations were used to identify patterns in contextual factors that were compared against patterns in metacognitive engagement. From the data collected and the analysis conducted, several outcomes were identified. The following section briefly describes those outcomes.

### **1.4 Significance of the Research**

This research provided several significant outcomes related to observational techniques used to identify metacognitive engagement and factors that impact metacognitive engagement. First, through this work, I developed the NOME coding strategy. This coding strategy, as well as the methodological approach used to collect the observational data, contributed to the research community, both in engineering education and in metacognition research. This study further supports the emerging methodology of observational data collection as an appropriate

methodological approach for the study of metacognition in natural settings. Furthermore, the NOME coding strategy is useful in providing researchers in engineering education a method of studying metacognition further in the context of engineering learning environments.

Second, using qualitative and quantitative methods, I provided a rich, detailed description of what metacognitive engagement looks like while students are studying in study groups. Specifically, my work provides an in-depth look at the types of behaviors that constitute metacognitive engagement as well as a discussion as to the behaviors that participants of this study used at higher or lower rates. This information is important in that it is useful in developing pedagogical interventions that can focus on developing weaker metacognitive behaviors and strengthening metacognitive behaviors that are engaged in at a higher rate.

Finally, I identified a number of potential contextual factors that connect with patterns in metacognitive engagement. These factors should be considered in the development of metacognition pedagogy as they could potential play a critical role in supporting these habits. The role of students' learning environments, learning resources, study group schedules, study group purpose, and workload play a potentially critical role in students' ability and willingness to engage in metacognition.

As described in this section, this research developed significant outcomes that are of benefit to researchers in education as well as educators. Stakeholders of this research are not limited only to these two categories and are further described in the next section.

### **1.5 Stakeholders**

There are several stakeholders for this research including researchers in engineering education, metacognition researchers, instructors in engineering education, students in the engineering disciplines, and the research site and participants of this research study. In Chapter

5, I outline how the results of this study provide specific implications for each of these sets of stakeholders.

The first stakeholders are researchers in engineering education. This research adds to the body of knowledge of how engineering students go about learning engineering content. Specifically, I have provided a rich description of the types of behaviors that constitute metacognitive engagement in an engineering undergraduate setting. I have also identified a number of contextual factors that are impactful to metacognitive engagement and are suggested for further study. This study also contributes to new assessment techniques that can be utilized in engineering education.

The second set of stakeholders include researchers in the area of metacognition. There is ongoing work in the field of metacognition to validate the use of observational methods as a tool for understanding how different groups engage in metacognition. Specifically, this work provides support for the observational methods developed by David Whitebread and his colleagues in observing children. This research provides support that the observational tools created by Whitebread et al. (2009) are generalizable to different age groups in different contexts. This work also provides further validation to the idea that observational methods are viable in metacognition research.

A third set of stakeholders are instructors and educators in the engineering disciplines. The outcomes of this research provide information on the base level of metacognitive skills of students studying engineering content in study groups. This information can be used to develop more effective curriculum for supporting metacognitive engagement in engineering students, both in and out of the classroom.

The fourth set of stakeholders was students in engineering disciplines. To help students better understand how to engage in their own learning, we must first understand how they choose to study and work without the intervention of teachers and facilitators. This work is pivotal in that it enters the students' natural environments for studying to understand how they work together to achieve their academic goals. By better understanding how students experience studying and how the environment impacts their ability to engage in metacognitive behaviors, we can develop interventions that can help them develop into stronger metacognitive thinkers.

A final set of stakeholders for this research study was the research site and participants of this study. As part of my ethnographically-informed work, I returned to the research site and met with the participants and instructors of the course from which I recruited. I was able to provide specific feedback and results to each participating study group as well as the instructors in order to support future academic progress. I also presented my research findings to the general faculty and student body because I could provide specific examples of how contextual factors impacted the metacognitive engagement of participating study groups.

### **1.6 Researcher Bias**

This study was subject to my own personal bias coming in as a researcher. It is my belief that metacognition is a critical skill set necessary for learning in the engineering disciplines. My deep-seated belief that metacognition is critical to learning could have had an impact on how I interpreted the results of this study. Specifically, because I believe so strongly in the need for metacognitive skills, I could have been prone to over interpret the existence of metacognitive engagement in student groups. Therefore, it was critical that I develop credibility and dependability checks to ensure that other researchers could help me minimize the impact of my

own bias into this research. Credibility and dependability checks that were used in this study are further discussed in Chapter 3.

### **1.7 Study Scope, Limitations, and Other Bias**

The goal of this research study was to identify if and how students are engaging in metacognitive behaviors while studying. The study was designed to examine students in the natural setting of their study group sessions to better understand their engagement with minimal interference from the researcher. From my study of the construct of metacognition, I believe that metacognition is a critical skill set that students need to be successful in engineering school and beyond. While it is my belief that metacognition is a critical skill set that all engineering students should possess, it was not the aim of this study to develop and support the metacognitive behaviors of the participants in this study, but to lay the groundwork for future research that will be dedicated to developing pedagogical interventions to develop and support the metacognitive behaviors of engineering students. Therefore, the scope of this study was focused only on identifying and understanding metacognitive engagement in naturalistic settings and not to develop any pedagogical intervention to be tested in this context.

Several limitations existed in this research study. Specifically, limitations existed around a limited sample pool, a limited metacognition framework, and interpretations only from the researcher perspective. While I provide a summary of these limitations here, a more detailed discussion of the limitations of this study is found in Section 3.11. The sample pool was limited in that participating groups were recruited from one small teaching focused college. Recruitment was further limited to students in a particular course at this teaching school. Therefore, results are not generalizable to the larger population of undergraduate engineering students but instead provide a rich picture of metacognitive engagement in this school context. Second, the

metacognition model utilized as a base for this study only includes cognitive aspects of metacognition and thus does not include emotional and motivational regulation. The inclusion of emotional and motivational regulation is suggested as an area for future work as this work will help to translate the outcomes of this research against what is known about self-regulated learning. Finally, this work is limited in that it only takes into account the interpretations of the researcher in regards to metacognitive engagement. Future work is also suggested for bringing in students voices and experiences through the use of interview data and member checking.

This study was subjected to two types of bias: sample bias and self-selection bias. Though these ideas are discussed more fully in Section 3.11, I briefly discuss these forms of bias in this section. First, the study was subject to sample bias in that participation was limited to those students who study in naturally formed study groups. It is possible that students who study individually behave in different ways than students who study in study groups. Second, this study was subject to self-selection bias in that participation in the study was voluntary. Again, it is possible that students who did not participate in the study fundamentally engage in metacognition differently than those who participated. Thus, the results of this study are reported as the habits of students who study in naturalistically formed study groups.

### **1.8 Study Context: NSF Funded Research Project**

This research conducted for my dissertation was part of a larger NSF-funded research project designed to understand “Does Motivation Matter for Conceptual Change? Exploring the Implications of “Hot Cognition” on Conceptual Learning” (Grant No. EEC-1150384). This five year NSF CAREER funded study focuses on understanding how student motivation and selection of learning strategies impact conceptual understanding and conceptual change, specifically in the area of thermodynamics (Matusovich & McCord, 2012). Using the model of

hot cognition presented by Linnenbrink and Pintrich (2003), this study seeks to answer the following research questions:

*RQ1 (Phase 1): What are the critical intentionality factors (i.e., students' motivation and learning strategy choice) and relationships among these factors that lead to successful conceptual change?*

*RQ2 (Phase 1): What are faculty beliefs about students' intentionality in conceptual change and what teaching strategies do they use to promote conceptual change?*

*RQ3 (Phase 2): What regular daily and/or critical incidents (instruction/learning experiences) precipitate conceptual change in a one-semester thermal sciences engineering course?*

*RQ3a (Phase 2): What daily and critical classroom teaching and learning experiences do students say help or hinder development of conceptual understanding?*

*RQ3b (Phase 2): What daily and critical daily teaching experiences do faculty say help or hinder development of conceptual understanding?*

*RQ4 (Phase 3): What teaching practices, based on Phase 1 and Phase 2 outcomes, support and encourage intentional conceptual change?*

A significant portion of the first phase of the larger work focused on the development of a nationwide survey to be used to investigate the motivation, learning strategies, and conceptual understanding of thermodynamics students (McCord & Matusovich, 2013). While developing the survey instrument, we found that a significant portion of learning strategies instruments that were previously developed were not appropriate for an undergraduate engineering context (Matusovich & McCord, 2013). This led to an effort to further study the learning strategies of

engineering students in order to develop an appropriate learning strategies measurement tool. My study supports the work contributing to RQ1 in that it further defines the construct of metacognition, a critical component of the learning strategy portion of the hot cognition model.

### **1.9 Summary**

The purpose of this study was to better understand if and how engineering students who study in groups engage in metacognitive behaviors by directly observing their behavior. Through this study, I sought to understand how contextual factors influence engagement in metacognitive behaviors by observing study sessions. This study is significant because we know that engagement in metacognition positively impacts learning but we do not know if engineering students actually engage in metacognitive behaviors while they study. Through the use of naturalistic observations and interviews, I addressed a gap in the literature about if and how engineering students studying in study groups engage in metacognitive behaviors as well as a need for a new methodological approach to study metacognitive engagement. The results of this study provide new insight on what we know about metacognitive engagement and how context plays a role in learning in engineering.

This document is divided into five chapters. Chapter 2 provides a synthesis of literature supporting this study. Specifically, I review literature on metacognitive theory, how metacognition impacts learning, how metacognition is taught and how metacognition is measured. My literature review provides evidence that there is little known about how students actually engage in metacognition when studying in study groups. The literature review also provides evidence that current methods of identifying metacognitive engagement are inadequate and new methods need to be developed to better understand metacognition in naturalistic environments.

Chapter 3 discusses the methodological approach developed to answer the research questions for this study. In chapter 3, I outline the research design, participant information, data collection and analysis procedures, IRB and ethical implications and measures to ensure validity and reliability.

The research findings, including the development of the NOME coding strategy, are presented in Chapter 4. A discussion of how the research results answer the research questions is presented in Chapter 5. Chapter 5 also includes a discussion of implications, areas for future work, and concluding remarks.

## 2 Chapter 2: Literature Review

An important purpose of academic programs in engineering disciplines is to help students understand the fundamental concepts that describe how the world works so that this information can be used in design, problem solving, and improvement. However, significant research in education has shown that engineering students are graduating from undergraduate programs without understanding fundamental concepts in areas such as physics, electricity, statics, materials and thermodynamics (Hestenes, Wells, & Swackhamer, 1992; Krause et al., 2009; Steif et al., 2010; Streveler et al., 2008). For example, research within engineering education has shown that many students hold robust misconceptions in the areas of thermodynamics, heat transfer, and fluid mechanics (Streveler et al., 2008). Related research on conceptual understanding and misconceptions has focused on how to identify misconceptions (Nottis, Prince, Vigeant, Nelson, & Hartsock, 2009; Steif & Dantzler, 2005; Streveler et al., 2011) and different pedagogical techniques that have been implemented to address misconceptions (Miller, Streveler, Olds, & Nelson, 2003; Nottis, Prince, & Vigeant, 2008; Yang, Streveler, Miller, & Santiago, 2009). Collectively this research supports the need to investigate ways to develop skills and tools that allow students to identify and repair their own misconceptions more adequately. Metacognition has been identified as one such area critical to the development of conceptual knowledge and addressing misconceptions (King & Kitchener, 2004; Luque, 2003; Pintrich, 1993a; Rittle-Johnson et al., 2001).

In this chapter, I define metacognition and discuss how engaging in metacognition supports learning and conceptual understanding. Specifically, I discuss the metacognitive model used by Whitebread in the development of his observational tools and how his work was used to frame this study. Then, I review how metacognition is typically measured in research and

teaching environments. Third, I specifically review observational methods and how these methods were used to provide insight into how engineering students are engaging in metacognition.

### **2.1 Defining Metacognition**

Metacognition is defined as a learner's knowledge about and regulation of their own cognition (Brown, 1987; Flavell, 1979). Metacognition is broken into two components: knowledge of cognition and regulation of cognition. Knowledge of cognition, or metacognitive knowledge, is described as the insight that the learner has about his own cognitive processes (Brown, 1987; Flavell, 1979). Regulation of cognition refers to the activities that a learner uses to oversee his or her learning (Brown, 1987). In the following sections, I describe metacognitive knowledge and regulation in more detail.

#### **2.1.1 Metacognitive Knowledge**

Flavell (1979) describes three specific types of metacognitive knowledge: person, task and strategy. Knowledge of persons refers to knowledge that a person holds about his/her own or someone else's knowledge, skills, or abilities in relation to his/her cognition; it is further broken down into three categories: knowledge of self, knowledge of others, and knowledge of universals (Flavell, 1979, 1987). Knowledge of self refers to the knowledge a person holds about his or her knowledge, skills, and abilities in relation to cognition. An example of knowledge of self is when a person knows that he or she is good at learning math concepts but not good at learning science concepts. Knowledge of others refers to a person's knowledge about the knowledge, skills, and abilities of others in relation to cognition. An example of knowledge of others is when a person knows that he or she is more knowledgeable about physics than his or her peer. Finally, knowledge of universals refers to a person's knowledge about universal concepts. For instance, a

small child may not know about the idea of a mistake but an adult knows about mistakes by experiencing them. The idea of a mistake is one that people are not born with but develop over time through experiences in a culture (Flavell, 1979, 1987).

Knowledge of tasks refers to any knowledge a person holds about the task to be undertaken (Flavell, 1979, 1987). The knowledge of tasks can include an understanding of the difficulty level of certain tasks as well as how different tasks relate to one another. For example, when a student attempts to learn about a certain topic, they may find that there is an abundant amount of information available to them. But when searching on a different topic, he or she may find that there is limited information available. The knowledge of how much information is available about a certain topic is a type of task-oriented knowledge. Another example of task knowledge would be when a student realizes that learning the multiplication tables is less complex than learning differential calculus.

Finally, knowledge of strategies refers to the understanding of which procedures are needed and most appropriate to reach a specific cognitive goal. While knowledge of tasks and strategies may sound similar, it is important to distinguish between these two subsets of knowledge. Knowledge of tasks is focused primarily on the task itself while knowledge of strategies is focused on the procedures to be engaged in to accomplish the task. Metacognitive strategies are used to achieve and monitor progress toward cognitive goals (Flavell, 1979, 1987). An example of knowledge of strategies would be when a student realizes that the best way for him or her to learn words for a spelling test is to rehearse the words by writing them over and over again on a piece of paper.

### **2.1.2 Metacognitive Regulation**

Within educational research, there is still significant debate as to what the theoretical model of metacognition should encompass. Consequently, there is no clear agreement, to date, on which metacognitive strategies should be included in the theoretical model of metacognition (Veenman, Van Hout-Wolters, & Afflerbach, 2006). The strategies that I have included in this review are the most highly discussed strategies by experts in the field at this time (e.g., (Baird, 1986; Brown, 1987; Tarricone, 2011; Whitebread et al., 2009)) and include planning, monitoring, evaluating, and control (Baird, 1986; Brown, 1987; Tarricone, 2011; Whitebread et al., 2009).

Planning refers to the activities that involve the selection of procedures necessary for performing a task, predicting the outcomes of learning, and scheduling the strategies used to learn (Brown, 1987; Whitebread et al., 2009). When a student engages in planning, he or she sets out to determine what strategies should be used to reach a certain goal. Then, as the student progresses in the task, the student will review their progress (monitoring activity) and determine if a new plan needs to be devised to reach the goal.

Monitoring refers to the ongoing on-task assessment of task performance, observation of a person's level of knowledge as well as the act of testing and revising knowledge and strategies used for completing a task (Brown, 1987; Whitebread et al., 2009). Monitoring activities may include reading a passage and determining if there are sections in the reading that do not make sense or working a problem and determining if the steps of the process are understood. Monitoring may also include checking and correcting the performance of another person or student that one is in contact with (Whitebread & Pino-Pasternak, 2013).

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Evaluation refers to the process of checking whether the way in which a task was accomplished was efficient and effective when compared to some criteria or standard (Brown, 1987). Examples of evaluation activities can include explaining a task, testing the outcome of a strategy that is to be used to achieve a goal and observing the progress of task performance (Whitebread & Pino-Pasternak, 2013).

Control refers to activities that show evidence of a change in how a task is being approached due to engaging in some monitoring activity (Whitebread & Pino-Pasternak, 2013). Examples of control activities include using non-verbal gestures to support one's own cognitive activity, applying a strategy that was previously learned to a new context, repeating a strategy in order to check the outcome of a solution, seeking help from others, and copying from a model (Whitebread & Pino-Pasternak, 2013).

The order in which metacognitive regulatory strategies are engaged in over the lifecycle of a task can be visualized in Figure 1. I developed this figure, drawing on the work of Nilson (2013); Winne and Hadwin (1998). As the task begins, the learner would be expected to identify the goal of the task, identify strategies that could be used to complete the task, and then assign certain responsibilities to different study group members, if the work is done collaboratively (planning). Once the task has been started, the learner then actively assesses progress and performance throughout the task (monitoring). If a specific strategy is deemed ineffective while working on the task, the learner identifies a new strategy, switches to the new strategy (control), and then continues to assess progress and performance (monitoring). In order for a task to be completed, the learner must determine if the original goal has been met (evaluation). Once the task is complete, the learner reflects and determines if the strategies were efficient and effective at solving the task (evaluation). If the strategy is deemed effective and efficient, the learner can

store that strategy in memory as the strategy to be used in the event that a similar task is encountered. While this order seems very linear in nature, it is important to note that actual progress on a task is not so linear in a natural setting. As the task at hand is defined and redefined, the learner moves back and forth between planning, monitoring/control, and evaluating. This back and forth movement is represented by the arrows in Figure 2.

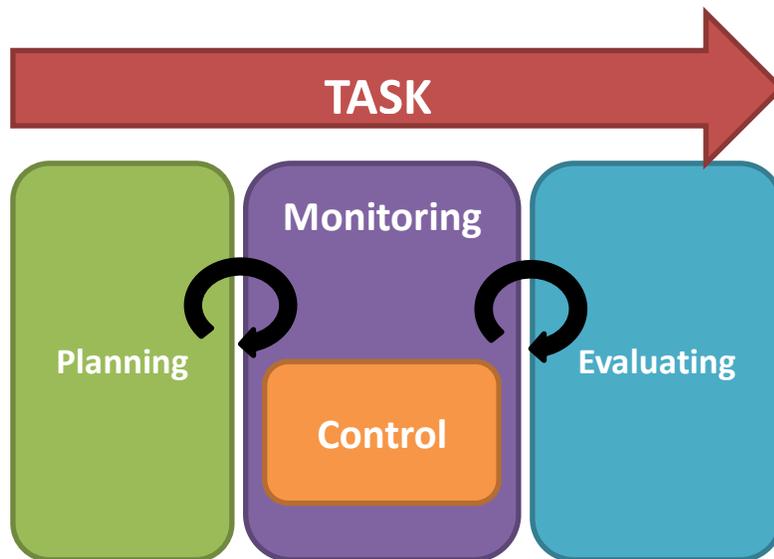


Figure 1 Metacognitive Strategies Over Lifecycle of a Task

### 2.1.3 Debates in Metacognitive Theory

Research on metacognition and learning is a relatively new field of study that emerged in the late 1970's and early 1980's through the work of Flavell (1979) and Brown (1987). Because metacognition is still an emerging area of research in education, there are several topics that are still under debate within the research community. These topics include self versus social metacognitive engagement, domain generality versus specificity, and the metacognitive development process. The positions researchers take on any of these topics can have significant

impacts on how research is conducted as well as the implications and conclusions that can be drawn.

### *2.1.3.1 Self versus Social*

Early research in metacognition focused specifically on how an individual understands his or her own level of knowledge and how an individual regulates his or her own thinking and learning processes (Volet, Vauras, & Salonen, 2009). Self-regulation is defined as “the cognitive and metacognitive regulatory processes used by individuals to plan, enact, and sustain their desired courses of action” (Volet, Vauras, et al., 2009, p. 216). In recent years, researchers have been investigating how learners engage in metacognition on a more collaborative level. This collaborative engagement is termed social regulation and is defined as “how individuals reciprocally regulate each other’s cognitive and metacognitive processes and sometimes engage in genuinely shared modes of cognitive and metacognitive regulation” (Volet, Vauras, et al., 2009, p. 216). Social regulation has many different forms: shared regulation, other regulation, socially shared metacognitive regulation. Learners engage in shared regulation when they engage in “constant monitoring and regulation of joint activity, which cannot be reduced to mere individual activity” (Vauras, Iiskala, Kajamies, Kinnunen, & Lehtinen, 2003, p. 35). Other regulation occurs when a momentary unequal situation occurs and one learner steps in to regulate the learning of another learner in order to equalize the imbalance (Volet, Summers, & Thurman, 2009). In other regulation, knowledge is not co-constructed. Instead, one learner is attempting to teach another learner. Finally, social shared metacognitive regulation is defined as “metacognitive regulation that takes place within genuine collaboration and cannot be simply reduced to individual regulation” (Iiskala, Vauras, & Lehtinen, 2004, p. 150).

While some researchers have attempted to study self and social regulation separately (Iiskala et al., 2004; Vauras et al., 2003; Volet, Summers, et al., 2009), Volet, Vauras, et al. (2009) argue that, when attempting to study learning in naturalistic settings, regulation is not reducible to individual and group engagement. Instead, the learners are seen as “multiple self-regulating agents who co-regulate each other’s engagement and learning, and at times operate as a social entity or system that is not reducible to aggregate individual metacognitions” (Volet, Vauras, et al., 2009, p. 219). Thus, because learners move through self and social regulation fluidly while in naturalistic settings, one cannot study the phenomena separately because they are, in essence, not separate. In this study, I have chosen to view metacognitive engagement as both self and social. Therefore, I have focused on both individual as well as collaborative engagement in metacognitive practices.

### *2.1.3.2 Domain Generality Versus Specificity*

Another topic of debate within research on metacognition is whether metacognitive skills are general or task/content specific (Veenman et al., 2006). This is of particular issue in the assessment of metacognition as well as in the development of instructional strategies for teaching metacognitive skills. A significant portion of historical research in metacognition has been focused in the area of domain specificity, where metacognitive engagement has been studied in reading (Veenman & Beishuizen, 2004; Zhang, 2001), math problem solving (Kramarski & Mevarech, 2003), and economics (Masui & De Corte, 1999). Little research has been done comparing metacognitive engagement across these domains (Veenman et al., 2006). The lack of agreement on whether skills are general or specific causes difficulty in both teaching and assessing metacognitive skills. For teaching, it is difficult to know whether metacognitive skills should be taught in the context of a specific domain (domain specific) or if skills can be taught in

an all-encompassing class that is meant to teach skills across all disciplines (domain general). For assessment, this debate has a significant impact on how assessment methods are designed for identifying metacognitive engagement (Pintrich, Wolters, & Baxter, 2000). Coming from the domain specific approach, methods such as self-report questionnaires are designed to task specific in how they ask questions. In contrast, domain general focused questionnaires ask about engagement that is not connected to a particular task. In order to design effective pedagogy and assessment practices, it is important that future work be dedicated to investigating this continuing issue.

### ***2.1.3.3 Developmental Stages of Metacognitive Skill***

The development of metacognition over time is another topic of debate in the field. There are several studies that have looked at how metacognition develops over time. For example, Alexander, Carr, and Schwanenflugel (1995) found that metacognitive knowledge begins to develop as early as 5 years old. While some researchers believed that metacognitive regulatory skills emerge in children around the age of 8 and develop further in the years that follow (Veenman & Spaans, 2005), Whitebread et al. (2005) has shown evidence that some metacognitive skills, such as planning and reflection, can be seen in children as young as 3 years old. It is also possible that certain metacognitive skills, such as monitoring and evaluation skills, develop later than other skills, such as planning (Veenman et al., 2006). Executive functioning, which is closely related to metacognitive skill, occurs in the pre-frontal cortex of the brain (E. E. Smith & Kosslyn, 2007). The pre-frontal cortex of the brain does not fully develop until the mid-20's. Thus, it is possible that full development of metacognitive skill may not occur until the mid-20's, when the pre-frontal cortex is fully developed. It is also possible that metacognitive skills may first develop in specific domains and then become more generalizable to other

domains (Veenman & Spaans, 2005). While there has been significant research dedicated to understand the development of metacognition at different stages of growth, there is still much that we do not know about how metacognitive knowledge and skills develop over time.

### **2.1.4 Theoretical Model of Metacognition**

For this study, I used a modified version of the metacognitive model used by Whitebread et al. (2009) to develop his C.Ind.Le coding scheme and CHILD 3-5 observational tool. This model was used to develop an observational coding strategy for studying the metacognitive abilities of children ages 3 through 5. The Whitebread et al. model includes metacognitive knowledge, metacognitive regulation and emotional and motivational regulation and was developed based on the work of Flavell (1979, 1987), Brown (1987), and Vygotsky (1980). Compared to other possible models (e.g., (Tarricone, 2011), Whitebread's model of metacognition is particularly useful for this study in that it has been used in prior studies that focus on observing the behaviors of participants in naturalistic settings.

My framework, shown in Figure 2.1, is a subset of the model suggested by Whitebread et al., as it does not include the components of motivational and emotional regulation. While the regulation of one's motivation and emotions is an important topic of discussion when developing self-regulated learners, my study was scoped to focus on the aspects of metacognitive knowledge and metacognitive regulation and did not focus on emotional and motivational regulation. Therefore, emotional and motivational regulation was not included in the framework shown in Figure 2.1.

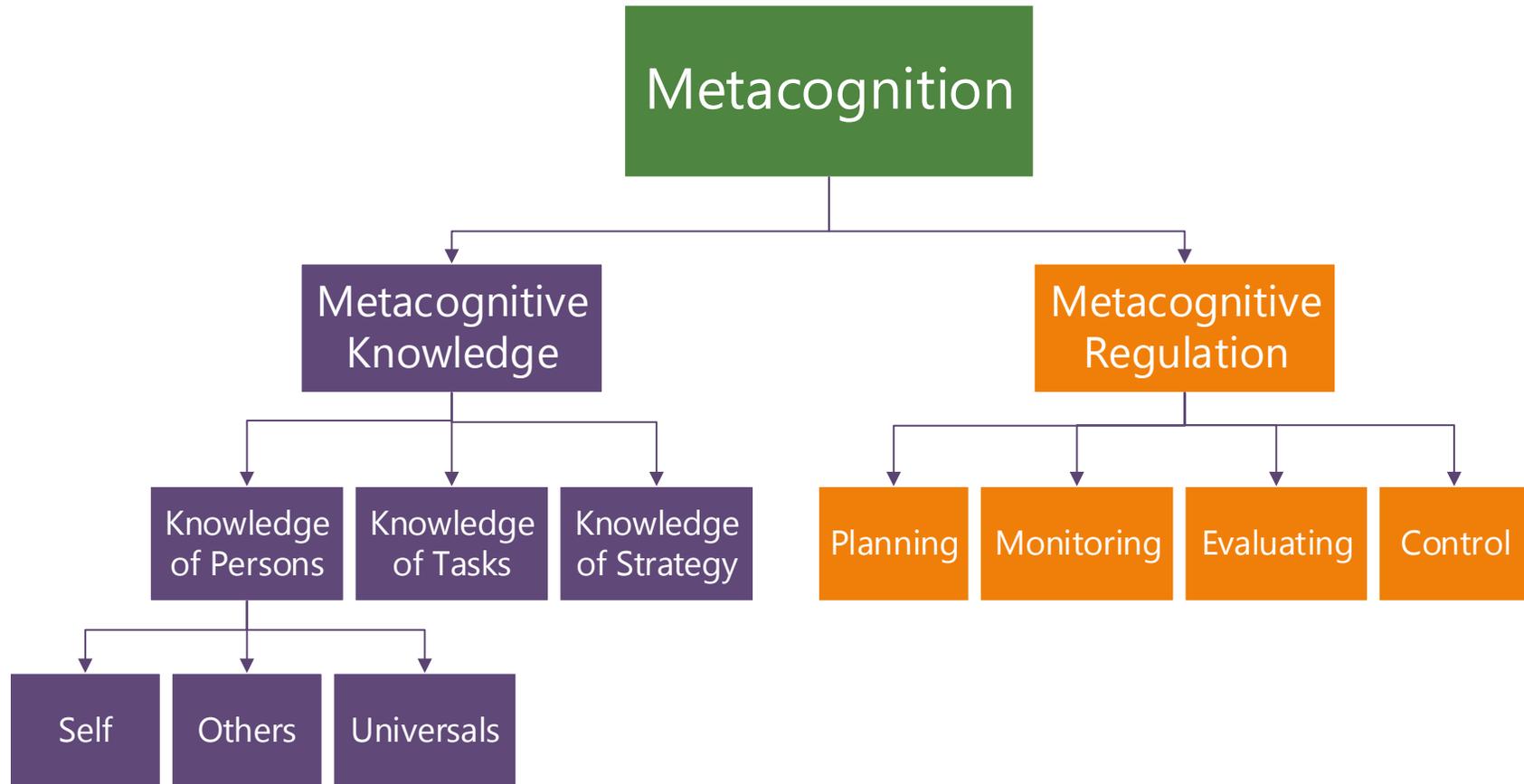


Figure 2 Metacognition Framework (Subset of Whitebread et al. (2009))

## 2.2 Metacognition and Learning

I have already argued that metacognition is important to learning. In this section, I support that assertion with evidence from the literature discussing the connections between metacognition and several areas of learning including self-regulated learning, learning in problem solving, conceptual learning, and learning in different environments.

### 2.2.1 Metacognition and Self-Regulated Learning

In this section, I provide a brief explanation of SRL in order to discuss how metacognition is a critical component of SRL. In order to understand SRL and how to support engagement in SRL in different contexts, we must understand the critical components, like metacognition, that comprise the SRL process.

Self-regulated learning (SRL) is the process that a learner goes through to enact and sustain cognitive functioning, behaviors, and metacognitive functioning to reach a set goal or goals (Corno, 2012). SRL is a complex process that includes the learner's beliefs about their own learning, motivations, pre-existing knowledge, and cognitive and metacognitive skills. It is a commonly held belief in education that the most effective students in a learning environment are the students who have a high level of awareness about their own knowledge level and take control of their own learning processes (Butler & Winne, 1995); these students are referred to as self-regulated learners. Though there are many different perspectives that provide different views of SRL, in general SRL theorists "view students as metacognitively, motivationally, and behaviorally active participants in their own learning process" (Zimmerman, 1986).

One example of an SRL model is the model developed by Butler et al. (2011). Shown in Figure 3, this model shows the interaction between what students bring to a learning context, their beliefs and emotions in the learning context, and the cognitive and metacognitive processes

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they engage in (highlighted in yellow) while in the learning context. Specifically, the cognitive and metacognitive processes represented in this process include the activities of planning, self-monitoring, and self-assessing, or evaluating. The model presented by Butler et al. suggests that cognitive and metacognitive processes are integral to the SRL process.

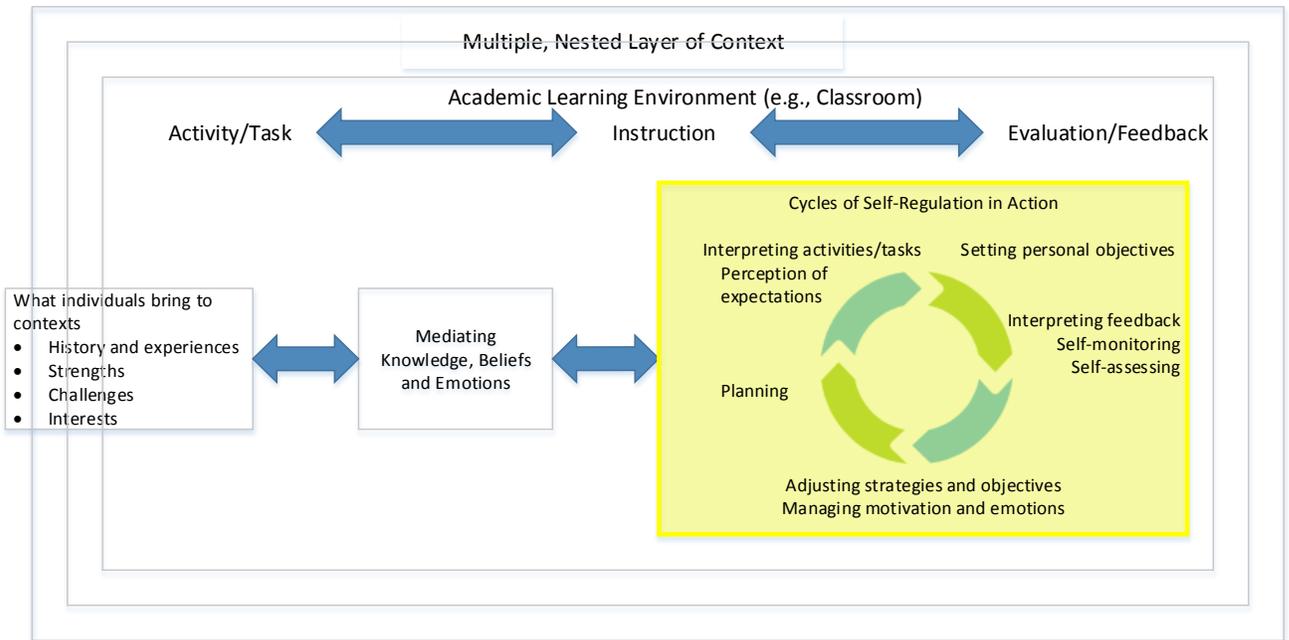


Figure 3 A situated model of Self-Regulated Learning (Butler, Cartier, Schnellert, Gagnon, and Giammarino, 2011)

There has been a significant call in recent years to better understand the contextual factors that impact engagement in SRL (Butler, 2002). Research in SRL has suggested that contextual factors such as instructor scaffolding (D. K. Meyer & Turner, 2002), pedagogical approach (Patrick & Middleton, 2002), interpersonal relationships as well as school policy or structure (De Groot, 2002), impact engagement in self-regulated learning strategies. For instance, some literature suggests that instructor scaffolding for metacognitive processes has an impact on student engagement in monitoring (Butler, 1998; D. K. Meyer & Turner, 2002).

Patrick and Middleton (2002) suggest that collaboration between peers can support monitoring behaviors, though this literature is situated in problem based learning environments that are specifically developed to support metacognitive behaviors.

As researchers push to understand the contextual factors that impact SRL, it is also critical that we focus on contextual factors that have an impact on engagement in metacognition. To do this, we must first verify using appropriate research methods that students are engaging in metacognition in naturalistic settings. While there is significant research that shows that engaging in metacognitive behaviors can have a positive impact on learning outcomes, we have little evidence to show that students are engaging in these metacognitive behaviors when in naturalistic settings. Also, learning happens in a range of settings and learner configurations. Therefore, it is important to understand how students engage in metacognition across these different settings. It is important to understand if and how students are engaging in metacognitive behaviors as well as how context impacts this engagement to further support work in the area of SRL.

### **2.2.2 Metacognition and Learning in Engineering**

Metacognition is particularly important to students in engineering programs due to the extensive focus on problem solving and conceptual learning in undergraduate engineering curriculums. Sheppard, Colby, Macatangay, and Sullivan (2006) describe three main components of engineering practice: engineering as problem solving, engineering as knowledge, and engineering as an integration of knowledge and process (Streveler et al., 2008). Sheppard and colleagues show the importance of problem solving and knowledge (including conceptual knowledge) in the education of engineering students. While it is critical to focus on these areas in order to prepare students for engineering practice, research has found that learning in problem

solving and conceptual knowledge can be particularly difficult for students, often due to the presence of robust misconceptions (Streveler et al., 2008). In this section, I support the argument that metacognition is a critical skill set that is useful in supporting students' learning in problem solving and conceptual knowledge as well as in repairing misconceptions.

### ***2.2.2.1 Problem Solving***

Problem solving is defined as “goal-oriented activity where the path or means to the goal is at least somewhat uncertain” (Dominowski, 1998, p. 25). Problem solving requires the student to think in a way that is directed towards achieving the goal of solving a problem. Metacognition, and specifically awareness and the management of mental processes, is necessary to guide goal directed thinking. Davidson and Sternberg (1998) believe that it is one's ability to think about their problem solving activities that defines him or her as a good problem solver. In their chapter on problem solving, Using theoretical and empirical evidence from multiple perspectives including cognitive science, mathematics, reading comprehension, and the physical sciences, Davidson and Sternberg (1998) discuss how metacognition plays a key role in the three major areas of problem solving: the givens, the goals and the obstacles.

The ‘givens’ are identified as “the elements, their relations, and the conditions that compose the initial form of a problem,” (Davidson & Sternberg, 1998, p. 48). When identifying the ‘givens’, or given information, in a problem, the solver encodes the information from the problem and develops a mental representation of the problem. This mental representation is a map or picture, developed in the mind, that represents the current state of the problem.

Metacognition is used to determine what is known about the problem and what is unknown. The known information as well as the information to be found is identified as the ‘givens’ of the

problem. Once this mental representation is developed, metacognition (monitoring and evaluation) is used to change the mental representation from the original state to the goal state.

The ‘goal’ is defined as “the desired outcome or solution,” (Davidson & Sternberg, 1998, p. 48). When working towards the goal of a problem, the metacognitive strategy of planning is used to develop the plan that is to be followed. Some research has shown that a person’s level of domain specific knowledge can affect planning, as experts have been shown to spend more time planning while novices tend to spend less time planning (e.g., (Larkin, McDermott, Simon, & Simon, 1980)). Also, it has been found that planning substeps to reach the final goal is actually easier than making a singular plan to reach the final goal (Hayes, 1989).

As students work towards achieving goals, they may encounter a series of obstacles. ‘Obstacles’ are defined as “the characteristics of both the problem and the student that make it difficult for the student to change the given state of the problem into the desired one or to recognize when the correct transformation has occurred,” (Davidson & Sternberg, 1998, p. 48). The metacognitive strategies of monitoring and evaluation have been identified as critical steps used in addressing obstacles during problem solving. Without monitoring and evaluation, obstacles can become stopping points for students during problem solving. When students reach obstacles that are difficult to pass, teacher interventions that offer new problem-solving strategies and encourage students to reflect on their progress have been shown to be useful in helping students move past obstacles (Davidson & Sternberg, 1998).

Within engineering education, metacognition has been shown to be a critical thinking process in problem solving. For example, Litzinger et al. (2010) conducted a study to look at the critical cognitive and metacognitive strategies that students engaged in while problem solving in statics. To achieve this aim, the researchers asked students to participate in think-alouds with

different statics problems. Participants were first clustered into two groups (strong and weak problem solvers) by looking at a combination of their scores on a statics concept inventory, two spatial reasoning tests, and their SAT scores. Participants were then asked to complete two statics problems while thinking aloud. Utterances of metacognitive monitoring and evaluating were counted for each problem completed by participants. Litzinger et al. (2010) found that stronger problem solvers used a higher rate of metacognitive monitoring than did weaker problem solvers. The research team also found that all participants used a higher rate of metacognitive monitoring when compared to metacognitive evaluation in order to solve the statics problems presented.

While not focused specifically in the area of problem solving, Lawanto (2010) has conducted work on how engineering students' engagement in metacognition changed over the course of an ill-structured design project. Through a quantitative self-report study, Lawanto (2010) found that a series of internal and external factors could be attributed to changes in metacognition over the course of a design project. Internal factors such as misjudging the complexity of the task, being fearful and failing, and misjudging one's own ability were cited as factors affecting metacognitive engagement. External factors such as lack of time, lack of support or resources, and receiving helps from others were also cited as factors impacting metacognitive engagement.

### ***2.2.2.2 Conceptual Learning***

If students enter into a learning environment with little or no knowledge about the subject to be studied, there are minimal barriers to constructing new knowledge and developing an understanding of the concepts that are a part of that domain (Pintrich, 1993a). Students do not enter into the classroom with clean slates. Instead, they enter with preconceived notions of how

the world works. These notions may or may not be aligned with the ideas that experts in that domain present. When a student holds a belief about a concept that does not align with the belief of the experts in the domain, they are said to hold a misconception and misconceptions must be addressed. One practice that can help students address misconceptions is the process of engaging in metacognitive behaviors.

Learning procedural knowledge can be helpful in engaging students in metacognitive behaviors and in developing conceptual knowledge as well as aiding in the repair of misconceptions. Rittle-Johnson and her colleagues have looked at conceptual change by looking at links between conceptual and procedural knowledge (Rittle-Johnson et al., 2001). In a series of studies, the research team looked at the iterative process that occurs while developing conceptual and procedural knowledge. Findings from the study led to three significant conclusions that support the use of metacognitive behaviors in conceptual change. First, as students develop more procedural knowledge, cognitive load is freed to engage in other processes such as planning and reflection. Second, misconceptions may be highlighted by improvements to procedural knowledge. Monitoring the procedures that students are using to solve problems can help highlight conflict between held beliefs and beliefs presented by experts. Finally, engaging in reflection on why procedures work may be a link between a student's gains in procedural knowledge and conceptual knowledge. These three findings show how metacognitive behaviors are critical in dealing with conceptual (and procedural) development.

Work in engineering education has also highlighted the important links between conceptual learning and metacognition. For example, Case et al. (2001) conducted a study looking at the metacognitive development of students in a sophomore level chemical engineering course. As students' metacognitive abilities further developed, it was also observed that students'

shifted their focus away from only procedurally based learning and began to focus on conceptual learning in their coursework. In a second study, Case and Gunstone (2002) found that students who initially started a chemical engineering course with a conceptually based approach to learning did not experience any development in metacognitive ability over the course of the term while students who entered the course with an algorithm based approach but moved towards a conceptually based learning approach over the course of the term experienced a significant development of metacognitive ability. The students who started with a conceptually based learning approach did not experience a shift in metacognitive ability because they started the course with a very high and complex approach to learning and thus did not need further skills to learn. In contrast, students who showed a shift towards conceptually based learning also showed a shift in metacognitive ability. From this study, it can be ascertained that, in order to shift to the conceptually based learning approach, more metacognitive skill was needed. Case et al.'s (2001) work highlights that, specifically in the domain of engineering, there is a strong connection between metacognitive engagement and conceptual learning.

Shown in this section, there are explicit connections to how metacognition is involved in problem solving as well as conceptual learning. As metacognition can be seen as holistically important in learning concepts, repairing misconceptions, and problem solving, in the next sections we discuss how metacognition is holistically important in many types of learning environments. Understanding how a learning environment is structured can help us understand how the context of a learning environment supports engagement in metacognition practices.

### **2.2.3 Metacognition in the Classroom**

Flavell (1987) discusses that, while we may be born with some metacognitive skills, most metacognitive skills can be taught and practiced. There is extensive research that has focused on

developing interventions to teach metacognitive skills in formal learning environments. The pedagogies that are developed tend to focus on the strategies used for regulating cognition: planning, monitoring, evaluation, and control. Research studies have been conducted to provide evidence that these particular pedagogical interventions both develop and support metacognitive behaviors in different learning contexts. For this study, I reviewed the following pedagogical strategies: inquiry teaching, studying expert strategies, portfolios and journals for reflection, and reciprocal teaching. By reviewing these pedagogical strategies, this section provided information useful in providing practical solutions to the research site during the report out portion of this study. In this next section, I review each of these pedagogical strategies in further detail.

### ***2.2.3.1 Inquiry Teaching***

Inquiry teaching is the process where students use a process oriented approach to solve problems through asking questions, creating solutions, and testing results (Schraw, Olafson, Weibel, & Sewing, 2012). Through engaging in the inquiry process, students can develop planning, monitoring, reflection and evaluation skills. Toth, Suthers and Lesgold (2002) tested a method of inquiry teaching using explicit reflection after each process stage. They found that pairing inquiry instructional methodology with explicit reflection practices helped students overcome reasoning difficulties and helped with transfer to new situations. White and Frederikson (1998) developed the ThinkerTool system that used the Inquiry Cycle and the Reflective Assessment tool to develop metacognitive strategies in students. In the Reflective Assessment process, students were asked to reflect on their own as well as their peers' progress in the Inquiry Cycle. The Reflective Assessment tool was designed to specifically develop monitoring and evaluation skills in students. White and Frederikson (1998) found that student learning improved due to the Reflective Assessment tool and the impact was greater with low

achieving students. Another inquiry model that has been instituted in the classroom is the Metacognitive Learning Cycle. The Metacognitive Learning Cycle (MLC) is a model developed after the Science Curriculum Improvement Study Learning Cycle (SCIS) (Blank, 2000). The MLC guides students through a process of exploring their science ideas while prompting for reflection at each stage of the cycle. After each stage is complete, students engage in reflective practices that ask them to follow the inquiry model developed by Posner et al. (1982). Students must provide evidence as to whether the science idea is intelligible, plausible, fruitful or dissatisfactory, which engages them in the metacognitive strategy of evaluation. Students keep a journal of their evidence as a way to reflect on what they are learning and how their conceptions are changing. Inquiry processes like the ones described have been shown to help students build skills in metacognitive reflection, monitoring, and evaluation. As discussed earlier in this chapter, reflection supports engagement in monitoring and evaluation. Therefore, all of the Inquiry Teaching techniques described engage students in reflection in order to support engagement in monitoring and evaluation.

### *2.2.3.2 Studying Expert Strategies*

Worked examples by experts can be useful in helping students learn problem solving processes (Atkinson, Sharon, Renkl, & Wortham, 2000; Craig, Chi, & VanLehn, 2009). Specifically, these worked examples provide a model of the problem-solving process for students to learn from. Further, the use of worked examples can be helpful when students are engaged in self-explanation of the process used by the expert. A self-explanation occurs when students state in their own words their understanding of how to solve a specific problem. Research has found that students who engage in self-explanations tend to use more self-monitoring statements and tend to be better problem solvers (Chi et al., 1989). These metacognitive monitoring skills can

help students make note of what information they already hold, what information they are lacking, and if what they already know matches with the knowledge presented in the expert strategy (Bransford, Brown, & Cocking, 2000).

There is evidence that students who engage in self-explanations of their thinking while working problems tend to perform better in problem solving activities (Chi et al., 1989; Dominowski, 1998). Specifically, students who think aloud and give reasons for their responses tend to perform better in learning activities. Chi and her colleagues (1989) found that students who engaged in more self-explanations were better problem solvers. When students are asked to verbally provide reasons for their choices, this process can help with concept identification, reasoning, getting through multi-step problems, and learning complex relations. The key that makes verbalizations successful is that students are engaged in metacognition during their verbalizations. These verbalizations help students engage in monitoring and evaluation activities and also help them focus on their task-related processes (Dominowski, 1998).

### ***2.2.3.3 Portfolios and Journals for Reflection***

Portfolios have been used to help students develop reflective skills (Nichols, Tippins, & Wieseman, 1997). Portfolios allow students to display artifacts of their work and provide evidence as to why that artifact is relevant to learning. In the process of selecting articles, students have the opportunity to reflect on their own learning and on how they are meeting cognitive goals. Several researchers have found that, by engaging students and teachers in reflective practices through the use of portfolios and journaling, metacognitive skills such as planning, monitoring, and evaluating were improved (Avraamidou & Zembal-Saul, 2006; Azevedo, 2005). One group of researchers found that by implementing electronic portfolios that were specifically developed to scaffold metacognitive practice into a 4<sup>th</sup>-6<sup>th</sup> grade curriculum,

skills such as planning and reflecting were improved (E. Meyer, Abrami, Wade, Aslan, & Deault, 2010). Journals have also been used as a reflective tool for students (Nichols et al., 1997). Journals allow a student to keep track of what they are learning in a particular content area and reflect on how learning has changed and progressed over time.

### ***2.2.3.4 Reciprocal Teaching***

Reciprocal teaching is a method for developing monitoring skills through reading that was first developed by Palincsar and Brown (1984). The method involves pairing an instructor and a student together and asking them to read difficult passages. The instructor and student take turns being the ‘teacher’ as they read a selection. During a turn, both the ‘teacher’ and ‘student’ read a passage silently. After the passage is read, the ‘teacher’ summarizes the passage that has been read. The ‘teacher’ then identifies parts of the passage that may have been difficult to understand and asks the ‘student’ several test-like questions. These questions are intended to determine if the ‘student’ understood the passage. The ‘teacher’ and ‘student’ swap roles every time a new passage is read. Palincsar and Brown (1984) were able to show that use of Reciprocal Teaching helps develop comprehension monitoring in students because this method requires students to read a passage with the intended purpose of determining what might be difficult to understand about the passage.

### ***2.2.3.5 Summary for Formal Pedagogies for Metacognition***

In the inaugural issue of *Metacognition and Learning*, Veenman, Van Hout-Wolters and Afflerbach (2006) provide three principles that are fundamental when developing learning interventions aimed at developing metacognitive skills. First, metacognitive strategy training must be embedded in the content matter so that the skills are connected to the content where they should be used. Second, students should be informed of the critical nature that metacognitive

behaviors play in learning in order to motivate them to work towards developing the skills.

Third, metacognitive skills should be taught over a prolonged period of time in order to guarantee that the use of metacognitive skills will be maintained (Veenman et al., 2006).

In all of the pedagogies reviewed herein, metacognitive strategies were taught or developed in the context of learning specific subject matter, i.e., metacognitive strategies were not taught in a separate course from content. This is important because there is a belief that many metacognitive skills are domain specific (Bransford et al., 2000). Therefore the context of where metacognitive strategies are taught can be extremely important. Understanding how metacognition can be taught in classroom settings was useful in the proposed study as I spent a significant amount of time observing behaviors in the context of the classroom setting. As I brought the results of this study back to the research site, I was able to discuss potential ways for supporting metacognitive engagement in the current classroom structure based on my knowledge of pedagogies developed for supporting metacognitive engagement.

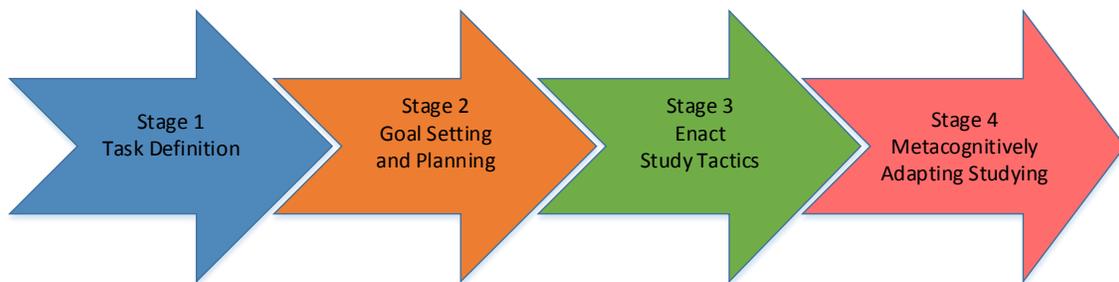
### **2.2.4 Metacognition Outside of the Classroom**

The need for engagement in metacognitive behaviors is not limited to formal learning environments such as the classroom or lecture hall. Winne and Hadwin (1998) suggest a four stage model (shown in Figure 4) of studying that shows that components of metacognition are key to studying outside the classroom. Here, studying is identified as an activity that:

- rarely includes direct intervention by a teacher or facilitator,
- is often a solo activity but can happen through peer mediation,
- often is prompted by a general goal set by the teacher that the student(s) refines at the study session and

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- while studying occurs, often involves synthesizing lots of different information sources (e.g. textbook, notes, homework problems, internet resources, etc.),
- the student(s) can engineer the learning environment
- the activity produces observable traces (e.g. notes, worked problems, outlines, etc.).



**Figure 4 Winne and Hadwin's Four Stages of Studying**

Stage 1 is called the task definition stage. In stage 1, students chart the study space or develop an understanding of the requirements of the task. They set goals and make inferences about the features of the task. Stage 2 is the goal setting and planning phase, where students reset goals and then make a plan for moving forward. Monitoring is involved to see if their goals match those of the ones that were given with the task. Next is stage 3, where students enact study tactics and initiate the plan that was developed in stage 2. In this stage, students monitor to see how they are doing and evaluate to see if a goal is achieved. Monitoring may lead to choosing new strategies or may result in the student determining there are no strategies they possess that can achieve the goal and so they choose to quit the task. Stage 4 is a longer term stage called metacognitively adapting studying. This stage affects longer term study strategies. Students monitor their progress and may determine that studying in the future should take a different

approach based on how the current plan worked. Students may also shift from task to mastery performance during stage 4. Finally, outcomes from the first three stages may cause students to lower their standards of work for future study sessions (Winne & Hadwin, 1998).

### ***2.2.4.1 Study Groups***

In recent years, engineering education researchers have been advocating for the need for more collaborative and cooperative learning environments in order to more effectively engage students in the learning process (K. A. Smith et al., 2005). The need for collaborative learning is based on research showing the positive impacts of collaboration on learning gains (Hsiung, 2012) as well as the need to provide students with learning environments that reflect the context they may find once they enter industry (Tonso, 2006). As we see an increase in the use of collaborative pedagogies such as Problem-Based Learning (PBL) and Inquiry-Based Learning, we may also expect to see an increase in collaboration amongst students, both in and out of the classroom. While formal pedagogies in the classroom provide structure to learning and how content is taught, informal settings like study groups allow these learning processes to emerge naturally and may occur with less structure. This push for more collaborative environments in engineering education provides evidence for the need to understand how students engage metacognitively in collaborative group settings such as study groups.

## **2.3 Assessment of Metacognition**

We must be able to assess metacognitive engagement in order to gain an understanding of existing practices and to measure the potential benefits of engaging in metacognition. In this next section, I review several popular methods of assessment used in metacognition research. These assessment techniques have been developed to assess engagement in both metacognitive knowledge and regulation of metacognition. It is important to remember that each assessment

technique offers many strengths as well as several weaknesses that must be taken into consideration when selecting an appropriate method for any research study. Some methods are designed to assess metacognitive engagement online, like observations and error detection studies, while others must be implemented as off-line measures, such as surveys and interviews. Some methods, such as survey tools, can be used to collect data quickly with a large number of participants while other methods, such as think-alouds and observations, require extensive effort to collect and analyze even small amounts of data. Though no data collection method is perfect or appropriate for every research situation, it is critical that the benefits and drawbacks of each method be taken into consideration when matching a method to a research purpose. After reviewing these measurement methods, I follow with a discussion of some of the problems researchers face when developing and selecting assessment methods for metacognition research. When considering the specific aim of this research study, this discussion of problems facing the assessment of metacognition led to the selection of observational methods for this study.

### **2.3.1 Self-report questionnaires**

Self-report questionnaires are a popular assessment method for measuring both metacognitive knowledge and metacognitive regulation (Baker & Cerro, 2000). Self-report questionnaires can be used to ask participants about knowledge and/or regulation before, during or after an intervention has taken place. These measures are popular because of their ease of implementation.

Several self-report questionnaires have been developed with the belief that metacognitive skills are domain-specific. To be domain-specific means that the metacognitive skills selected for use by a student in a particular domain are a function of the domain (Veenman, 2011). Thus, domain-specific skills would be used in one domain only and would not be transferable to

another domain. The Index of Reading Awareness (IRA) is a questionnaire developed to measure metacognitive knowledge in reading in young children (Jacobs & Paris, 1987). This domain specific questionnaire contains 20 items that consist of four subcomponents: evaluation, planning, regulation and conditional knowledge. The Motivated Strategies of Learning Questionnaire (MSLQ) was developed to measure motivation and learning strategies within a single class context (Pintrich, 1993b; Pintrich, Smith, Garcia, & McKeachie, 1991). This is a domain-specific questionnaire comprised of six motivation constructs and nine learning strategies constructs. Metacognitive monitoring and self-regulation are measured in one 12 question scale called Metacognitive Self-regulation.

Another group of self-report questionnaires were developed with the belief that metacognitive skills are domain-general. When a set of skills is domain-general, it means that these skills are common to many domains and are thus transferable between different domains (Veenman, 2011). The Metacognitive Assessment Inventory (MAI) is a domain general questionnaire that looks at both metacognitive knowledge and regulation. It is comprised of 52 items where participants report agreement on a number line. This questionnaire was originally developed to be used with college students. The Learning and Study Strategies Inventory (LASSI) was developed for domain-general use (Weinstein & Palmer, 2002). It is comprised of 77 items that yield 10 subscales: attitude, motivation, time management, anxiety, concentration, information processing, selecting main ideas, study aids, self-testing and test strategies.

### **2.3.2 Interviews**

Interviews are another popular method of gathering information about metacognitive knowledge and regulation of cognition (Baker & Cerro, 2000). While many interview protocols are developed for specific studies by the researcher, Zimmerman and Martinez-Ponz (1986)

developed a structured interview protocol for gathering information on knowledge, monitoring, strategy use and regulation. In this developed protocol, participants are asked to discuss how they would handle situations in a classroom discussion, studying at home, a short writing assignment, a mathematics assignment, an end of term test, a homework assignment and studying at home. Responses are categorized into one of fourteen categories that represent knowledge, monitoring, strategy use and regulation.

### **2.3.3 Think-aloud protocols**

Think aloud protocols have been used to gather information about the strategies used during problem solving or reading (Pintrich et al., 2000). In a think aloud protocol, a participant is given text or a problem and asked to think out loud while they work or read. Responses are coded to determine what metacognitive strategies were used. Chi and colleagues used think aloud protocols in many of their research studies, including studies that looked at the effect of self-explanation on conceptual development (Chi et al., 1989).

### **2.3.4 Error-detection studies**

Error detection studies are a method used to assess the comprehension monitoring skills of participants (Baker & Cerro, 2000). Error detection studies have been conducted in content areas such as reading and mathematics (Baker & Cerro, 2000). In an error-detection study conducted by Baker (1979), students were given a particular passage of reading that contained errors. These errors included inconsistent information, inconsistent references to nouns, and inappropriate logical connectors. Students were asked to read the passage and identify areas that made reading difficult. Students that found more mistakes in the reading passage were said to be better at comprehension monitoring. Palinscar and Brown (1984) also used the method of error-

detection in their study on Reciprocal Teaching. To assess whether students' comprehension monitoring skills improved through use of the Reciprocal Teaching method, Palinscar and Brown developed an error detection assessment to judge participants' abilities to find errors in a passage of reading. Eight stories were developed, six of which had one line of the story that did not make sense with the rest of the story. The researchers gave students a passage to read one line at a time and asked them to determine if each line of the story they read made sense individually. They then gave students access to the entire story to read and asked if there were any lines that did not make sense. They found that students that participated in Reciprocal Teaching improved in their comprehension monitoring skills and were able to more readily identify the lines that did not make sense in the story (Palinscar & Brown, 1984).

### **2.3.5 Observations**

Baker and Cerro (2000) suggested that naturalistic observations are an assessment approach that is used to understand what students actually do in regards to metacognition. They suggested that interviewing in conjunction with observations may be helpful to gain perspective from the student as to why they engaged in certain practices.

Bryce and Whitebread (2012) conducted a study that observed the metacognitive abilities of 3-5 year old children while playing. In this study, the researchers were able to provide evidence that children as young as 3 years old do possess metacognitive ability, which was previously thought to be untrue. Using the observational coding strategy developed by Whitebread et al. (2009), the researchers used video-taped observations of children at play to study the verbal and non-verbal cues of children to determine level of metacognitive ability. Bryce and Whitebread also provided evidence to show that there are quantitative and qualitative differences in how children engage in metacognitive activities based on age. Not only do older children

engage in more metacognitive activities than younger children, but older children also engage in different metacognitive activities than younger children when performing the same task. For instance, when asked to build a train track based on a model, younger children were found to check their own work more often while older children were found to check the model provided more often, thus showing differences in the monitoring skills used between younger and older children.

Volet and colleagues used similar observational methods when studying college level veterinary students (Volet, Vauras, Khosa, & Iiskala, 2013). In this work, Volet and colleagues (2013) specifically looked at how veterinary students that work together in self-formed groups used socially shared metacognitive regulation (SSMR) to make progress on case-based projects (Iiskala et al., 2004). Volet and colleagues (2013) found that veterinary students did, in fact, engage in metacognitive behaviors but much of this engagement focused on low level content processing.

### **2.3.6 Benefits and Drawbacks of Different Measurement Methods for Metacognition**

As previously discussed, there are multiple methods that have been used to measure metacognition in different settings and for different purposes. Each method has its own benefits and drawbacks. A summary of the benefits and drawbacks for each method is shown in Table 2.1. In summary, the table explains that self-report questionnaires and interviews are the most widely used methods used in metacognition research though there are concerns that what participants report as engagement may not be what they actually do. Think-aloud protocols and observations are used as on-line measurements (methods of collecting data while an activity is in process) of metacognition though these methods can be difficult to score.

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No method is perfect and thus the researcher is responsible for weighing the benefits and drawbacks of any method based on what needs to be known. It is critical when selecting methods for any study that the research questions be a guiding factor in which method is selected (Creswell, 2009).

Table 2 Pros and Cons of Metacognition Assessment Methods		
<i>Method</i>	<i>Pros</i>	<i>Cons</i>
<i>Self-report questionnaires</i>	<p>Data can quickly be gathered with a large number of participants</p> <p>Analysis can be conducted statistically</p> <p>One of the primary methods for collecting data on metacognitive knowledge (Baker &amp; Cerro, 2000)</p> <p>Can be a valid and reliable source of information if strict protocols are followed (Baker &amp; Cerro, 2000)</p>	<p>What the participant reports may not be what they actually do in a natural setting (Veenman, 2011)</p> <p>Due to disagreements about whether metacognition is domain-specific or domain-general, instruments can only be used when the assumption of domain-specificity or generality is clearly stated by the researcher (Pintrich et al., 2000)</p>
<i>Interviews</i>	<p>Researcher can directly ask the participant what they are doing or thinking (Baker &amp; Cerro, 2000)</p> <p>One of the primary methods for collecting data on metacognitive knowledge (Baker &amp; Cerro, 2000)</p> <p>Can be a valid and reliable source of information if strict protocols are followed (Baker &amp; Cerro, 2000)</p>	<p>May not have conscious access or be unwilling to express thoughts and experiences (Baker &amp; Cerro, 2000)</p> <p>Questions may not be understood by all participants (Baker &amp; Cerro, 2000)</p> <p>Questions may induce responses based on social desirability (Baker &amp; Cerro, 2000)</p> <p>Open ended responses are often difficult to score (Baker &amp; Cerro, 2000)</p> <p>What the participant reports may not be what they actually do in a natural setting. (Veenman, 2011)</p>

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Table 2 Pros and Cons of Metacognition Assessment Methods (cont)

<i>Method</i>	<i>Pros</i>	<i>Cons</i>
<i>Think-aloud protocols</i>	<p>Can be used to determine the effect of metacognition on certain learning outcomes in a specific context</p> <p>Supplies an on-line (during task) measure of metacognition</p>	<p>The procedure of a think aloud may disrupt the task (Baker &amp; Cerro, 2000)</p> <p>The cognitive processes used may not be available to consciousness to be discussed (Baker &amp; Cerro, 2000)</p> <p>Think aloud protocols are difficult to score (Baker &amp; Cerro, 2000)</p> <p>Personal characteristics (age, motivation, anxiety, verbal agility and willingness to reveal oneself) may affect how a participant responds (Baker &amp; Cerro, 2000)</p> <p>Care must be used when developing questions and probes as these can cue participants in how to respond (Baker &amp; Cerro, 2000)</p> <p>Tasks need to be difficult, complex, and novel enough to require the use of metacognitive skill (Baker &amp; Cerro, 2000)</p>
<i>Error-detection studies</i>	<p>Can be used to determine the effect of metacognition on certain learning outcomes in a specific context</p>	<p>Ecological validity is affected because participants are not used to being given readings or problems with intentional mistakes (Baker &amp; Cerro, 2000)</p>
<i>Observations</i>	<p>Can be used to measure what students actually do in different environments</p> <p>Supplies an on-line (during task) measure of metacognition</p>	<p>Time intensive (Baker &amp; Cerro, 2000)</p> <p>Required significant resources for data collection and analysis (Baker &amp; Cerro, 2000)</p> <p>Interpretations of participant behaviors must be made for analysis (Whitebread et al., 2009; Whitebread &amp; Pino-Pasternak, 2013)</p>

### **2.3.7 Problems Facing Assessment of Metacognition**

Beyond methodological issues, metacognitive assessment is further challenged by inconsistent definitions of metacognition. Because the term metacognition has been used so broadly to cover many topics, it can be problematic when developing or selecting assessment procedures if the specific construct has not been clearly defined (Baker & Cerro, 2000). Lack of clear definitions hampers measures of construct validity (Pintrich et al., 2000). Construct validity relates to evidence that shows that what is being measured is connected to the abstract construct of interest (Cronbach & Meehl, 1955). Because abstract concepts such as aptitude and interest cannot be measured directly by measurement tools, the researcher must present evidence that the tool that has been developed is an appropriate way of indirectly measuring the construct to be studied (Cronbach & Meehl, 1955). When constructs for metacognition are not well-defined, it can be difficult to develop assessment techniques that measure what the researcher is hoping to measure. The issue of whether metacognition is domain general or domain specific also presents a problem when developing and selecting assessment methods for metacognition (Pintrich et al., 2000). If metacognitive skills are domain general, then assessment methods such as the IRA and the MSLQ would be inappropriate. In turn, if metacognitive skills are domain specific, tools such as the MAI and the LASSI are inappropriate. Further research needs to be conducted to determine if and what metacognitive skills are domain general or specific.

Another significant concern that researchers have when selecting methods for studying metacognitive engagement lies in whether metacognition is a conscious or non-conscious process. There is an on-going debate in metacognition research as to whether engagement of metacognitive behaviors is a conscious or nonconscious process (Schraw et al., 2012; Veenman, 2011). This debate stems from the connection of metacognition and executive control, a domain

of study in cognitive psychology (Hacker et al., 1998). If metacognition is the product of nonconscious processing, it is very likely that one will not be aware of the processing steps involved in engaging in metacognition (Hacker et al., 1998). Therefore, asking participants about their metacognitive engagement may not be an effective means for understanding what participants actually do as they may be incapable of accurately reporting what they actually do.

Of the methods reviewed in this section, observational methods are most appropriate for understanding if and how participants engage in metacognitive behaviors. Observations allow participants to do what they would normally do in their contextual settings thus providing a picture of metacognitive engagement without interference from the researcher. Observations also allow the researcher to observe what participants are doing thus negating the issue of the nonconscious nature of metacognition.

### **2.4 Summary**

Research has shown that metacognitive skill has an impact on learning, specifically while problem solving and while studying. Many pedagogical approaches have been developed to support the use of metacognition during learning. While these interventions have shown that students who participate in these types of classrooms do engage in metacognition, it is also important that we understand the metacognitive skill of students that are taught in classrooms where metacognitive scaffolding is not intentional. One key component that is critical in studying students' engagement in metacognitive behaviors is the appropriate selection of methods. A few studies have been conducted that show that, when desiring to understand use of metacognitive behaviors in a naturalistic setting, observational methods are appropriate for data collection. Therefore, an ethnographically-informed qualitative study using observational

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methods as the primary mode of data collection is an appropriate approach for studying metacognitive engagement of undergraduate engineering students in naturalistic settings.

### 3 Chapter 3: Methods

This chapter describes the research methods used in this study. The purpose of this study was to understand how students are engaging in metacognitive behaviors as they study engineering content in groups as well as to understand the contextual factors that impact engagement in metacognitive behaviors. The overarching research question for this study was: *How are engineering students engaging in metacognition when they are studying together in study groups?*

To answer this question, I answered a series of sub-questions:

*RQ1: How can students' use of metacognitive behaviors be identified in naturalistic settings (study groups)?*

*RQ2: What metacognitive behaviors are students engaging in when studying engineering content in groups?*

*RQ3: What contextual factors contribute to engagement in metacognitive behaviors?*

To answer the research questions, I used ethnographically-informed qualitative methods, including observations and interviews.

In this chapter, I provide an overview of the study. I then provide the rationale for the selection of ethnographically-informed qualitative methods as the approach for this study. I provide a brief overview of the pilot study conducted for this project in order to outline what was learned from the pilot study to develop the methodological approach for the larger project. Next, I discuss the research site and participants. I then outline data collection and analysis procedures. Finally, dependability and credibility measures, ethical considerations, role of the researcher, and limitations of this study are discussed.

### 3.1 Research Process Overview

To answer the research questions proposed for this study, I developed a four-phased research process, shown in Figure 5. Phase 1 represents the development and execution of a pilot study used to develop the methodological approach for the research study. Phase 2 was the full-scale data collection for this study. Phase 3 was the data analysis step. As shown in Figure 5, Phases 2 and 3 occurred simultaneously and were cyclical in nature (as indicated by the arrow) in order to ensure data saturation. Finally, Phase 4 focused on the development of outcomes from the data analysis process.

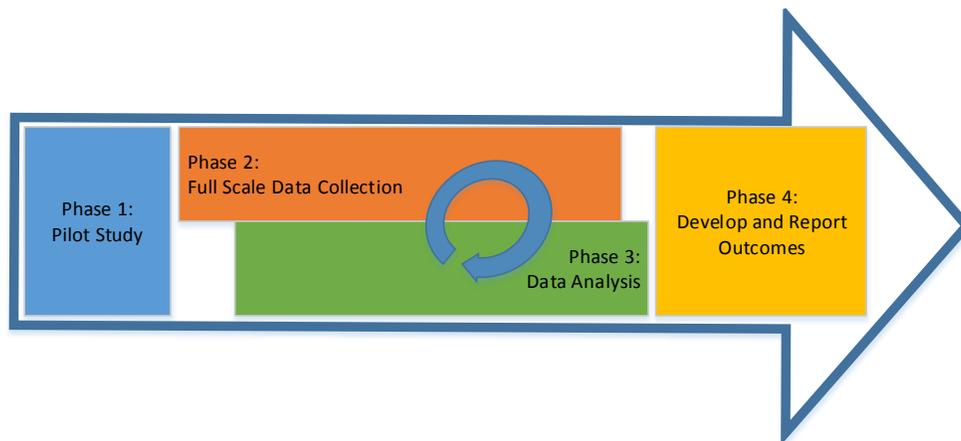


Figure 5 Research Cycle for Metacognition

Before providing further details on the steps, it is necessary to justify my methods selection. This includes a brief discussion of the worldview I brought to the study and how it impacted the development of the approach of this study and a description of the ethnographically-informed qualitative methods used in my study. This description, as well as evidence from my pilot study, supports why participant observations were the primary mode of data collection for Phase 2.

### 3.1.1 Worldview

I brought a pragmatic worldview perspective to this study. Creswell (2009) defines a pragmatic worldview as one that is primarily focused on the problem at hand and thus uses any available resource to answer the research questions. For this study, I was interested in looking at engagement in metacognition as well as how context impacted engagement. However, I found that current measurement methods for metacognition were not appropriate for naturalistic settings. Although metacognition has typically been studied in laboratory environments or has been measured using off-line tools such as self-questionnaires or interviews, these methods were not useful for a study in a naturalistic setting. Thus, I investigated other qualitative methods that would be useful in investigating metacognitive engagement in natural settings.

In pursuing ethnographically-informed methods as a methodological approach, it was important to think about how the use of ethnography would align with my pragmatic worldview. Watson (2011) argued that when we hold a pragmatic worldview, to use ethnographically-informed methods we must let go of the question ‘What is ethnography?’ and instead ask ourselves how we might best use ethnographic traditions to most effectively conduct research in our topic area. Though ethnographic methods are not typically used in the study of metacognitive engagement, these methods are appropriate for studying phenomena in natural settings. A pragmatic worldview aligns with work in ethnography, as a standard practice in ethnography is to enter the research field, i.e., the natural setting, begin to observe and then determine what other questions need to be asked. Therefore, like Watson, I focused on how could I best use ethnographically-informed qualitative methods and, consequently, developed my first sub-research question to focus on the design of methods for studying metacognition in naturalistic settings. I then conducted a pilot study to confirm this approach.

### **3.2 Methodological Approach**

In order to answer the research questions for this study, I conducted an ethnographically-informed qualitative study consisting of three main parts. The first part of the study focused on the development of a methodological approach, including a coding strategy that could be used to identify metacognitive engagement for undergraduate engineering students in naturalistic settings. The second part of the study focused on identifying the metacognitive behaviors of undergraduate engineering students while they studied engineering content in study groups. The third part of this study focused on identifying contextual factors that were potentially impacting metacognitive engagement. In the following section, I justify the use of ethnography as the methodological approach for this study. This discussion is followed by a discussion of a pilot study conducted to provide evidence of the successful use of ethnography for identifying metacognitive engagement in naturalistic settings.

#### **3.2.1 Research Design – Ethnographically-Informed Qualitative Methods**

Spradley describes ethnography as a study of what people do, what people know, and the things that people make and use (Spradley, 1979, 1980). Broadly, ethnography is the pursuit of understanding the human species and Spradley cites several specific contributions that the use of ethnographic methods provides to understand the human species. First, ethnographic methods are used to understand human behaviors. Spradley states, “Ethnography yields empirical data about the lives of people in specific situations” (Spradley, 1980, p. 16). In an ethnographic study, the researcher is trying to understand human behavior – what people do and why they do it. Through the use of multiple methods, most typically observations and interviews, the ethnographic researcher is immersed in the lives of members of the culture-sharing group (Creswell, 2013). Second, ethnography is used to understand complex societies. While

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ethnography developed out of the anthropological tradition in studies of small, non-Western populations, ethnography is now used to study many different types of cultures from religious organizations to school cultures. Ethnography is used to see how people with diverse perspectives and backgrounds interact with one another. Third, ethnography can lead to discovering grounded theory. While many research studies seek to test and support formal theories, there are times when new theories need to be developed through grounding in empirical research, or what Glaser and Strauss (1967) call grounded theory. This approach is especially useful in that it can minimize ethnocentrism, or the judgment of one culture based on the rules and regulations of another culture (Spradley, 1980).

When choosing to conduct an ethnographically-informed study, it is important to start out by thinking about the scope of the project to be undertaken. Spradley (1980) noted that the scope of ethnographic work lies on a continuum, like the one shown in Table 3. Macro-ethnography, which lies at one end of the spectrum, focuses on understanding complex societies and generally involves the study of multiple communities with the support of numerous research teams. A macro-ethnography involves the use of significant resources and time in order to conduct the full research study. At the other end of the spectrum is the micro-ethnography, or study that focuses on the study of a single social situation. Micro-ethnographies are smaller in nature, require fewer resources, and can be conducted in a shorter amount of time when compared to macro-ethnographies. My study was conducted on a micro-ethnography scale, in that focused on the single social situation of engaging in metacognition.

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SCOPE OF RESEARCH	SOCIAL UNITS STUDIED
Macro-Ethnography  Micro-Ethnography	Complex society
	Multiple communities
	A single community study
	Multiple social institutions
	A single social institution
	Multiple social situations
	A single social situation

For this study, I wanted to focus on understanding how students engage in metacognition (RQ2) and on the contextual factors that contributed to this engagement (RQ3). Specifically, I sought to understand the complex world of student study groups, aligning with the first and second contributions highlighted by Spradley. Students come into study groups with different academic backgrounds, different working styles, and different skill sets for learning. Therefore, I wanted to see how different students came together in study groups and engaged in metacognition. It was not my intention to use a grounded theory approach to develop a new theory of how context impacts engagement to answer RQ3, therefore this study does not exactly align with the third contribution highlighted by Spradley. However, I did use an inductive approach to look at themes of contextual factors that contributed to engagement because we know very little about how context impacts metacognitive engagement. I was able to analyze and interpret my data by drawing on a variety of theories that may explain the contextual factors that I observed.

Ethnography takes the culture-sharing group as the unit of analysis for a study (Creswell, 2013). In the case of this study, the culture-sharing group would be the study group being

observed because the purpose of the study is to understand metacognitive engagement while studying in a study group. While there may be individual engagement in metacognition during study sessions, this engagement may be impacted by the context of the study group. Therefore, for this study I took the study group, not the individual participant, as the unit of analysis.

### *3.2.1.1 Participant Observations*

For this study, observations were the primary method of data collection. Participant observation, or the strategy of immersing oneself in the research field to experience and note events, is the primary method of data collection in traditional ethnographic research (Rossman & Rallis, 2012; Spradley, 1980). Glesne (2011) describes the main outcome of participant observation as the understanding of the participants, their behavior, and the setting. Lofland and Lofland (1995), Glesne (2011) and Spradley (1980) all discuss the role of the researcher during participant observation as on a continuum of participation. Lofland and Lofland (1995) describe the continuum as to how much the researcher's role is known to the participants. The researcher's role can be completely hidden from participants, completely revealed to the participants, or somewhere in between, where the participants know that the researcher is observing but may not know all of the details of what the researcher is observing for. Glesne (2011) and Spradley's (1980) continuums focus on how involved the researcher may be in the day to day activities of participants. Table 4 shows Spradley's (1980) portrayal of this participation continuum. As a non-participant, the researcher views the actions of the participants as through a one-way mirror and has little to no interaction in what is occurring. On the opposite end of the spectrum, a full, or complete, participant occurs when the researcher is an existing ordinary member of the culture being studied and continues in that role while conducting

research. For each of these continuum perspectives, it is important for the researcher to define their role based on what is most pertinent for the research study.

Table 4 Spradley's Continuum of Participation

<i>Degree of Involvement</i>	<i>Type of Participation</i>
High  Low	Complete
	Active
	Moderate
	Passive
No involvement	Nonparticipation

For this study, I acted as a passive participant observer who was partially known to the participants during observations. Being a passive participant allowed me to ask questions of the participants when necessary without significantly altering the context of the study group session. It was important that participants knew that I was observing but did not necessarily know specifically what I was observing for during their study sessions. By informing participants of what metacognition was and that I was observing them for those behaviors, I could have inadvertently affected their behavior. Therefore, participants knew that I was observing but did not know the details of what I was observing. Details of the specific observations conducted are discussed further in Section 3.5.1.

**3.2.1.2 Ethnographic Interviews**

Interviews were a secondary method of data collection originally intended to help answer RQ3 which aimed to understand the contextual factors that contribute to engagement in metacognitive behaviors. The use of a combination of observations and interviews, which is consistent with the purpose of ethnography, was for the purpose of understanding the meaning behind certain behaviors in the study group setting (Spradley, 1979). While it was my intention

to use the full ethnographic interviews in order to answer RQ3, after data collection was complete, I determined that the fieldnotes taken during each observation were very rich and thus could provide significant evidence of contextual factors that potentially impacted metacognitive engagement. Therefore this study was scoped to only focus on one interview question which was intended to provide further support for the need for observational methods when studying metacognitive engagement. Details of the ethnographic interviews conducted are described further in Section 3.5.2.

### ***3.2.1.3 Ethnography in Engineering Education***

In this study, the contributions of ethnography described by Spradley are all relevant and thus provide justification for the use of ethnographically-informed qualitative methods in this study. Other researchers have also used ethnographic methods for engineering education research. For example, Tonso (2006, 2007) conducted an in-depth ethnographic study over four years providing insight into how engineering student design teams work together. She conducted a series of participant observations and ethnographic interviews with design teams ranging from freshmen to senior year at an engineering campus in the United States as well as ethnographic interviews with faculty members associated with each design team. Tonso focused on understanding the ways engineering design teams worked together and how the culture of the campus impacted the social interactions of the students on the design teams (Tonso, 2006, 2007). My study draws inspiration from Tonso's ethnographic approach though I focused on the understudied area of how engineering study groups engage in metacognition and how the context impacted engagement. My study dove into the complex world of study groups and described how students engaged in metacognition and how the context associated with the study group impacted their ability or willingness to engage. I used existing theories to describe metacognitive

engagement but then took a more inductive approach in understanding how context impacts engagement.

### **3.3 Pilot Study**

Because methods are lacking for studying metacognition in naturalistic settings, a pilot study was conducted during the Spring 2013 semester in order to develop an ethnographically-informed methodological approach suitable for a larger study. Specifically, the pilot study focused on developing the observational methods to be used in the larger study. In the pilot study, no interviews were conducted. During this pilot study, a total of three observations were conducted across two different study group contexts. Group One consisted of two students of a local community college. The two students were peer tutors in a tutoring center. Both students were taking the same statics course. One observation was conducted with this group that lasted approximately one hour and 45 minutes. Group Two consisted of four engineering students at a large research university in the southeast. All four students were taking the same dynamics course. Two observations were conducted with this group that lasted approximately three hours each. These observations occurred in the apartment of one of the group members. A total of approximately eight hours of observations were conducted across both settings. All observations were video and audio recorded for the purpose of transcription and analysis. Extensive fieldnotes were also taken during each observation.

Although I examined all observation videos, analysis for the pilot study focused on the first observation conducted with Group One. The purpose of the pilot study was to confirm that the methodological approach developed was appropriate for the larger study. Therefore it was not necessary to analyze all of the observation data as a small subset was sufficient to determine that this approach was appropriate. The Group One observation was conducted over a period of

one hour and 45 minutes. From the full observation recording, episodes of on-task activity were identified. An episode is defined as a sequence of sentences or phrases that are marked with a beginning and an end. The beginning and end of each episode is determined by identifying shifts in the topic of conversation (Van Dijk, 1982). Episodes were selected for further analysis if they represented times of on-task engagement. On-task engagement was defined as times when study groups were actively discussing the assignment or content focus or were not discussing topics unrelated to their coursework. Identifying and selecting episodes aided in eliminating off-task discussion from analysis as well as providing context for the assignment of metacognitive coding. In all, 108 distinct episodes were identified for the duration of this observation (1 hour and 45 minutes). Sixteen of the 108 episodes were selected for further analysis because they represented episodes of high cognitive engagement and on-task activity. A table of the episodes identified is shown in Appendix A. Using a modified version of Whitebread et al. (2009) coding strategy, shown in Appendix B, these episodes were coded for metacognitive engagement. Several examples of coded episodes can be found in Appendix C.

Metacognitive engagement was identified in all sixteen episodes analyzed. Table 5 displays the counts of metacognitive coding from the 16 episodes analyzed for the pilot study. Only primary codes were displayed for analysis for the pilot study. From the analysis, participants engaged in more monitoring and control activities and few knowledge of strategy activities. In the pilot episodes, there was no evidence in engaging in knowledge of persons activities.

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Table 5 Metacognitive Engagement of Group One (Pilot Study)						
	Monitor	Control	Evaluate	Plan	Knowledge of Task	Knowledge of Strategy
Monitor	40					
Control	14	30				
Evaluate	11		22			
Plan		1		12		
Knowledge of Task (KofT)		2		1	10	
Knowledge of Strategy (KofS)				1	1	4

The initial analysis of this data set provided confidence that metacognitive engagement could be identified by identifying episodes and using a modified version of Whitebread et al.’s (2009) coding strategy. However, I determined that Whitebread’s original coding strategy was not appropriate for use in an undergraduate engineering context. Several of the subcodes in the original framework as well as many of examples were more applicable to the young children originally observed in the creation of Whitebread et al.’s (2009) framework. For example, during the pilot observations, I observed that participants frequently checked answers, either with one another or against answers provided by an expert. I also observed that participants engaged in the strategy of checking strategies with one another as they worked on different problems. These behaviors were not identified in Whitebread et al.’s (2009) original coding strategy. Additionally, many of the examples for each subcode focused on specific observable behaviors for young children. For example, an example for engaging in knowledge of persons was a child saying “I can write my name,” or “I can count backwards.” After conducting several observations with undergraduate engineering students, I realized that the examples provided by

Whitebread et al. would not be useful when observing engineering students. Thus, I needed to focus on the development of sub-codes and examples appropriate for an engineering context.

Also, through the pilot study I determined that camera placement was critical in that viewing of non-verbal cues is necessary for complete coding of metacognitive engagement. Several metacognitive behaviors, especially control behaviors, were displayed more as non-verbal behaviors, such as erasing from a page and using hand gestures to aid cognitive activity. Finally, through the process of conducting observations, I also realized that the fieldnotes taken during observations would be critical in identifying contextual factors that potentially contributed to metacognitive engagement. Therefore, extra care was taken during the full study to take detailed ethnographic fieldnotes during each observation. Through what I learned by conducting the pilot study, I moved forward with conducting the full study, discussed in the following sections.

### 3.4 Research Site and Participants

Spradley (1980) asserts that, when investigating social situations, the ethnographic researcher interacts with three primary elements: the place, the actors, and the activities. These three components comprise the social situation under study, as shown in Figure 7.

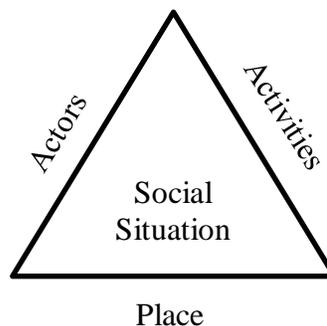


Figure 6 Components of Social Situation in Ethnographic Research

In the next sections, I address all three of these areas. First, I introduce the place, or the research site for this study. Next, I describe the activities, or the course where students were recruited from. I then describe the actors, or each study group that participated in this study. Finally, I give a description of my participation in collecting the observational data.

### **3.4.1 Research Site**

Participants of my study were students at Small Teaching Focused College (STFC). This school has approximately 2000 undergraduate students, most of which major in an engineering discipline, science or math. Class sizes typically range from 20-25 students per class. STFC offers a range of extra-curricular student programming including athletics, fraternities and sororities, arts programming, technical clubs and religious clubs. A majority of students at STFC participate in at least one extracurricular activity. Approximately 99% of students graduate from STFC with offers of employment.

STFC has been noted for its excellence in teaching and is nationally recognized as a top undergraduate engineering institution in the United States. This research site was particularly beneficial for this study because the institution has a culture that promotes collaborative learning through class group projects, extracurricular group design projects, space allocations for group study and group work, and small class sizes that allow for more personal contact among the class population. This site was also beneficial in that its academic population had not been ‘over-studied,’ as some undergraduate populations connected with engineering education research programs and centers have been. When populations are over-studied, response rates often drop making it difficult to recruit participants. I experienced this challenge with my pilot study. In contrast, at STFC my research was supported by several faculty members who helped to ensure ease of access to potential participants within the student body.

### 3.4.2 Course and Recruitment

This study was designed to focus on identifying metacognitive engagement in problem solving type courses. Problem solving is defined as “a set of steps consisting of formulating or representing a problem, selecting the relations pertinent to solving the problem, doing the necessary calculations, and verifying the logic used to see if the final answer makes sense” (Donald, 2002b; Reif, Larkin, & Brackett, 1976). Thus, courses with a focus in problem solving engage students in problems that require them to provide a description of the problem, develop a plan for solving the problem, implement the plan by doing all the necessary calculations, and then check that all the steps used are valid and that the final answer makes sense. Problem-solving courses are not just limited to engineering curricula. In fact, problem solving courses, as previously described, can be found in most of the physical sciences. One difference in the nature of problem solving courses among the sciences is in the applied or theoretical nature of the problem solving processes (Donald, 2002b). For example, both physicists and engineers engage in problem-solving. Physicists are generally more worried about the “analysis, generalization, and synthesis of hypotheses” (Donald, 2002a, p. 63). In contrast, engineers focus on “the analysis and synthesis of designs, where one reaches decisions based on incomplete data and approximate models.” In essence, physics, and many of the physical sciences, are focused on theoretical work while engineering is focused on learning strategies and procedures for applying theoretical knowledge.

To further scope this study, I focused on problem-solving courses that specifically applied engineering content. Courses like statics, dynamics, and thermodynamics are considered engineering problem solving courses. These problem solving type courses have been identified as areas where students have difficulty with conceptual learning and repairing misconceptions

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(Streveler et al., 2008). Thus a focus on problem solving type courses in engineering content added to the body of knowledge on how to help students in these challenging courses. Courses such as calculus, differential equations, chemistry, or physics were not considered problem solving type courses because they do not focus specifically on engineering content and thus were excluded from this study. While problem solving can and does occur in courses in mathematics and the physical sciences, I intentionally focused the study on engineering problem solving courses. Engineering courses that focus on engineering design were excluded from this study as design courses tend to be taught such that study groups would not be naturalistically formed.

The course selected at STFC was a sophomore engineering course that focused on teaching a problem solving heuristic (PSH) in the domain of conservation and accounting principles. The PSH course was taught in the mechanical engineering department but included mechanical and biomedical engineering students. Due to high enrollment (270 students total) and small class sizes, this course was taught over nine sections by six different instructors. The course met four times per week for ten weeks. Each class session was 50 minutes in length. Classes were primarily lecture based though some instructors did integrate active learning activities at different times throughout the academic term. The course had a common syllabus, common homework assignments, and common exams. Two homework assignments were due each week and typically consisted of solving four open-ended problems. While students were required to turn in individual homework assignments, students were allowed to work in groups to complete these assignments. Four examinations were conducted over the period of the academic term. Three exams were conducted during the term and were non-cumulative. One exam was conducted at the end of the academic term and was cumulative. Instructors had liberty to give quizzes and extra assignments to their specific course sections as they felt necessary. This course

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was selected because it offered access to a large population of students and was identified as one of the most difficult problem solving courses in the sophomore year at STFC.

As noted before, the PSH course set out to teach a specific problem solving heuristic to students. While the course focuses on teaching conservation and accounting phenomena (conservation of mass, conservation of linear momentum, conservation of angular momentum, conservation of energy, accounting of entropy), the approach taught in this PSH course focuses on teaching the students to situate the problems they encounter with the following questions:

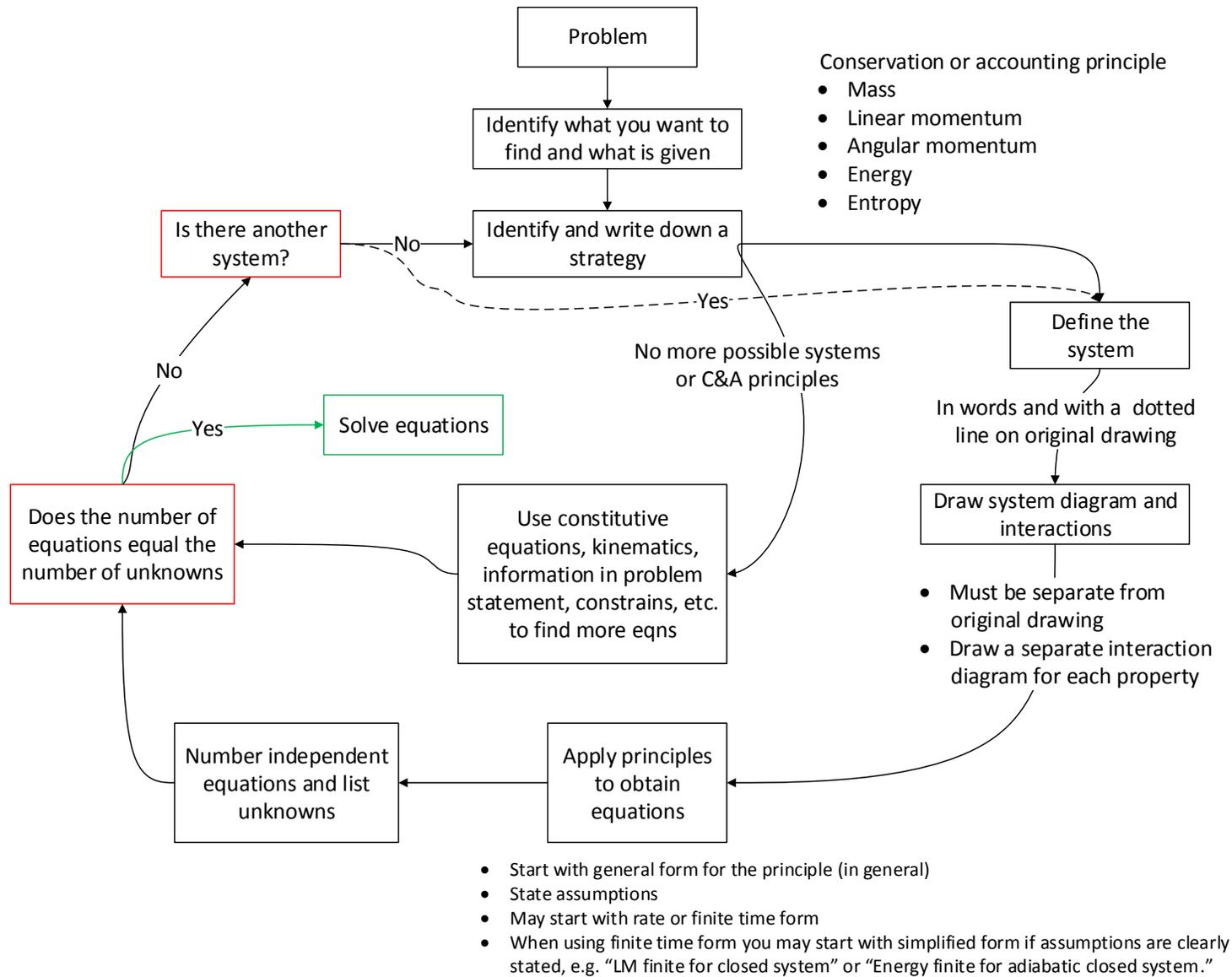
1. How is it calculated?
2. How is it stored?
3. How is it transported?
4. How is it created or destroyed?

Students are taught to solve all problems in the course using the Accounting Principle:

$$\begin{array}{c} \left[ \begin{array}{c} \text{Stuff} \\ \textit{accumulated} \\ \text{inside the} \\ \text{system} \\ \text{during a} \\ \text{time period} \end{array} \right] = \left[ \begin{array}{c} \text{Stuff} \\ \textit{entering} \\ \text{the system} \\ \text{during a} \\ \text{time period} \end{array} \right] - \left[ \begin{array}{c} \text{Stuff} \\ \textit{leaving} \\ \text{the system} \\ \text{during a} \\ \text{time period} \end{array} \right] + \left[ \begin{array}{c} \text{Stuff} \\ \textit{produced} \\ \text{inside} \\ \text{the system} \\ \text{during a} \\ \text{time period} \end{array} \right] - \left[ \begin{array}{c} \text{Stuff} \\ \textit{consumed} \\ \text{inside} \\ \text{the system} \\ \text{during a} \\ \text{time period} \end{array} \right] \\ \text{Accumulation} \qquad \qquad \text{Input} \qquad \qquad \text{Output} \qquad \qquad \text{Produced} \qquad \qquad \text{Consumed} \end{array}$$

The problem solving heuristic taught in this course is shown in Figure 7. This representation was developed by one of the instructors of the PSH course to represent the process to be used to solve engineering problems. While the course was not originally designed to develop or support metacognitive behaviors, it is likely that, by engaging students in a specific PSH, this pedagogical approach supports engagement in metacognitive behaviors more than traditional engineering courses that do not follow a similar format.

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**Figure 7 Problem Solving Heuristic Taught in PSH Course**

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While students were originally recruited through the PSH course, it was later discovered that all participants were also enrolled together in an electrical circuits course because mechanical and biomedical engineering students at STFC took a common set of courses during their sophomore year. Both the PSH course and the electrical system course represented two of these common core courses. Because all the students were enrolled in both courses, they also frequently worked on homework for both courses in study groups. Due to this fact, data was collected for both the problem solving course and the electrical systems course. While these courses focused on different engineering content, they were both organized in a way where students were required to solve open-ended problems. Thus, both courses were classified as problem solving type courses. By opening up the focus of observations, this allowed flexibility and more opportunities to meet with study groups. This option also allowed for the collection of data in different engineering content in order to determine if course content played a role in differences in metacognitive engagement.

Recruitment occurred primarily through face to face contact. After permission from the instructors, I was allowed to recruit in six of the nine sections (approximately 180 students). During the second and third class days, I made an announcement at the beginning of the class in order to recruit naturally formed study groups to participate in the research study. After a short description of the study, interested students were asked to write down their names and email addresses on provided slips of paper so I could contact them with further details. After two days of recruitment, 41 potential participants were identified. An email was sent to each potential participant further describing the study and asking one contact member from each study group to contact me to set up an initial observation. Three study groups responded and initial observations

were scheduled. Snacks for each study group session observed were provided as the incentive for participating in this study.

### **3.4.3 Researcher Participation**

As a part of data collection, I conducted observations in three key areas: study group sessions, class periods, and instructor meetings. Figure 8 shows all observations conducted over the academic term. An X in the figure represents an instance where an observation was conducted. Designators of Class A, Class B, Class C, and Class D represent observations conducted in class sections among different instructors. Observations conducted in the instructor meetings are listed next. Finally, observations conducted with each of the three study groups are listed at the bottom of the table under the study group names OFF, LIB, and ON. These study groups are described in further detail in a later section. The greyed regions on the observation schedule represent time periods where classes were not in session or the researcher was not available to conduct observations. A total of approximately 90 hours of observations were conducted over the academic term at STFC. Also, eleven one-hour interviews were conducted during the academic term. In the next section, I describe each of these types of observations in further detail.

#### ***3.4.3.1 Class Period Observations***

In order to observe potential contextual factors that impact metacognitive engagement, it was important that I observe the class settings in which the participants engaged with instructors. As part of this study, I conducted observations in the classrooms of study participants in order to observe the course structure or the PSH course. Because the participants spanned across three instructors, it was not possible for me to attend each class session each day. I rotated between different classes throughout the week. Though my participants only represented three of the four

instructors I originally recruited from, in order to ensure anonymity of the participants, I rotated through all four instructors throughout the week. Fieldnotes were taken during each class period that was observed. The class sessions were not video or audio recorded.

### *3.4.3.2 Instructor Meeting Observations*

As part of this study, I was also invited to attend weekly instructor meetings for the problem solving course. Weekly instructor meetings lasted approximately one hour and focused on discussing upcoming content, issues in the previous week, test construction, and potential educational practices to try. During instructor meetings, only fieldnotes were taken. These sessions were not video and audio recorded. For these meetings, I recorded the topics of conversations. In order to separate myself from potential conflicts, I excused myself from meetings where tests were being constructed so as not to know content of the exams.

It is important I note that, because I was observing in many of the classes for this course, I was asked on multiple occasions to provide feedback to the instructors as to what I might suggest they could do better in their classrooms. I was uncomfortable at the beginning of the term in providing this feedback because I feared that my interjection would in some way tamper with the results of my study and so excused myself from this activity. Near the end of the term, I began to provide some feedback and suggestions to the instructional faculty as to what they could do to improve the course. These suggestions were taken and tried on several occasions. While I do not believe that my participation in this activity in any way affected the results of this study, it is important to note that the instructional faculty were very interested in feedback they could use to improve the course. The culture of the institution and the teaching faculty do play a pivotal role in student development and thinking and thus do make an impact on student engagement in metacognitive behaviors as a whole.

***3.4.3.3 Study Group Session Observations***

I observed at every study session that I was invited to by each study group. The times and locations of each study session were dictated by the study group. Each of these observations was video and audio recorded. For each observation, I set up the camera such that I could see the faces of each participant as well as their work on the table where they were seated. I positioned myself away from the table so as to create separation between myself and the participants. I actively took extensive field notes during each study session. Extensive fieldnotes were also taken during each observation. While there was no protocol for the observations, I made sure to focus my attention on listening for utterances of metacognitive engagement in order to record what events were occurring before, during, and after utterances. My interaction with the participants during these observations was minimal. At times, participants would talk to me or ask me questions. I attempted to answer all questions or comments succinctly so as to minimize my impact of being in the room. On a few occasions, events of interest occurred that I wanted to ask these study groups about. I held these questions until the end of the observation and then asked the study group before leaving.



**3.4.4 Participants**

There were three study groups that participated in this study. In total, 14 students participated, though that number fluctuated from week to week because some participants only studied occasionally with their study groups. These study groups had a specific location (or set of locations) where they met to study. I have defined the three study groups as follows: Study Group 1, the off campus housing study group, or OFF; Study Group 2, the library study group, or LIB; and Study Group 3, the on-campus housing team, or ON. As the unit of analysis for this study was the study group, I focus on describing each study group in the following section. Nevertheless, it is important to note the individual members of each study group. Therefore, Table 6 provides information about each individual participant in this study, including their pseudonym, the study group in which they participated, their course section, their major, and their gender.

Table 6 Participants for Metacognition Study				
Group #	Name	Course Section	Major	Sex
OFF	Adam	B	ME	male
	David	B	ME	male
	Leonard	A	ME	male
	Terry	A	ME	male
	William	B	ME	male
	Daniel	Other	ME	male
LIB	Benjamin	B	ME	male
	Becca	B	BME	female
	Jenny	B	BME	female
	Michael	B	ME	male
	Gary	A	ME	male
	Cara	D	BME	female
ON	Chris	D	ME	male
	Wilson	D	ME	male

**3.4.4.1 Study Group 1: OFF**

Study Group 1, or the off-campus housing study group (OFF), was comprised of six male students. All of the study group members of OFF were members of the same fraternity and thus lived together in a fraternity house. Five of the six students were also involved in other organized extra-curricular activities outside of fraternity activities. Because the students were involved in both extra-curricular and fraternity activities, the study group had limited time to meet together for studying and working on assignments. All observations with OFF were conducted at the fraternity house. Studying occurred in the large dining room on the main floor of the house. The dining room was located adjacent to the house kitchen. The observations conducted typically started around 9pm and ended around midnight. Members of OFF were in three different course sections of the PSH course.

**3.4.4.2 Study Group 2: LIB**

Study Group 2, or the library study group (LIB), was comprised mainly of two male students and one female student. Other students (one male and one female student) would join study sessions at certain times of the academic quarter. These students met during their first year at STFC where they started studying together as a group. Each of the core participants were involved in some type of extra-curricular activity. For example, one student (Michael) participated in an internship through STFC, another student (Benjamin) participated in a fraternity and lived in the dormitory as an advisor to first year students and the final student (Jenny) participated in several music groups on campus. LIB had a set meeting schedule each week. Because homework assignments were due twice a week, study group meetings typically occurred twice per week. These sessions were scheduled two days prior to when homework assignments were due. The study group members stated that by working on homework two days

before homework was due, they would have time to speak to the professor if they needed help. Study group sessions occurred in the campus library in a closed study room. All the core group members of LIB were a part of the same course section in the PSH course.

### ***3.4.4.3 Study Group 3: ON***

Study Group 3, or the on-campus housing study group (ON), was comprised of two male students. These students lived in the same dormitory together on campus. Both students participated in a campus club sport and one student worked on campus. ON had a random schedule for studying and working on homework. Start times for observations ranged from 4:30pm to 12:30am. All observations occurred in the dormitory, either in the study lounge or in the lobby of the floor where the study group lived.

## **3.5 Data Collected**

In this section, I describe the data collected for this study. First, I discuss all observations that were conducted and then discuss how I selected a subset of interventions for further analysis. I then describe the interviews I conducted with participants and how one particularly relevant question was analyzed for this study.

### **3.5.1 Observations**

Over the academic term, 18 observations were conducted across all three study groups. The total time of study group observations was 43 hours. Table 7 displays key information about each observation that was conducted for this study. Such information includes: the date, the start and end time, the location of each observation, and which observations were selected for further analysis. Nine observations were selected for further analysis because they represent a range of scenarios and provide a variety of situations for a comparative analysis of metacognitive engagement and represented with an X under the Analysis column.

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The marked observations were selected for further analysis because they represented events of interest during the academic term. For instance, observations 2, 3, and 4 were selected because they represented times when all three study groups were working on the same homework assignment. Because the study groups were working on the same assignment, I was able to compare metacognitive activity and look at group differences. Observation 11 was selected because OFF was working on a homework assignment for an electrical systems course. The selection of this observation allowed me to look at differences in metacognitive engagement due to course content. OFF also asked for an older student to attend the study session in order to act as a tutor for the electrical systems content during this observation. Observation 6 was selected because LIB attempted to work on a homework assignment after taking three tests in one day. This observation was selected in order to see if metacognitive engagement was impacted due to a higher than normal course workload when compared to typical study sessions. Observation 7 was selected because LIB had to reconvene the study group to work on the homework assignment again from Observation 6 because they were not able to complete the assignment. The observation was selected because it allowed for a comparison of metacognitive engagement when an assignment was revisited after a first attempt. Observation 13 was selected because LIB used this time to study for their second exam in the PSH course. The selection of this observation allowed me to compare metacognitive engagement when studying for an exam versus when the study group was working on a homework assignment. Observation 16 was selected because it represents an evening where LIB deviated from their normal routine of working on homework two nights before the assignment was due. On this evening, the study group started the homework assignment one night before the assignment was due. The selection of this observation allowed me to compare differences in metacognitive engagement when a

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study group's normal study group schedule changed. Observation 18 as selected because it represents an evening where ON studied in a different location than Observation 4. The selection of this observation allowed me to compare differences in metacognitive engagement based on differences in study location.

Observation #	Date	Study group	Start Time	End Time	Location	Analysis ?
1	9/15/2013	2	9:00 PM	12:05 AM	Library Small Study Room	
2	9/18/2013	2	7:30 PM	10:00 PM	Library Small Study Room	x
3	9/19/2013	3	4:30 PM	6:30 PM	Dorm Study Room	x
4	9/19/2013	1	9:00 PM	12:00 AM	Fraternity House	x
5	9/22/2013	2	8:00 PM	11:00 PM	Library Small Study Room	
6	9/25/2013	2	9:00 PM	12:00 AM	Library Small Study Room	x
7	9/26/2013	2	8:00 PM	11:00 PM	Library Small Study Room	x
8	9/29/2013	2	8:00 PM	11:00 PM	Library Small Conference Room	
9	9/30/2013	3	12:20 AM	2:30 AM	Dorm Lobby	
10	10/2/2013	2	8:30 PM	11:00 PM	Library Small Study Room	
11	10/7/2013	1	9:00 PM	12:00 AM	Fraternity House	x
12	10/9/2013	2	8:00 PM	11:00 PM	Library Small Study Room	
13	10/14/2013	2	8:00 PM	11:00 PM	Library Small Conference Room	x
14	10/27/2013	2	8:00 PM	12:00 AM	Library Small Study Room	
15	10/29/2013	3	12:30 AM	3:30 AM	Dorm Lobby	x
16	10/31/2013	2	10:00 PM	1:00 AM	Library Large Study Room	x
17	11/10/2013	2	9:00 PM	11:05 PM	Library Small Study Room	
18	11/16/2013	2	7:00 PM	9:00 PM	Dorm Room	

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Ethnographic fieldnotes were also taken by hand during and after each observation with a study group and recorded in a dated composition notebook (Emerson, 1995; Lofland & Lofland, 1995).

On the right hand pages, observational notes were taken in black ink. These notes represented actions, activities, and discussion that occurred during the observation. Questions and comments were recorded in green ink on the left hand side of the notebook and were logged next to the specific observational notes that were connected to the questions and/or comments.

Interpretations of actions, activities, and discussions were also recorded during and after the observations. These interpretations were recorded in pink ink so as to be distinct from questions and comments. The use of different colored ink was useful in that it helped distinguish between notes regarding actual observed behaviors, inferences made during the observations, and questions to be asked at a later time. Figure 9 shows an example of field notes taken during an observation with participant identifiers redacted.

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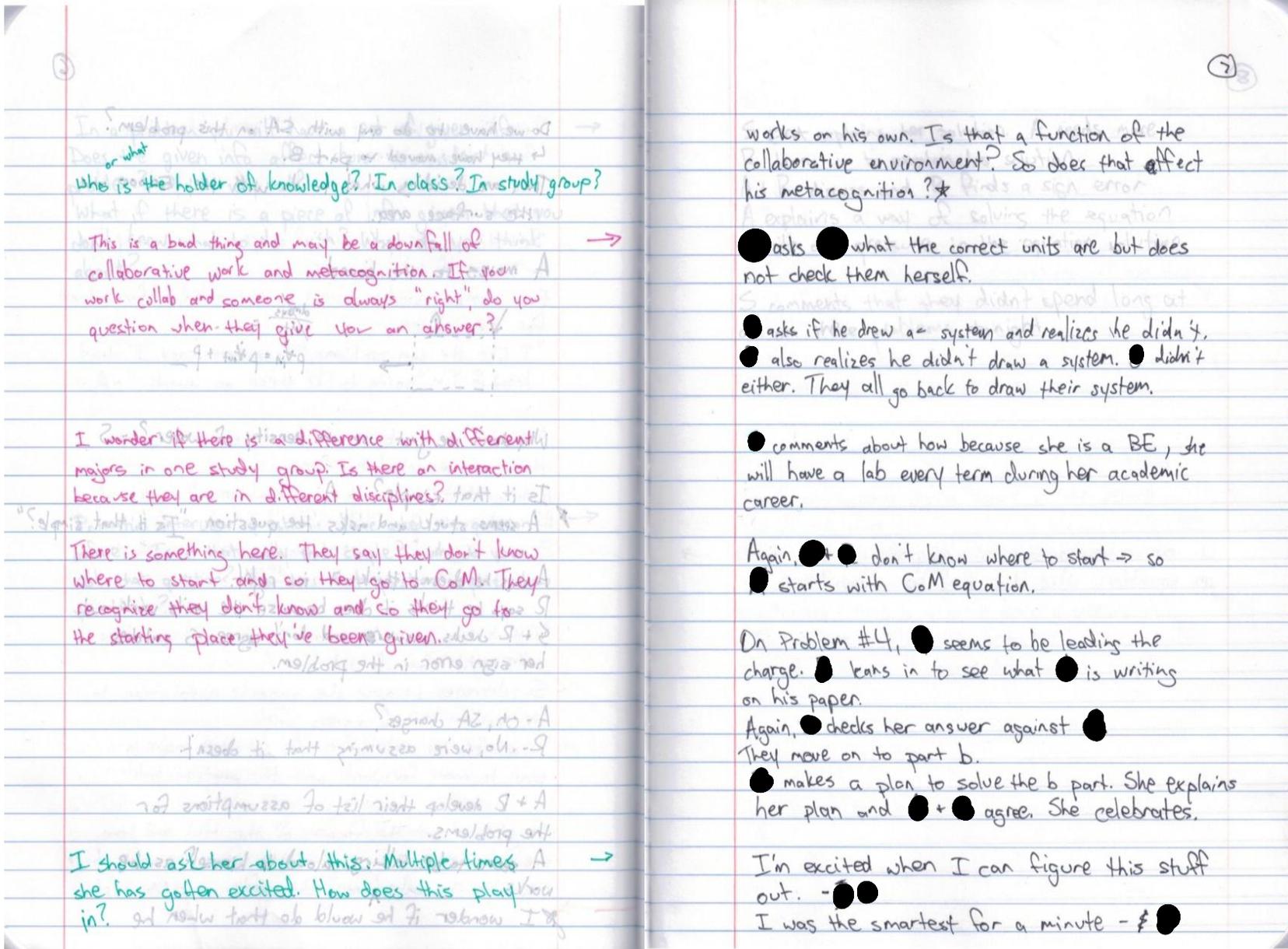


Figure 9 Example of Fieldnotes (Identifying Information Redacted)

### 3.5.2 Interviews

A claim of my study was that observational techniques are necessary due to the fact that metacognitive behaviors are predominantly sub-conscious in nature. Because metacognitive behaviors are subconscious, students do not have the ability to self-report on their habits in a reliable manner. To further support this claim, an interview question was developed to collect self-report data from the participants of this study specifically aimed at asking the participants to self-report their own metacognitive behaviors in the PSH course. The interview was conducted with 11 of the 14 participants during weeks 6 and 7 of the academic quarter. This question was initially piloted with one participant. The original question asked the participant to rank their metacognitive behavior on a scale of one to ten, where one indicates the behavior most frequently used and ten indicates the behavior used the least. This student identified that it was difficult to compare metacognitive knowledge and metacognitive regulation thus he could not compare all together. He instead ranked metacognitive regulation from one to five. Based on the results of the pilot interview, the following interview question was developed and administered to ten of the remaining participants during weeks six and seven of the academic term:

*[Interview Question]:* When I come and observe, I am looking for whether you are engaging in metacognition or not. Are you familiar with the term metacognition?

*[Interview Question]:* Metacognition is a person's knowledge and regulation of their learning processes. We can think of it this way:

*[Interviewer provides the following graphic for participants to review]*

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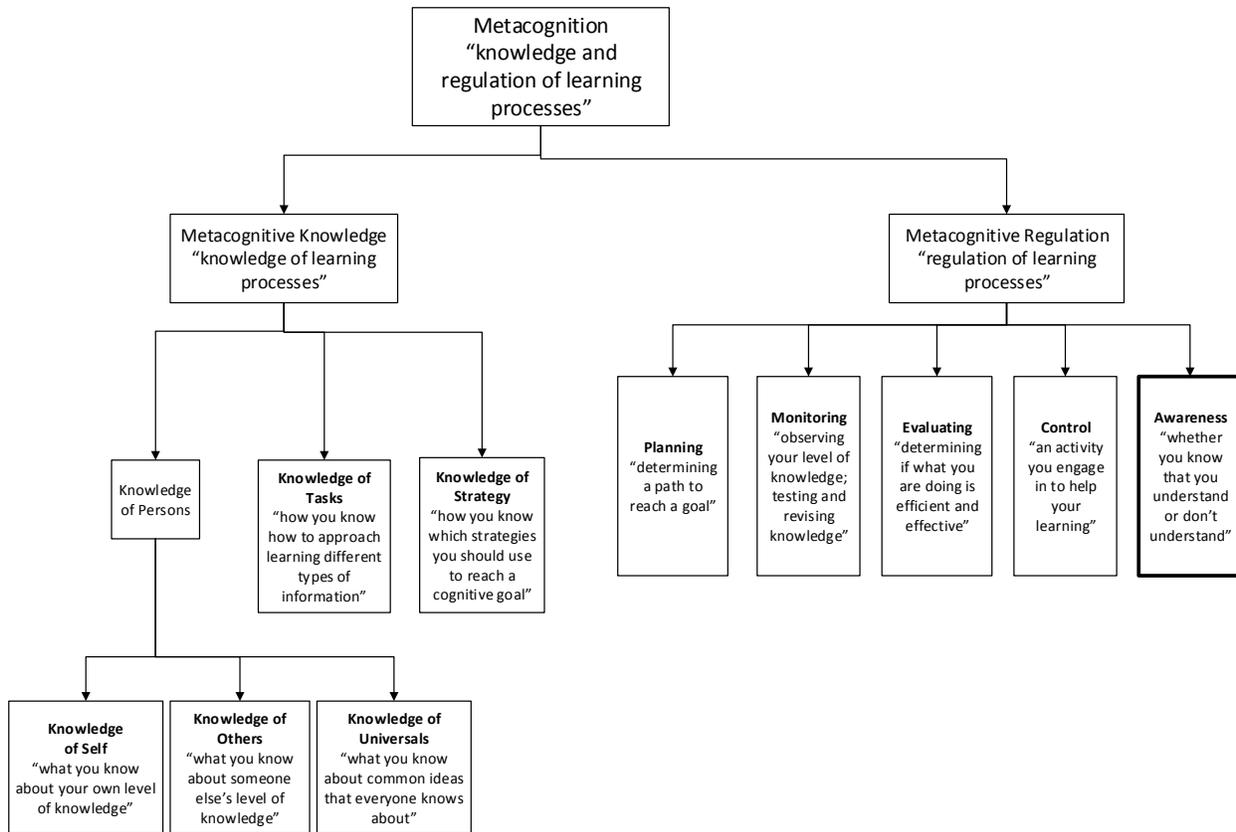


Figure 10 Metacognition Taxonomy Used in Interviews

[Interview Question]: Let me ask you: Do you think that you use metacognition when you study?

Can you give me some examples?

[Participants asked to provide examples]

[Interview Question]: Think about how you study. If you had to rank these boxes in order from what you use the most to what you use the least, could you do that?

[Participants were asked to rank their habits from one to five in the boxes provided, where one indicates the habit that is most used and five is the habit least used.]

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Order (1 – used most; 5 – used least)	
Knowledge of Self	
Knowledge of Others	
Knowledge of Universals	
Knowledge of Tasks	
Knowledge of Strategy	

Order (1 – used most; 5 – used least)	
Planning	
Monitoring	
Evaluating	
Control	

[*Interview Question*]: Why did you rank these in this way?

[*End Interview*]

I then compared the rankings provided by each student with the observed metacognitive activity from all of the observations that they participated in for this study.

While full interviews were conducted with 11 participants, this study has been scoped to focus on only the last interview question collected due to the fact that the fieldnotes from each observation were rich enough to provide evidence of contextual factors that potentially impacted metacognitive engagement. The full interview protocol was developed by gathering the questions recorded during observations and identifying themes in those questions and included topics such as resource use in study sessions, how the participants understand if they understand a concept and how participants determine the difficulty level of certain homework problems. The full interview protocol used can be found in Appendix D. The remaining portions of the interviews will be used for future research.

### **3.6 Data Analysis**

In this section, I describe the methods used to develop the observational coding strategy, perform the metacognitive analysis on the observational transcripts and then conduct the contextual analysis of the observational fieldnotes.

#### **3.6.1 Development of Observational Coding Strategy**

An observational coding strategy was developed in order to code the observations used for this study. Bakeman and Gottman (1986) discusses how observations occur on a spectrum from purely physical based schemes to socially based schemes. A physically based scheme looks at purely physical actions that can be well-defined and require no interpretation by the observer. A socially-based scheme looks to observe behaviors that require interpretation or inference to identify certain behaviors and thus require a well-trained observer. Bakeman and Gottman (1986) suggest that socially based observations are no less “real” than physically based observations. Instead, they (socially-based) provide a different level of description than physically based protocols. The observation coding strategy developed for this study was based on the work of Whitebread et al. (2009) which was a socially-based observational protocol because it required the observer to understand the context of the task at hand in order to appropriately code behaviors. The primary codes and definitions from the Whitebread coding strategy were used in the development of my coding strategy. My development work focused on refining and developing new subcodes and examples that were specific to an undergraduate engineering context.

In order to develop the observational coding strategy used to evaluate the metacognitive behaviors of participants in this study, three observations were selected to be the focus of initial coding strategy development. During the second week of the PSH course, an observation was

conducted with each of the participating study groups (Observations 2, 3, and 4). Each study group session focused on the same homework assignment. These observations were selected because they represented similar activities between the three study groups. In order to discuss how codes were developed, I first discuss the assignment that was the focus of each observation. I then discuss how episodes were defined for each observation. Then I provide a brief summary of each observation including how many episodes were identified and how those episodes were coded in order to develop the observational coding strategy.

### *3.6.1.1 The assignment*

The assignment that was the focus of these observations was a set of four homework problems in the PSH course. Conservation of mass was the particular conceptual focus of these four homework problems. The first two problems asked students to use species accounting equations to determine a set of unknown mass flow rates and compositions in a jam making process. For each problem, the problem statement provided a system diagram as well as an incomplete table providing certain mass flow rates and compositions for the specified process. The first two problems required a very similar solution process and were only different in the system diagram that was provided.

The third problem in the assignment focused on water flow between two ponds, one at a higher elevation than the other. The problem was segmented into three parts. The first part asked students to determine the height,  $h$ , needed to keep one of the lakes at the specified design conditions. The second part asked students to calculate a new height,  $h_1$ , when taking into account evaporation. The third part asked students to find the time rate of change in the second pond if the feed from the first pond is stopped as well as the time it takes for flow to stop coming

out of the second lake. All of problem three could be solved using conservation of mass principles.

The fourth problem in the assignment provided a graphic of an inflatable balloon with air entering the opening of the balloon at a constant speed. Air was also leaking out of the balloon at a hole. This problem had two parts. The first part asked students to develop an equation for the time rate of change of the balloon volume. This equation was to be reported symbolically but not solved. The second part of the problem asked students to find the steady-state volume of the balloon. Again, all the parts of problem four could be solved using conservation of mass principles.

Lecture material needed to complete problems three and four were covered on class numbers 5 and 6 (see Figure 8). Species accounting content and procedures were covered in the lecture during class number 7. This homework assignment was assigned during class number 7 and was due at the beginning of class number 10.

### 3.6.2 Data Analysis Procedure for Observations

The three selected observations were analyzed using a two-step procedure that includes identifying episodes of on-task engagement and coding using the metacognitive framework, as shown in Figure 11. This section describes each step in detail.

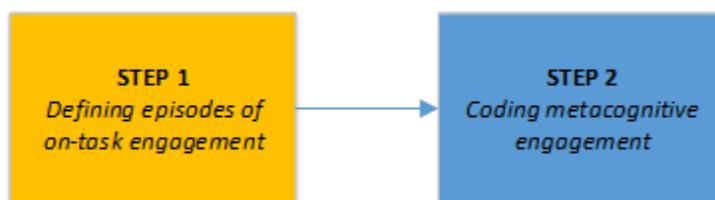


Figure 11 Analysis Strategy for Development of Observational Coding Strategy

### ***3.6.2.1 Identification of Episode***

Step 1 of the data analysis process included identifying episodes of on-task engagement. Episodes are described as “coherent sequences of sentences of a discourse, linguistically marked for beginning and/or end, and further defined in terms of some kind of ‘thematic unit’ – for instance, in terms of identical participants, time, location or global event or action.” (Van Dijk, 1982, p. 117). The thematic unit for the episodes in this study was a global action which I determined to be the length of time that the participants discussed one particular topic of conversation. An episode began at the start of a particular topic and ended when the discussion shifted to a new topic. Thus, an episode contains a series of back and forth sequences of the discussion among different participants that focus on a specific topic of conversation. Therefore, episodes were defined by looking at shifts in the topic of conversation during study group sessions.

Episodes were selected for further analysis if they represented periods of on-task discussion. Each observation had a specific purpose defined by the study group (working on homework, studying for an exam, etc.). On-task discussion was considered any discussion related to the main purpose of the session. For example, discussions focused on working on a homework problem were selected for further analysis while discussions related to extra-curricular activities or related to distractions (such as watching Youtube videos or checking social media) were not selected for further analysis. In order to develop the coding strategy used for the entire study, episodes were identified in three observations. Each observation is described in the following sections.

3.6.2.1.1 *Off-Campus Housing Study group (OFF) Observation 2*

This observation was conducted at the fraternity house where the participants lived and started at approximately 9pm the evening before the homework assignment was due. Five of the study group members (Adam, David, Leonard, Terry, and William) met together to work on the homework assignment at the common dining room table on the main floor of the fraternity house. Another study group member (Daniel) joined about halfway through the observation to work on specific parts of the assignment as he had been working alone but needed help from the group. The observation lasted approximately 90 minutes. In this time, the study group did not complete all four homework problems assigned. As part of analysis, 95 episodes were identified. Forty-five episodes were identified as examples of on-task time and were selected for further analysis. The total time of these forty-five episodes represents 59% of the total time of the observation.

3.6.2.1.2 *Library Study group (LIB) Observation 3*

This observation was conducted in the library study room on campus and started at approximately 7:30pm two nights before the homework assignment was due. The three core study group members (Benjamin, Jenny, and Michael) were present at this study session. The observation lasted approximately 150 minutes. During this time, all four homework problems were completed. As part of the analysis, 109 episodes were identified. Sixty-one of those episodes were identified as examples of high on-task time and were selected for further analysis. The total time of these sixty-one episodes represents 59% of the total time of the observation.

3.6.2.1.3 *On-Campus Housing Study group (ON) Observation 4*

This observation was conducted in the study room of the dormitory where the study group members lived and started at approximately 4:30pm the day before the homework assignment was due. Two members (Chris and Wilson) were present during this observation. The observation lasted approximately 90 minutes. During this time, only one of the homework problems assigned was completed. As part of the analysis, 74 episodes were identified. Thirty-one of those episodes were identified as examples of high on-task time and were selected for further analysis. The total time of these thirty-one episodes represents 38% of the total time of the observation.

**3.6.2.2 *Coding of Episodes***

In Step 2, after episodes were been identified, I used the framework developed by Whitebread et al. (2009) as a starting point to code for metacognitive engagement. Table 8 provides the primary codes and definitions used to code the episodes analyzed in the first three observations.

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Table 8 Definitions from Whitebread Framework for Metacognitive Engagement		
Category	Primary Code	Definition
Metacognitive Regulation	Planning	Any verbalization or behavior related to the selection of procedures necessary for performing the task, individually or with others.
	Monitoring	Any verbalization or behavior related to the ongoing on-task assessment of the quality of task performance (of self or others) and the degree to which performance is progressing towards a desired goal
	Evaluation	Any verbalization or behavior related to reviewing task performance and evaluating the quality of performance (by self or others)
	Control	Any verbalization or behavior related to a change in the way a task had been conducted (by self or others) as a result of cognitive monitoring
Metacognitive Knowledge	Knowledge of Persons	A verbalization demonstrating the explicit expression of one's knowledge in relation to cognition or people as cognitive processors.
	Knowledge of Tasks	A verbalization demonstrating the explicit expression of one's own long-term memory knowledge in relation to elements of the task.
	Knowledge of Strategies	A verbalization demonstrating the explicit expression of one's own knowledge in relation to strategies used or performing a cognitive task, where a strategy is a cognitive or behavioral activity that is employed so as to enhance performance or achieve a goal

From the pilot study conducted, I learned that the examples and some of the subcodes used in the original C.Ind.Le coding strategy were not appropriate for an undergraduate engineering context. Therefore, I devised a strategy for developing a new coding strategy using the C.Ind.Le as a base. Using the original Whitebread coding strategy as a starting point for coding, all 137 episodes from the three observations were coded. Primary codes were assigned to each turn showing evidence of metacognitive engagement. These primary codes were assigned by looking at each turn and generating an explanation of what was occurring in that particular situation. This explanation was compared to the primary code definitions to determine if there was a match. After primary codes were identified, subcodes were then assigned to each of the

turns identified as metacognitive. If subcodes from the original framework were appropriate for a particular turn, that subcode was applied. If no appropriate subcode existed, a summary of activity was generated. After all coding was completed, the applied subcodes and summaries were reviewed. New subcodes were developed based on the summaries and unused subcodes from the original framework were eliminated. An example of a coded episode is shown in Table 9. Additional examples of coded episodes can also be found in Appendix E. These examples show how explanations were generated for turns identified as metacognitive (shown in the *Explanation* column). These explanations were used to determine which primary code and subcode should be assigned to each turn identified as metacognitive. For example, in the first line of Table 9, the explanation reads “William checks to see where other members are in their progress to complete the task.” Based on this explanation and checking against the definition of the primary code for monitoring (shown in Table 8), I determined that William was engaged in a monitoring activity that aligned with the subcode of “Checks Progress.” This process was followed for each turn that showed evidence of metacognitive engagement.

It is important to note that not all lines are coded for metacognitive engagement. If a line was not coded for metacognitive engagement, this means that this particular part of the discussion or behavior was not evidence of metacognitive engagement. Though not all the lines in a discussion showed evidence of metacognitive engagement, it is important to note that the discussion, as a whole, was productive in that it contributed towards progress on the task at hand.

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Table 9 Example of Coding: OFF Observation 1 (Beginning of Problem)

Observed Activity	Analysis		
	Explanation	Primary Code	Subcode
William: So, you're looking at your system?	William checks to see where other members are at in their progress to complete the task	monitoring	checks progress
David: So...			
Leonard: So...			
William: So, this one's just on file right?	William makes a plan to look at the file in order to complete this assignment.	planning	making a plan
Terry: How did you get done copying that given so fast?	Terry notes that William completed writing down the given information quickly.	evaluation	comments on success/ quality of
William: Cause I have a hand and I can write.			
Leonard: Got him.			
William: Burn. Here it is.			
Leonard: Mixed in a mixture with sugar solution and what?	Leonard asks for clarification because he does not know what the word pectin means.	monitoring	checks understanding
William: Don't ask, just...			
Leonard: What is pectin?	Leonard again asks for the definition of pectin.	monitoring	checks understanding
William: Just don't ask. You can't ask questions when it comes to this stuff.	William is joking with Leonard; this is not a control activity		
Leonard: I've just never seen that...I don't think I've ever seen that word before. Pectin.	Leonard comments that he does not know the word pectin.	monitoring	comments on understanding
Adam: Hey, do you know what homework set this is?	Adam collects information so that he can start the task.	planning	collects information
William: Did you already do the [electrical systems]...or the [problem solving course]?	William asks Daniel if he has completed the task.	monitoring	checks progress
Daniel: Uhh...most of it. Which one are you guys on?	Daniel asks about the progress the group has made on the task.	Monitoring	checks progress

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After all episodes from the three observations were coded, the new subcodes were collected and common occurrences were identified in order to merge like subcodes together. Several new subcodes were developed, including (but not limited to) a subcode referencing the use of the course's homework format, a subcode referencing activities where participants checked answers and strategies with one another, and a subcode referencing discussions regarding the reasonableness of answers to homework solutions. All examples for each subcode were updated to reflect actual verbalizations from the observations. Through this process, the new observational coding strategy was developed and used for the balance of this study. The new coding strategy provides the primary codes and definitions that were used as well as the subcodes developed through the coding process. The new coding strategy, named the Naturalistic Observations of Metacognition in Engineering (NOME) coding strategy, is shown in Table 10. A more detailed description of the comparison between Whitebread's coding strategy and the NOME are found in Chapter 4.

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Table 10 Naturalistic Observations of Metacognition in Engineering (NOME) Coding Strategy

<b>Metacognitive Knowledge</b>	
<b>Subcode</b>	<b>Example</b>
<b>Knowledge of Persons:</b> A verbalization demonstrating the explicit expression of one's knowledge in relation to cognition or people as cognitive processors. It includes knowledge about cognition in relation to:	
<u>Self:</u> Refers to own capabilities, strengths and weaknesses, or academic/task preferences; comparative judgments about own abilities	<i>I'm feeling pretty good about myself. I'm like gonna know what to do.</i>
	<i>Well, I thought I understood circuits but I don't so let's be glad this isn't a circuit.</i>
<u>Others:</u> Refers to others' processes of thinking or feeling toward cognitive tasks	<i>No, he's actually pretty good about explaining things.</i>
	<i>To be honest, he'd probably get a better grade than any of us in that class cause he just knows, he just knows everything. I just assume he knows everything.</i>
<u>Universals:</u> Refers to universals of people's cognition	<i>[No examples available]</i>
<b>Knowledge of Task:</b> A verbalization demonstrating the explicit expression of one's own long-term memory knowledge in relation to elements of the task.	
<u>Across Tasks:</u> Compares across different tasks (similarities/differences)	<i>So is this a bit like when we were doing the ideal gas law last time?</i>
	<i>This is literally like the exact same problem we did in class.</i>
<u>Task difficulty:</u> Makes a judgment about the level of difficulty of cognitive tasks or rates the tasks on the basis of pre-established criteria or previous knowledge	<i>Yeah, they look pretty simple.</i>
	<i>Sheesh. This looks like it might be a lot of work,</i>
<b>Knowledge of Strategy:</b> A verbalization demonstrating the explicit expression of one's own knowledge in relation to strategies used or performing a cognitive task, where a strategy is a cognitive or behavioral activity that is employed so as to enhance performance or achieve a goal	
<u>Evaluates Effectiveness:</u> Evaluates the effectiveness of one or more strategies in relation to the context or the cognitive task	<i>This would be so much easier if we just put this in Maple.</i>
	<i>I study better for tests not by myself necessarily but just like alone without anyone looking at me.</i>
<u>Explains Procedures:</u> Explains procedures involved in a particular task	<i>The strategy is conservation of linear momentum.</i>
	<i>Then the mass flow rate of the mixture has to be the same as the addition of one, two and three.</i>
<u>Explains Approach:</u> Explains to others how he/she has done or learned something	<i>Ok, so we're going to have <math>dP_{sys y dt}</math> and <math>dP_{sys x dt}</math> and we're also going to have a free body diagram.</i>
	<i>So, I have this still over here and I substituted that whole thing.</i>

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<b>Metacognitive Regulation</b>	
<b>Subcode</b>	<b>Example</b>
<b>Planning:</b> Any verbalization or behavior related to the selection of procedures necessary for performing the task, individually or with others.	
<u>Collects info:</u> Collects information or resources necessary to solve the task	<i>Alright, so what's number 7?</i>
	<i>How many files do we have?</i>
<u>Assigns a task:</u> allocates individual roles and negotiates responsibilities	<i>Actually, you should take the turbine...or the generator. I wonder if we'd get the same answer.</i>
	<i>Give me a problem.</i>
<u>Makes a plan:</u> Decides on ways of proceeding with the task	<i>You should have somebody start on the third one though.</i>
	<i>I'm probably just going to work back through all the examples we did in class cause that's what we always do when we do our homeworks.</i>
<u>Homework format:</u> Works on homework format designated by assignment or instructor	<i>Mhmm. Ok, so that's our name, our CN box, our class and the set.</i>
	<i>(all read the problem statement and write intros on paper)</i>
<u>Covered:</u> Discusses what topics or concepts are included on an assignment or will be covered on an exam or project.	<i>(Speaking about upcoming test) This, yeah we have relative motion on this one right?</i>
	<i>They won't make you prove that. You just need to know that that's how it works.</i>
<u>Goals:</u> Sets goals and targets	<i>[No examples available]</i>

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<b>Metacognitive Regulation</b>	
<b>Subcode</b>	<b>Example</b>
<b>Monitoring:</b> Any verbalization or behavior related to the ongoing on-task assessment of the quality of task performance (of self or others) and the degree to which performance is progressing towards a desired goal	
<u>Checks goal:</u> Checks back to the goal or what needs to be found in the task	<i>What are we finding? The distance from... So we're just looking for velocity?</i>
<u>Memory retrieval:</u> Comments on or rates one's memory retrieval	<i>I'm trying to remember what he said about that. I don't remember what it is.</i>
<u>Mental clarity:</u> Comments on mental clarity/focus	<i>This is how crazy I am guys. I'm just...I'm losing it tonight. S: Are you on the struggle bus today? A: I am.</i>
<u>Error-detection:</u> Detects an errors in a strategy or procedure	<i>F***, I messed something up. I had one wrong decimal. Which of course messes everythin up. Everything.</i>
<u>Self-commentates:</u> talks to oneself outloud for mental dialogue	<i>(quietly while writing on paper) Six point four. (talks to himself as he enters equations into Maple)</i>
<u>Corrects others:</u> Corrects the performance of other(s)	<i>No, you're not multiplying by the two thousand... Oh, no. No. You've got to do the percentage.</i>
<u>Comments on Understanding:</u> Comments on own understanding;	<i>Ok. That makes sense. This is where I'm confused because there's really nothing.</i>
<u>Known/Unknown info:</u> Points out known/unknown information	<i>Ok, so...we're given all that. And those are just in terms of m1. Umm...and then let's see, what are we given? We're given the surface area.</i>
<u>Self-corrects:</u> Self-corrects one's own performance	<i>Mass flow six equals 0.33...hang on... Oh, never mind. Ok. I looked at the numbers wrong.</i>
<u>Checks progress:</u> Checks the progress of oneself or others; reviews progress on task (keeping track of procedures currently being undertaken and those that have been done so far)	<i>Did you calculate that up already? So, you're looking at your system?</i>
<u>Checks understanding:</u> Checks the understanding of oneself or others; Asks for clarification to support cognitive activity	<i>Is this, is this mass flow one then? Right there? What's a kilowatt?</i>
<u>Checks strategy:</u> Checks a strategy to be used to complete a task	<i>So, mass flow rate is, well m1 equals 1000 kilgrams per hour, right? So we take the percentage times that amount?</i>
<u>Checks answer:</u> Checks an answer against the answer of someone else or a given answer	<i>Did you get 284.6? Two hundred eighty four point six? When you multiply .14 times 2032.5? What did you get?</i>

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<b>Metacognitive Regulation</b>	
<b>Subcode</b>	<b>Example</b>
<b>Evaluation:</b> Any verbalization or behavior related to reviewing task performance and evaluating the quality of performance (by self or others)	
<u>Correctness/Accuracy:</u> Comments on correctness or accuracy	<i>I think I did this wrong.</i> <i>Damn, these damn near add up to one hundred, so it must be right.</i>
<u>Reasonableness:</u> Comments on reasonableness of an answer or strategy	<i>Whoa, I got a ginormous flow rate.</i> <i>Why are these numbers so ridiculously small?</i>
<u>Success/Quality:</u> Comments on success or quality of performance	<i>And it all works out and it's awesome.</i> <i>It only took me an hour to get one done.</i>
<u>Progress:</u> Observes or comments on progress	<i>We're actually getting ahead.</i> <i>I am so far behind you guys.</i>
<b>Control:</b> Any verbalization or behavior related to a change in the way a task had been conducted (by self or others) as a result of cognitive monitoring	
<u>Motion or Gesture:</u> Uses physical motion/non-verbal gesture in order to support cognitive activity	<i>Writes in the air with finger</i> <i>Holds arms up to show size</i>
<u>Asks for help:</u> Asks for help from someone else	<i>Umm...can we write it on the board because I am having trouble visualizing what you are saying?</i> <i>So, if you could look at it really quick that would be great. I messed something up.</i>
<u>Model/Representation:</u> Makes, uses or refers to a common model/representation to be used to aid cognitive activity	<i>Draws a system on the whiteboard</i> <i>Writes the steps to solve a problem on the whiteboard</i>
<u>Verbally repeats:</u> Verbally repeats a strategy to help with understanding	<i>So, two three of two point five [This is a repeated statement]</i> <i>Saying one number at a time to make sure it is communicated properly to someone else</i>
<u>Repeats strategy:</u> Repeats a particular strategy in order to check effectiveness	<i>Ok, well maybe I shouldn't...I'm going to try this again.</i> <i>I just need to rewrite this one because I just...</i>
<u>Changes strategy:</u> Changes strategy as a result of previous monitoring	<i>(Erases something from his paper and rewrites)</i> <i>Alright, instead of doing this method, let's do the short circuit current method.</i>
<u>Helps others:</u> Helps another person in the group	<i>Let me see this (takes S paper to look at steps to see if something is incorrect)</i>
<u>Effectively:</u> Suggests and uses strategies in order to solve the task more effectively	<i>[No examples available]</i>
<u>Previous Strategy:</u> Applies a previously learnt strategy to a new situation	<i>[No examples available]</i>

### 3.6.2.3 *Checking Agreement for the Observational Coding Strategy*

As part of the development of the NOME coding strategy, I wanted to ensure that the coding strategy could be reliably used by different researchers. While many researchers use the term ‘reliability’ in the development of research studies, those versed in observational techniques, especially those focusing on socially-based schemes, find the term reliability to be too restrictive (Bakeman, 2000; Bakeman & Gottman, 1986). When checking reliability, a researcher seeks to check if what is coded matches the ‘truth.’ In socially-based schemes of observation, it is difficult to define ‘truth’ because socially-based schemes require inference during the analysis process. Therefore, it is more important to check agreement between two or more observers (Bakeman, 2000; Bakeman & Gottman, 1986). While one generally accepted technique for checking agreement is by reporting an agreement percentage, this calculation has been noted to be misleading. Generally, agreement percentages are calculated as follows:

$$P_A = \frac{N_A}{N_A + N_D} \times 100$$

Where

$P_A$  is the percentage agreement

$N_A$  is the number of agreements and

$N_D$  is the number of disagreements

The difficulty with the percentage of agreement lies in the fact that it is difficult to define what constitutes an agreement and disagreement. For example, an agreement in one research context could mean that two independent coders assigned the same code to a particular segment in a transcript. In another context, agreement could refer to two independent coders in agreement that a certain segment in a transcript should be coded. Both of these examples focus on agreement but in entirely different ways. If definitions can be developed, it is also difficult to interpret what an

agreement percentage means. While a numerical value of 0.9 or above is generally acceptable, this number is only a rule of thumb and has no empirical evidence to back it up (Bakeman & Gottman, 1986). A final issue with an agreement percentage lies in the fact that some agreement can happen due to chance (Bakeman, 2000; Bakeman & Gottman, 1986).

In order to combat the inadequacies found in traditional agreement calculations, I used a method of calculating agreement through a two-step process developed by Bakeman and Gottman (1986) specifically for use in socially-based observational studies: agreement in unitizing and absolute level agreement. Agreement in unitizing refers to the level of agreement that two independent coders have on which segments in a transcript constitute a codable segment. Absolute level of agreement refers to the level of agreement that two independent coders have on what code to assign a particular segment in a transcript. This two-step process takes into account agreement and disagreement in the coding process as well as factors in agreement due to chance. To check intercoder agreement using this two-step process, episodes were selected from each of the three observations used to develop the observational coding strategy for a second researcher to code using the newly developed coding strategy. The second researcher was selected for this process due to her experience with qualitative coding on numerous research studies as well as her experience with intercoder agreement trials for other researchers. This researcher was also selected because the researcher did not hold pre-conceived notions about whether students engaged in metacognitive strategies. Therefore, this researcher also aided in ensuring that my bias did not inflate the results of this study. After training with the observational coding strategy was complete, these episodes were independently coded by the second researcher. First, agreement in unitizing (Bakeman & Gottman, 1986) was checked by determining the level of agreement on the turns identified as codable segments. In

this level of agreement, I attempted to determine if there was agreement on which segments should be coded. Agreement was recorded in a 2 x 2 matrix that looked at each turn to determine if there was a match between the two researchers as to whether that turn was coded for metacognitive engagement or left uncoded. The value of agreement in unitizing was calculated by dividing the number of agreements by the total number of segments for the coding sample. The value was reported as a percentage in order to compare the value obtained in this study to previous studies utilizing socially-based observational coding strategies for metacognitive engagement, like the C.Ind.Le.

Next, agreement was checked by looking at the absolute level agreement in the assignment of codes. In this level of agreement, I attempted to determine if there was agreement between two coders on which codes to assign to certain behaviors. To determine this level of agreement, a confusion matrix was developed using the primary codes (knowledge of strategies, planning, etc.) as the primary axes. An example of a confusion matrix is shown in Figure 12. A confusion matrix is a graphical representation of agreement between two researchers. The first researcher is represented by the rows and the second researcher is represented by the columns. A tally is recorded to show how each researcher coded a particular segment. These tallies are used to calculate Cohen's kappa ( $k$ ). Cohen's kappa is "an index that characterizes agreement in applying a coding scheme." Cohen's kappa is a summary index that is calculated from the confusion matrix (Bakeman, 2000, p. 150) using the following equation:

$$\kappa = \frac{P_o + P_c}{1 - P_c}$$

Where

$P_o$  is the proportion of agreement that is observed and

$P_c$  is the proportion of agreement expected due to chance

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$P_o$  is computed by summing all of the agreeing tallies along the diagonal of the confusion matrix.

$P_c$  is calculated by summing all of the chance probabilities for all of the categories in the coding strategy.

Confusion Matrix for Intercoder Agreement									
		2nd Researcher							Total
		Knowledge of Persons	Knowledge of Task	Knowledge of Strategy	Planning	Monitoring	Evaluation	Control	
1st Researcher	Knowledge of Persons	1	0	1	0	1	0	0	3
	Knowledge of Task	0	11	0	3	0	0	0	14
	Knowledge of Strategy	0	0	10	1	2	0	0	13
	Planning	0	0	0	16	1	0	1	18
	Monitoring	0	0	0	2	31	0	0	33
	Evaluation	0	1	2	0	3	10	2	18
	Control	0	0	0	0	0	0	1	1
	Total	1	12	13	22	38	10	4	100

Figure 12 Example of Confusion Matrix for Intercoder Agreement

Cohen's kappa is preferred as a measure of agreement because it takes into account agreement due to chance. To determine if the value of kappa is acceptable, it is compared to the sampling distribution of kappa, developed by Fleiss, Cohen, and Everitt (1969). The results of agreement check are discussed in Section 4.1.2 because the development of the coding strategy is an outcome of this study.

**3.7 Analysis of All Observations**

Once the observational coding strategy was developed, all of the observations identified in Table 11 were analyzed using the two step process in Figure 11 and were coded using the coding strategy shown in Table 10. Table 11 displays information about each of the nine observations selected for further analysis, including the study group that was observed, the date the observation took place, the number of episodes identified and selected for analysis, the total time of the observation, the time length of selected observations for coding, and the percentage of each observation that was selected for analysis.. Though I was open to the development of new codes through this process, no new codes emerged.

Table 11 Observations Selected for Metacognitive Analysis							
Obs #	Study Group	Date	Total Episodes	Episodes Selected for Analysis	Total (HH:MM:SS)	Selected (HH:MM:SS)	% of Obs Analyzed
2	2	9/18/2013	109	61	2:21:06	1:23:31	59%
3	1	9/19/2013	95	45	1:36:52	0:57:16	59%
4	3	9/19/2013	75	31	1:28:19	0:33:25	38%
6	2	9/25/2013	55	36	1:13:32	0:48:39	66%
7	2	9/26/2013	87	52	1:54:37	1:17:59	68%
11	1	10/8/2013	110	61	2:59:54	2:01:48	68%
13	2	10/14/2013	93	52	1:28:49	0:44:33	50%
15	3	10/29/2013	121	68	2:22:29	1:06:11	46%
16	2	10/31/2013	77	54	2:45:53	2:07:45	77%
Total			822	460	18:11:31	11:01:07	61%

Once coded, the data from each observation was quantized in order to look for patterns among the data. Quantitization of qualitative data is a generally accepted practice in research when looking to identify patterns in the qualitative data that may not be seen by qualitative methods alone (Maxwell, 2010). In order to look for patterns in the coded data, the

metacognitive codes were quantitized and bar charts were developed for each observation. The method of quantitizing data is not a method traditionally used with ethnographically-informed work. However, quantitization does align well with my pragmatic worldview as well as the purpose of this research study.

Two of the main purposes of this study were to provide a picture how engineering students were engaging in metacognition and how context potentially impacted this engagement. In order to effectively look for and convey patterns in the observational data, it was necessary to devise a way to display the data in a way that would allow comparison between observations and different contextual situations. Therefore, a quantitative solution was necessary. To display information on the types of metacognitive behaviors students were engaging in, a series of pareto charts was developed in order to display not only the behaviors observed but also a rate of engagement in each behavior. The rate of engagement (observed behaviors per minute) was a reporting value originally used by Whitebread et al. (2009) for reporting the behaviors of the children in their study. In order to work towards developing a consistent language for which to compare results, I adopted a similar procedure for reporting numerical values. Reporting as a rate of engagement is also helpful in that it eliminates length of the observation as a parameter for comparison. The observations that I conducted were controlled by the participants of the study groups. Therefore, the length of the observations varied in length from one hour to four hours. In order to provide a way to compare metacognitive engagement among the different observations, I reported engagement as a rate in order to normalize the data among differing observation lengths.

Using turns as a method for counting, rates for metacognitive knowledge and metacognitive regulation were calculated using the following equation:

***Rate of observed behavior***

Eq 1

$$= \frac{\# \text{ of turns coded for metacognitive behavior}}{\text{Duration of Observation in Minutes}}$$

The units associated with the rate of observed behavior is observed behaviors per minute. In their study of metacognitive regulation in collaborative learning among veterinary students, Volet et al. (2013) defined a turn as a verbal comment or phrase from one individual until another student joined the conversation. Any discussion is made up of a series of turns which represents participants going back and forth in a conversation. For example, take the follow conversation:

Tom: Hello Sally. How are you?

Sally: Hi Tom. I'm doing well. How are you doing?

Tom: I'm really good as well. Thanks for asking.

In the preceeding conversation, there were three turns. Tom took the first turn by asking Sally how she was doing. Sally took the next turn by responding and asking Tom a question in return. Tom took the third and final turn by answering Sally's question. Turns are one way of quantitizing units in a conversation.

In order to provide a way to compare metacognitive behaviors for different contextual factors, developed a series of bar charts that compare metacognitive behaviors in different contexts. A sample bar chart is shown in Figure 13.

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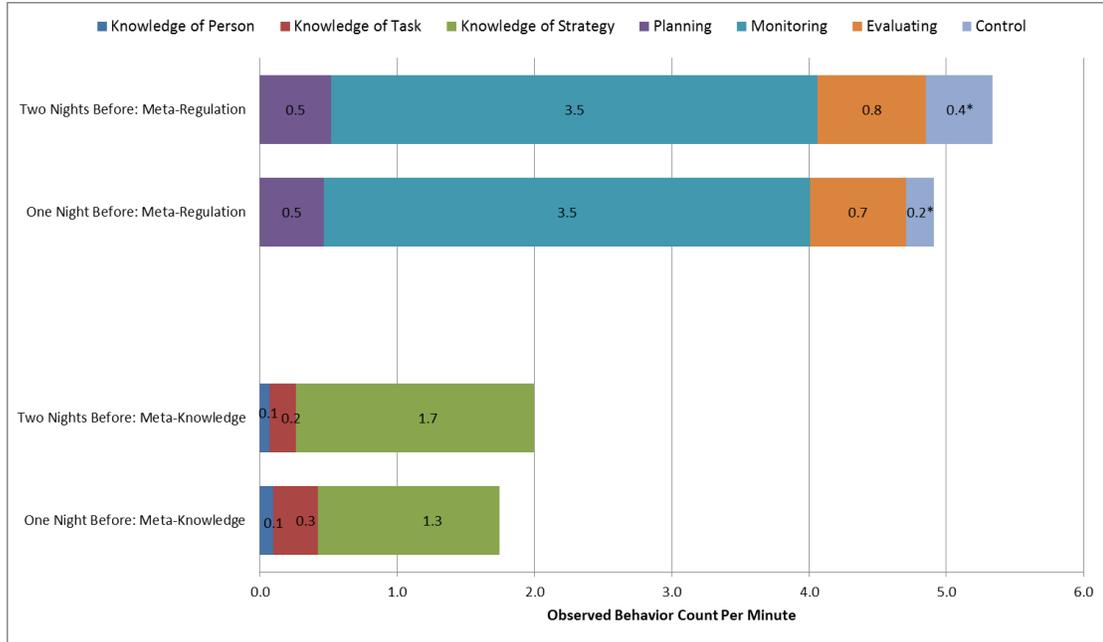


Figure 13 Sample Bar Chart for Metacognitive Engagement

The numerical values reported in Figure 13 represent the rate of observed behaviors for the observations (as calculated from Eq 1).

Metacognitive knowledge and metacognitive regulation were further broken down to show engagement in the primary categories from the coding strategy (knowledge of persons, planning, etc.). In Figure 13, the major bars are broken into segments that represent each individual primary code. For example, the metacognitive regulation bar is broken into segments representing the rate of observed behavior in planning, monitoring, evaluating, and control strategies. Those percentages were calculated using the following equations.

$$Planning\ Rate = \frac{\#\ of\ turns\ coded\ as\ Planning}{Duration\ of\ Observation\ in\ Minutes}$$

Eq 2

$$\text{Monitoring Rate} = \frac{\text{\# of turns coded as Monitoring}}{\text{Duration of Observation in Minutes}} \quad \text{Eq 3}$$

$$\text{Evaluation Rate} = \frac{\text{\# of turns coded as Evaluation}}{\text{Duration of Observation in Minutes}} \quad \text{Eq 4}$$

$$\text{Control Rate} = \frac{\text{\# of turns coded as Control}}{\text{Duration of Observation in Minutes}} \quad \text{Eq 5}$$

The segments making up metacognitive knowledge (persons, task, strategy) were calculated using similar equations. Figure 14 connects how different segments of the bar chart were calculated using the associated equations.

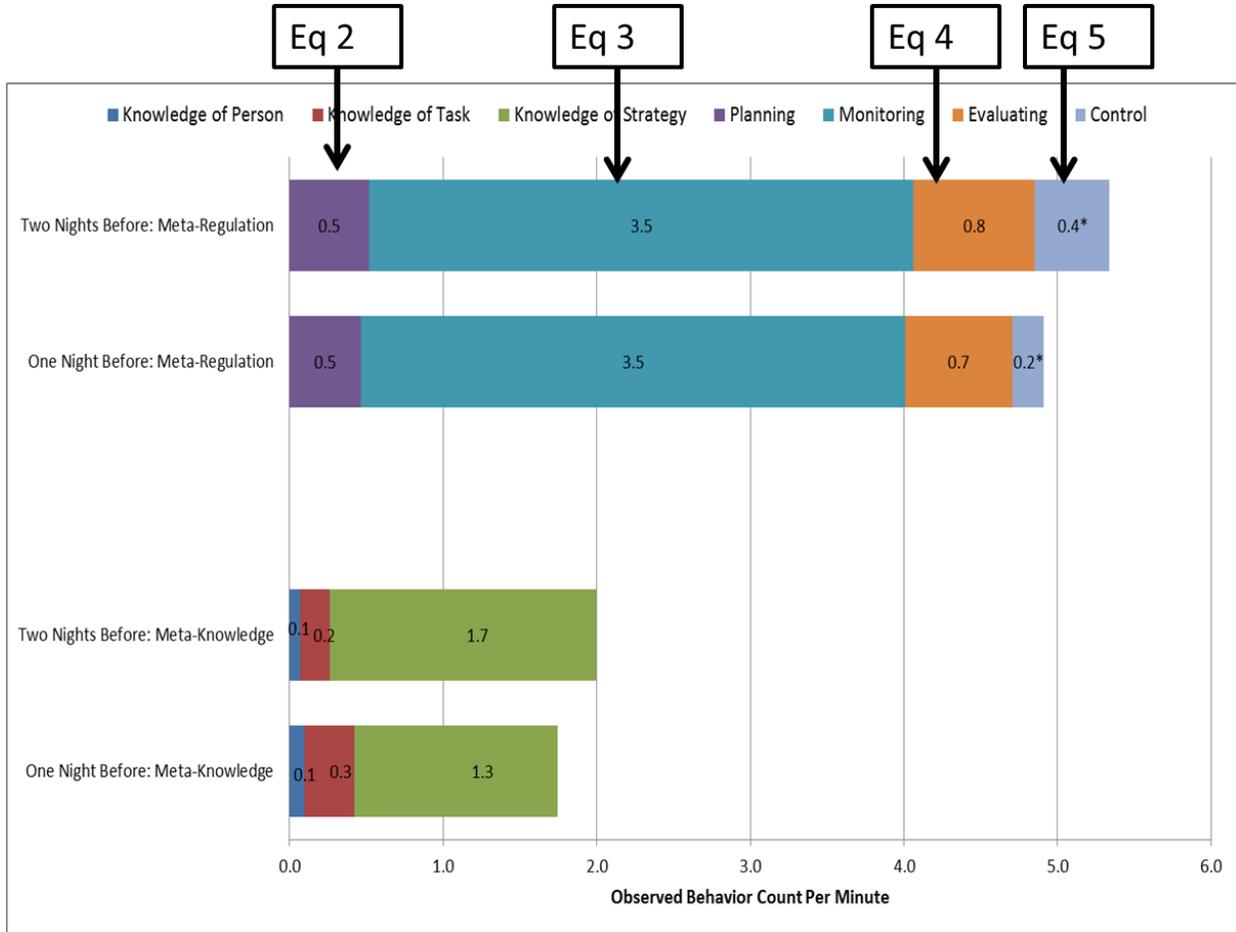


Figure 14 Bar Chart for Metacognitive Engagement (With Eq Designators)

### 3.7.1 Analysis of Fieldnotes

In order to identify contextual factors that potentially impacted metacognitive engagement, it was next necessary to analyze the data from observation fieldnotes. For each observation conducted, extensive fieldnotes were recorded. Observation fieldnotes were coded using both initial and focused coding (Lofland & Lofland, 1995). Initial coding, or open coding, is an inductive process that allows for themes and categories to emerge from the data. Initial coding was accomplished through the process of writing questions and inferential comments during and after each observation, as discussed in Section 3.5.1. Focused coding is then done by using the emerging themes and categories developed from the initial coding. Focused coding was

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accomplished by collecting all of the questions and inferential comments into a single location and identifying themes (example of fieldnotes and inking shown in Figure 9). This inductive coding process was used to define themes and categories that were relevant to engagement in metacognitive behaviors.

After the questions and inferential comments from the fieldnotes were collected and combined, the following categories emerged:

- Learning Environment
- Resources Used
- Working in a Group
- Study Group Schedule
- Impact of Workload
- Roles during a Study Session
- Checking Answers
- Finding Mistakes
- About the Class
- View of Knowledge
- Use of Examples
- Confidence
- Problem Format
- Problem Characteristics
- Working in a Group
- Resources Used

Once the categories were developed, I reviewed the fieldnotes to determine which categories needed to be included in the ethnographic interviews in order to gain understanding from the participants. Certain categories were identified as categories that were thoroughly explained through the use of ethnographic fieldnotes alone. Table 12 displays the codes that developed from the categories that were sufficiently explained through the use of ethnographic fieldnotes from the observations. These codes were explored further in order to answer the third research question for this study. Categories that could not be fully explained by the ethnographic fieldnotes alone were included in the ethnographic interviews conducted with the participants. The interview protocol is found in Appendix D of this report.

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Table 12 Ethnographic Fieldnotes Codebook Explained Through Observations		
Code	Subcode	Characteristics
<b>Learning Environment:</b> Details about how the learning environment was arranged		
	Common Space	A space that was utilized by more than just the members of the study group
	Set Apart Space	A space that was utilized only by the members of the study group
<b>Resources Used:</b> Specific resources used by the study group and/or individuals in the study group		
	Textbook	The use of the course textbook as a study aid for a study session
	Notes	The use of notes taken by students while in the class session
	Example Problems	The use of example problems provided by the professor during the class session
	Full Worked Solutions	The use of fully worked solutions from previous students who took the course
	Whiteboard/Common Writing Space	The use of a whiteboard or other common writing space that was used to share information with the entire group
	Other Students	The use of other students outside of the study group as help aids for a study session
	Internet	The use of internet resources as a study aid during a study session.
<b>Working in a Group:</b> The purpose of group work for a particular observation		
	Working on Homework	A study session purpose of completing a homework assignment
	Preparing for an Exam	A study session purpose of preparing for an upcoming examination
<b>Study Group Schedule:</b> Details about the scheduling of study sessions		
	Time of Day	The time of day a study session is held
	Proximity to Deadline	The proximity a study session is held to a deadline
	Scheduled	A study session that is planned on a schedule and schedule is communicated to researcher
	Last Minute	A study session that not planned on a particular schedule and minimal notice is communicated to the researcher
<b>Impact of Workload:</b> This particular category was an emergent detail from one specific observation; it highlights a particular event of interest		
<b>Roles during a Study Session:</b> Emergence of different participants leading the discussion for certain topics; This code was more focused on individuals in the study group and not on the study group as a whole		

### 3.7.2 Statistical Analysis for Contextual Factors

In order to determine if any of the contextual factors identified were statistically significant in explaining differences in metacognitive engagement, a non-parametric rank-sum test was run on each grouping. Non-parametric tests are a subgroup of statistical tests that are used with small samples sizes and other samples from which a normal distribution cannot be assumed (Dodge, 2008c). The Mann-Whitney Test and the Kruskal-Wallis Test are both nonparametric hypothesis tests that have the goal of determining if one population is different than another population or a group of population (Dodge, 2008a, 2008b). Specifically, the Mann-Whitney Test is used to determine if there are differences between two populations while the Kruskal-Wallis Test is used to determine if there is a difference between one population and multiple other populations. Thus, for contextual factors containing only two groups, the Mann-Whitney Test was applied, while contextual factors with three or more groups used the Kruskal-Wallis Test. With a null hypothesis that the population groups were the same, the Kruskal-Wallis Test or the Mann-Whitney Test were applied in order to determine if the null hypothesis could be rejected, thus showing statistically significant differences between groups. These tests were run using an alpha value of 0.1. This significance level was selected because the purpose of this portion of the study was to identify potential contextual factors that impact metacognitive engagement. I was not attempting to provide causatory evidence that certain contextual factors cause differences in metacognitive engagement. Instead, I was trying to identify potential contextual influences that could be the focus of future work in the area of metacognitive engagement. Therefore, a less stringent significance level is appropriate for this analysis.

While an alpha value of 0.05 is generally accepted as the appropriate measure for both normal and nonparametric tests, many educational researchers believe that statistical significance

with an alpha level of 0.05 does not provide a full picture about differences between populations (McLean & Ernest, 1998; Robinson & Levin, 1997; Thompson, 1996). Instead, these researchers believe that we must select appropriate significance levels for the studies we plan to conduct as well as report on the power of the analyses that we are conducting, which is typically reported as the effect size (Robinson & Levin, 1997). The probability statistic is used to report if there are differences between two groups while the effect size is used to report the magnitude of the difference between groups (Piastra & Justice, 2010). To report effect size, many researchers report a value of Cohen's  $d$ . Cohen's  $d$  "represents the standardized mean differences between groups" (Piastra & Justice, 2010). Cohen suggested that results be interpreted in the following manner: a value of  $d = 0.2$  is considered small, a value of  $d = 0.5$  is considered medium, and a value of  $d = 0.8$  is considered large (Cohen, 1988). For small sample sizes, Cohen's  $d$  underestimates the effect size and so Hedges'  $g$  is a form of Cohen's  $d$  that can be used to calculate effect size with an impact due to small sample size (Hedges, 1981).

Thus, for this study, a significance level (alpha) of 0.1 was used in hypothesis testing to determine if there were statistically significant differences between contextual groups. If a statistical difference is found between any group, it will be denoted on the corresponding bar graph with an asterisk (\*), as shown in Figure 14. Significance is also reported by providing the probability value ( $p > 0.1$ ) as well as the effect size (e.g.,  $g = 0.6$ ). Overall, very few of the contextual factors identified showed evidence of statistical significance. For the contextual factor of learning environment, engagement in control activities was significantly different between spaces that were set apart and spaces that were common. For the contextual factor of study group schedule, engagement in control activities was significantly different between sessions where

studying occurred two nights before a due date and when studying occurred one night before a due date. These results are further explained in Chapter 4.

### **3.8 Quality of Research**

Multiple strategies were used in order to ensure the quality of this research, both in regards to dependability and credibility. The following measures stand apart from the earlier discussion (Section 3.6.2.3) which outlined the process of checking intercoder agreement for the development of the observational coding strategy. Section 3.6.2.3 discussed a specific measure of quality used to check only the development of the observational coding strategies in order to ensure that the coding strategy could be reliably used by multiple researchers. The measures discussed in the section were used to ensure quality throughout the entire study, from data collection through data analysis and finally into dissemination.

To ensure that the data and interpretations from the data are trustworthy, it is important to build quality into the research. Traditional terms used to describe quality that are rooted in positivist methodologies are validity and reliability (Creswell, 2013). Many qualitative researchers are moving away from the use of these traditional terms to terms such as dependability and credibility in order to provide a distinct demarcation between the methodological traditions (Borrego, Douglas, & Amelink, 2009). Following along with these qualitative traditions, I define quality in terms of dependability and credibility. It is important to note that these steps to ensure quality have been selected based on the needs of the research study. Creswell (2013) suggests that these strategies are found in many types of qualitative research but there is no specific set of strategies that should be utilized for any particular methodological approach. Combined with a pragmatic worldview, the strategies reflect the needs of this study and not for ethnographic traditions.

Dependability addresses how the research design was thoughtfully planned. A dependable study is rigorously designed and clearly states how and why decisions were made in the development and implementation of the study (Rossman & Rallis, 2012). It is critical that measures be taken to prove dependability of the research results of a study. Creswell (2009) outlined a number of steps a researcher can take to ensure dependability in a research study. To ensure dependability of this study, I selected several of the strategies suggested by Creswell that best fit with the research purpose and implemented them in this study. Those dependability measures are as follows:

- Episodes that were identified were transcribed verbatim and included non-verbal cues. After transcription, episodes were checked against the video and audio recording to ensure that there were no obvious mistakes to the transcripts.
- Intercoder agreement was used to check consistency of coding for the metacognitive regulation coding. I was the primary coder for all of the data for this project. For intercoder agreement, another researcher was asked to code selected episodes to determine the level of agreement. This process was used mainly in the development of the observational coding strategy. Results of this intercoder agreement are discussed in Chapter 4.
- Definitions of metacognitive knowledge and regulation were used for coding episodes. During the coding process, definitions were continually checked to ensure there was no drift away from original meaning.
- Memos were used to record mental notes during coding.

By implementing these procedures into this study, I ensured that the data analysis that was being conducted was aligned with the original purpose, which was to identify metacognitive behaviors

in study group sessions. By reviewing the transcripts for accuracy, I ensured that the data I was analyzing accurately reflected the actual words of the participants. By using intercoder agreement checks as well as continuous checks against the definitions from the coding strategy, I ensured that my coding aligned with the model I was using for the study and that coding was accurate and repeatable. Finally, by using memoing during coding, I was able to record my thought process during the coding process so that those thoughts could be revisited and checked throughout the span of the analysis process. By engaging in these steps, I ensured that rigor was built into the data analysis and interpretation procedures.

Credibility refers to evidence that supports that the results of a study are believable (Borrego et al., 2009). Creswell (2009) also outlined a number of steps a researcher can take to ensure credibility in a research study. To ensure credibility of this study, I selected several of the strategies suggested by Creswell that best fit with the research purpose and implemented them in this study. Those credibility measures are as follows:

- A pilot study was conducted prior to full data collection in order to ensure that the methodological approach could be used to collect data appropriate to answer the research questions outlined for the study.
- A clear statement of bias was developed and presented later in this chapter so as to be transparent with the readers. This bias statement provides the reader with information as to how my background information affects the interpretations generated in this study.
- I spent a significant amount of time studying the participants in the natural setting of their study groups. This prolonged time in the field allowed me to provide richer and more accurate details about the settings in which the study occurred.

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- Rich, thick descriptions of the settings and events were used in order to give readers a clear picture of the experiences of the participants.
- While team research is typically suggested as a way to combat quality issues while in the field (Lofland & Lofland, 1995), the scope of this research study did not warrant the use of multiple researchers in the field. Therefore, in substitution for a second researcher in the field, I used a peer debriefing strategy so as to enhance accuracy. This peer debriefer was present at the research site during data collection and thus served as a sounding board for discussions and questions during the data collection process. This peer debriefer also reviewed sections of my study so as to ask me questions. The questions were used to refine parts of the study so that the results are interesting to a broader audience.

Because an important contribution of this study is the development of a methodological approach for investigating metacognitive engagement in engineering study groups, it was important to ensure that the methodological approach developed could accurately be used to investigate metacognition in naturalistic settings. The purpose of conducting the pilot study was to ensure that the methodological process developed could accurately be used to identify metacognitive engagement before data was collected for the full study. Through the collection of data in the pilot study, I built confidence that the methodological approach I developed could be used and thus moved forward with the full study.

I spent a significant amount of time with all of the participants from this study. Through this extended period in the field, I was able to learn a great deal about how these students approached studying and learning in different environments and for different purposes. During this extended period in the field, I was able to identify potential items of interest at one time

period and either confirm or disconfirm their existence in another time period. I have used rich, thick descriptions of this experience in order to communicate what was learned through the process of being in the field. The use of detail and rich description is meant to provide a picture of this 'study group world' to educators that do not have the opportunity to go into the field like I did. Part of the rich description that I provided included a statement of my personal bias as a researcher, as my bias could have potentially affected the data collection and interpretation process.

Finally, my engagement with a peer debriefer while in the field was a critical step in the data collection process. As I made decisions about how to proceed in the data collection, I used the peer debriefer as a sounding board to ensure that I was staying on course towards my research objectives as well as thinking through all the possible consequences of decisions I made.

The use of all of these strategies ensured that my research process was explicit and clear to the readers of this study. By being transparent and building in peer checks, I ensured that my research goals were being met and that the data that my data analysis and interpretations could be trusted by the community at large.

### **3.9 Human Subjects Research and Ethical Considerations**

Before the recruitment process for this study began, I obtained Virginia Tech human subjects research approval through the Institutional Review Board (IRB). Participant permission was obtained before the data collection process was initiated. The current IRB approval for this project is IRB 13-645. The protocol approval covered the collection of observation data, interviews and artifact data for this study. An additional protocol was submitted and approved at

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STFC (RHS0190) due to the fact that I was located at the research site during the data collection process for this study. Both IRB protocols remain open at their respective institutions.

As part of the IRB review process, I considered several ethical implications in regards to this study. First, it was critical to ensure anonymity of participants of this study. While anonymity is a typical concern for any human subjects research study, it was important in this particular study that I guarantee anonymity of participants in order to protect these students from undue harm from the instructional staff. Students were allowed to volunteer for this study and many students chose not to participate. It was important to keep the identities of those that participated and those that did not participate anonymous so that students did not feel coerced into participating for this study. Anonymity was also crucial in that I was observing the behaviors of students in their natural settings. I needed to ensure anonymity to my participants so that they would feel comfortable to engage in their normal activities, even if those normal activities were unethical in regards to school policies. I am grateful that the participants of this study were willing to allow me access to their world of studying in that I was able to gain an understanding of what habits they were engaging in in order to persist in their course. I would not have been able to gain such a rich understanding without offering anonymity as part of their participation.

Second, as the researcher, it was vital that I did not interact with the activities occurring in the study group. Specifically, it was important that I maintained my role as the researcher and refrained from assisting the participants in the study activity. This was critical due to the fact that I was not an expert with the subject matter being studied and could have negatively impact learning and knowledge construction by interacting with the participants.

### **3.10 Researcher Bias and Challenges**

In this section, I talk about two types of bias encountered in this study: researcher bias and participant bias. I also talk about challenges that were associated with this type of research, specifically around the area of participation and distance. My bias as a researcher as well as the challenges that I faced in the field had the potential of negatively impacting how data was collected as well as how data was analyzed and interpreted in this study. Therefore, it was necessary that I explicitly state my bias as well as state the challenges I faced in order to ensure that these areas were not creeping into how the study developed. By making the biases and challenges explicit, I was able to reflect on them throughout the research process in order to keep myself in check and not allow the data collection or analysis process to become skewed.

#### **3.10.1 Researcher Bias and Challenges**

As a researcher, I entered the research site with a certain bias. While many research traditions call for the need to conduct research ‘un-biased’ in order to be objective, ethnographic fieldwork and interpretive research makes no such claim (Lofland & Lofland, 1995). In order to collect the data necessary for this study, I was required to enter the setting and become familiar with the participants and their behavior. Therefore, this required me to get close to the students that were taking part in this research study. To successfully conduct this study, I had to confront my personal story and bias, as it would be with me as I began to interpret the results of this study. In this section, I attempt to describe my personal story that I brought into this research study. My undergraduate and graduate degrees are in mechanical engineering. Therefore, in both my undergraduate and graduate work, I participated in engineering problem solving type course at many different levels. By having my own experiences in the types of courses that I observed, I entered with a belief that students would engage in metacognition while studying content in these

problem solving courses. While several faculty members that I spoke to before starting this project expressed that they believed that metacognitive engagement would be minimal, I entered this study believing that I would find that all students engage in some way in metacognition. This bias could have presented a problem as I analyzed data in that I could have been looking to prove my hypothesis correct and thus prioritizing data confirming my hypotheses and showing that metacognitive engagement does occur. In order to mitigate this bias, I asked a second researcher to perform intercoder activities to look at the level of agreement among the analysis. Thus, I had to justify my coding strategy to someone else and could not privilege some data over others.

### **3.10.2 Challenges**

One of the significant challenges that I encountered during this research study was in the area of participation and distance from the participants. I entered the study with the intention of being a minimally participative researcher. This means that, while I could have some contact with the participants during observations, much of my time would be spent at a distance with as little contact as possible. I chose this route because I wanted to have as little impact on the setting as possible so as not to change the behavior of the participants while I was present. In the first few observations, this strategy worked as I was able to sit in a corner of the room and maintain detachment from the participants. This strategy became more difficult as I proceeded with the study as I began to get to know each of the participants. As I spent more time with each group and they got comfortable with my presence, interactions between the participants and I began to become more frequent. As I attended classes with the participants, it became more difficult to minimize interactions with participants during these class periods.

Lofland and Lofland (1995) describe four categories of issues that field workers encounter while working in the field: loathing, marginalization, sympathy, and identification.

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Loathing refers to a hatred of the group that is being studied and a desire to withdraw due to that loathing. Marginalization refers to a desire to get closer to participants in order to understand their position more fully. Sympathy refers to feeling sorry for the trouble or hardships that participants are going through. Identification occurs when the researcher gets so close to participants that they begin to internalize the perspective of the participants. During this study, I encountered feelings in all four of these categories to varying extremes. At the beginning of my data collection, I experienced feelings of marginalization with all three groups. I wanted to get closer to each group in order to understand what was happening that impacted their learning most. While I got closer with some groups, this marginalization feeling continued with other groups throughout the entire study.

At times, I felt sympathy for the groups that I was interacting with. I had the opportunity to see an up close and personal perspective of how these students work and what impacts their ability to work. Many times, I felt bad as I saw participants struggle in learning certain content areas. I also felt bad when I saw students break down after receiving poor grades after putting in significant effort to study. Many times, it took significant strength on my part to hold back from jumping in and helping students as they study. Because the main goal of my study is to help students and student learning, I found it difficult to sit back and watch as students struggled, knowing that if I could step in, I could help.

While there were times that I felt sympathetic towards students, there were other times where I loathed the actions that I observed and the discussions that I heard. Many times, I became frustrated as I saw students waste time during study sessions. I became even more frustrated when I saw students resort to unethical tactics to complete assignments. And other

times, I was disgusted to hear some of the informal conversations that students had with one another. During these sessions, I wanted to say something or leave the situation.

And yet, even among the times of frustration and disgust, there were many times where I began to identify with the participants that I was interacting with. Throughout their challenges and triumphs in study sessions, I saw them as students that wanted to succeed. And it was dangerously easy to see myself in their place. During these times, I found it 'easier' to interact with the participants during their observations. I found myself falling into their distractions and conversations much more easily. At times, I felt like I was one of them.

I disclose all of this information to note that there was a constant pull during my data collection. The pull was between two questions: Am I close enough? and Am I too close? There was a constant reorientation after each observation that occurred. During data collection, I would share with different debriefers about the events going on in the field. As stated in an earlier section, I used the debriefers as a substitute for a research field team, which is typically suggested in ethnographically-informed work in order to ensure the quality of decisions made in the field (Lofland & Lofland, 1995). The debriefers were immensely helpful in determining when to push forward and when to pull back in the field. So, while my time in the field wasn't 'perfect,' I do believe that I achieved a balance of close and distant.

### **3.11 Limitations and Bias**

There are several limitations associated with this study. These limitations do not impact the quality of the research conducted. Instead, the limitations define the scope of work conducted. First, this study focuses on a very specific sample of participants. The original sample population for this study was approximately 270 students in the PSH course. A total of 14 participants participated in the actual study, thus making up approximately 5% of the total

sample population. While this is a small sample, a significant amount of time was spent with these participants to provide a rich description of the events that transpired. Thus, due to this limited pool size, results from this study are not generalizable to undergraduate engineering students from diverse institutional settings. Instead, the outcomes of this study relate contextually to students at small teaching focused engineering schools. In order to widen the study to be generalizable to a larger undergraduate engineering population, future research can use similar methods to collect data at large research institutions as well as institutions with more racial, ethnic and gender diversity.

Second, the participant pool was limited in several ways. The participant pool was limited to one school, specifically STFC. Due to the nature of data collection, it was important to spend a significant amount of time with each study group, thus necessitating that I stay at one research site for the duration of data collection. Participation was also limited to students that study in study groups. This limitation was due to a methodological need for studying students in a setting where they would naturally speak to one another without the interaction of the researcher. Participation was also limited to undergraduate students focusing on engineering problem solving content. While metacognition may be necessary in other engineering content areas such as creativity and design, the literature specifically states that metacognition is critical in problem solving. Therefore the pool was limited to this coursework.

A third limitation to this study is the use of a scoped metacognition framework. The original Whitebread observational model included metacognitive knowledge, metacognitive regulation and emotional and motivational regulation. While emotional and motivational regulation is a critical component of self-regulatory framework, I looked only at the cognitive components of metacognition. Therefore, outcomes from this study are limited to cognitive

engagement and do not speak to the emotional and motivational regulatory engagement that students engaged in during study group sessions. Emotional and motivational regulatory analysis with this data set is an area for future research and can help translate the results from the current study to studies focusing on research in self-regulated learning.

Finally, this work is limited to the interpretations and inferences made by the observer/researcher in developing and using the observational coding strategy. The quality of these inferences was enhanced through intercoder agreement trials. Though quality of the coding strategy has been checked, the qualitative analysis and interpretations were still limited to only inferences made by the researcher. During data collection, interviews with students were collected alongside the observational data. This study has been scoped to focus only on a subset of observations and to not include the interviews because the rich nature of the observation fieldnotes provided ample evidence for contextual factors that impact metacognitive engagement. While the majority of the interview data was not used for this study, results from the study were shared with the participants and instructors from the research site in order to determine if those that participated in the study agreed with the outcomes and conclusions developed.

The limitations described here represent limits due to the scope of this project. Chapter 5 discusses areas of future work and addresses each of these limitations specifically.

### **3.11.1 Participant Bias**

This study was also subject to two forms of bias: sample bias and self-selection bias. Both forms of bias are discussed in further detail in the following sections.

### **3.11.1.1      *Sample Bias***

Sample bias is defined as the problem that occurs when trying to use a sample as a means of studying a larger population (Lynn, 2004). The problem of sampling bias occurs when the sample that is selected does not have the exact same characteristics of the population to be generalized to. In the case of this study, sample bias occurred in the selection of students that participate in study groups. Students that study in study groups may be different than students that do not study in study groups. Therefore, the results of this study are reported as the metacognitive behaviors of students that study in study groups and are not reported as the habits of undergraduate engineering students over all.

### **3.11.1.2      *Self- Selection Bias***

Self-selection bias is defined as the bias that occurs when participants are allowed to select for themselves whether they will or will not participate in a study (Olsen, 2004). The voluntary nature of human-subjects researchers provides the particular problem where those that volunteer for a specific study could potentially represent a different population than those that choose not to participate in a research study. In the case of this study, participants were asked to participate voluntarily in this study. Therefore, it is possible that students that volunteered to participate in this study may be different than students that did not volunteer for this study. For example, students who volunteered to participate in this study all showed evidence of engaging in metacognitive behaviors at some point during all the observations. It is possible that students that did not volunteer do not engage in metacognitive behaviors on a regular basis while studying. It is also possible that students that did not volunteer to participate in this study engage differently than the students that volunteered and were observed. One way to account for this bias was to fully describe each of the members and the study groups that participated in this

study. By providing this description, those that read this report can decide if the results of this study are generalizable to their population.

### **3.12 Summary**

The methodological approach discussed in this chapter were grounded in the purpose of the research study and the research questions such that data collection and analysis were rigorously conducted in order to appropriately answer the research questions. This study, using ethnographically-informed participant observations as a primary data collection method, studied the metacognitive engagement and contextual factors that contributed to this engagement in engineering students studying in study groups. An observational coding strategy was developed in order to code study group observations for metacognitive engagement. Fieldnotes from observations were coded in order to identify salient themes in contextual factors that, when compared to metacognitive engagement, showed patterns in differences in engagement. Chapter 4 provides results based on my analysis.

#### 4 Chapter 4: Results

This chapter presents results pertinent to answering the research questions stated in section 3.1 as well as supporting evidence for methodological claims made for this study.

Therefore, this chapter is organized into categories:

- 1) A developed observational coding strategy (NOME) that demonstrates the need for and ability to use observational methods for studying metacognition in naturalistic settings. The NOME coding strategy can be used for future research in the study of metacognitive engagement in naturalistic settings in engineering education. Supporting evidence for the development of the coding strategy include:
  - a) Similarities and differences between the original observational coding strategy developed by Whitebread (C.Ind.Le) and the NOME coding strategy developed for the current study (RQ1)
  - b) Evidence of the reliability of the observational coding strategy (NOME) developed for the current study (RQ1)
  - c) Evidence further supporting the need for observational methods for metacognitive engagement as opposed to self-report methods (RQ1)
- 2) A discussion of what observable metacognitive behaviors look like in naturalistic settings as well as what metacognitive behaviors undergraduate engineering students engage in higher and lower rates (RQ2)
- 3) Patterns in metacognitive behavior compared against observed contextual factors (RQ3), including:
  - a) Learning Environment: How study groups set up the different learning environments for their groups

- b) Learning Resources: How study groups used different resources as aids in working on homework and studying
- c) Study Group Schedule: How study groups implemented schedules for studying
- d) Study Group Purpose: How study groups structured their study time for different study group purposes
- e) Workload: How study groups functioned under varying workloads

In the following sections, I present key findings and supporting evidence in each of these areas.

### **4.1 The NOME Coding Strategy**

An important outcome from this study is the NOME coding strategy, shown in Table 10. In order to study the metacognitive behaviors of undergraduate engineering students, I first had to develop an appropriate methodological approach for studying metacognition in naturalistic settings because no such instrument existed when this study began. As part of my study, I developed the NOME coding strategy, an instrument developed to identify the metacognitive behaviors of undergraduate engineering students. Currently, I recommend limiting the application of the NOME to contexts that focus on undergraduate engineering students as that is the setting in which it was developed; participants from this study were limited to undergraduate engineering students participating in engineering problem solving courses. Due to the fact that problem solving is an activity shared among many disciplines, it is possible that the NOME coding strategy could be applied in other contexts apart from undergraduate engineering. Future work should focus on validating the use of the NOME in other undergraduate contexts such as mathematics and the physical sciences, as these are disciplines that focus on similar problem solving processes. Future work could also focus on validating the NOME coding strategy outside of the context of problem solving, such as critical thinking, design, and hermeneutics.

The following sections describe the work conducted to develop the NOME coding strategy to be used to identify metacognitive engagement. These sections highlight the primary differences between the NOME coding strategy and C.Ind.Le coding strategy, the evidence of reliability of the NOME, and further evidence supporting the need for observational methods in studying metacognitive engagement.

### **4.1.1 Comparison of the C.Ind.Le and the NOME Coding Strategy**

The NOME coding strategy built upon the C.Ind.Le coding strategy (described in section 2.1.4) to yield a similar, yet different coding strategy appropriate in an undergraduate engineering context. One difference between the two coding strategies are the use of examples that support each subcode. For the C.Ind.Le, Whitebread et al. (2009) used examples that were consistent with the behaviors of 3-5 year old children. For the NOME, I updated the examples to reflect behaviors of undergraduate engineering students. The examples provided are actual examples from the observation transcripts that represent each metacognitive behavior included in the NOME. Table 13 summarizes the revisions that I made based on the results of my study to the C.Ind.Le coding strategy in order to create the NOME coding strategy. This table is organized in order to display information about coding additions, revisions, and unsupported codes. Additions refer to primary codes or subcodes that were newly created for the NOME and did not originally exist in the C.Ind.Le but emerged from the data for this study. Modifications refer to primary codes or subcodes that were taken from the original C.Ind.Le coding strategy but were modified in a way to be more appropriate for an engineering context. Unsupported codes refer to primary codes or subcodes that were originally found in the C.Ind.Le that were not supported by the data collected for my study. The behaviors were not observed in the observations that were analyzed. These codes were included in the NOME coding strategy

without supporting examples. In the next section, I describe how the results of my study led to differences between the C.Ind.Le (Appendix B) and the NOME coding strategy (Table 10) as well as explanations of the differences between the two coding strategies.

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Table 13 Comparing the C.Ind.Le and the NOME Coding Strategies

Primary Code	Additions	Modifications	Unsupported
Knowledge of Persons			<i>Knowledge of Universals</i>
Knowledge of Tasks	No subcode changes were made.		
Knowledge of Strategies	No subcode changes were made.		
Planning	<b>Homework Format, Current Plan, Covered</b>	The original subcode <i>Seeks and collects necessary resources</i> was expanded to include the collection of information for the purpose of planning.	<i>Sets goals and targets</i>
Monitoring	<b>Mental Clarity, Comments on Understanding, Checks Understanding, Known/Unknown Info, Checks Strategy, Checks Answers, Checks Goal</b>		
Evaluation	<b>Reasonableness</b>		
Control	<b>Verbally repeats</b>		<i>Suggests and uses strategies in order to solve the task more effectively, and Applies a previously learnt strategy to a new situation</i>

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In the category of knowledge of persons, the major difference between the C.Ind.Le and the NOME is the lack of support for the primary category of knowledge of universals in the NOME. Though knowledge of universals was present in the original metacognition model shown in Figure 2, evidence of behaviors indicating the use of knowledge of universals was not present in the data for this study.

Under the primary code of knowledge of tasks, there were no significant differences between the subcodes developed in the C.Ind.Le and the subcodes developed in the NOME. Thus, the primary codes and subcodes in the NOME are similar to those found in the C.Ind.Le. The major difference between the NOME and the C.Ind.Le in the area of knowledge of tasks lies in the examples that were used to describe each subcode.

Under the primary code of knowledge of strategies, there were no significant differences between the subcodes developed in the C.Ind.Le and the subcodes developed in the NOME. Thus, the primary codes and subcodes in the NOME are similar to those found in the C.Ind.Le. The major difference between the NOME and the C.Ind.Le in the area of knowledge of strategies lies in the examples that were used to describe each subcode.

Under the primary code of planning, there are several differences between in the C.Ind.Le and the NOME. First, the original subcode of *Seeks and collects necessary resources* was expanded to include the collection of information for the purpose of planning. Significant evidence from the observations showed that students collected physical resources as well as information in order to engage in planning strategies. Second, the subcode for **Homework Format** was added to the NOME. The homework format for the PSH course was a scaffolded approach provided by the instructors to engage students in planning activities. This specific

behavior would not have been reflected in the original population through which the C.Ind.Le was developed. Third, the subcode of **Covered** was developed in place of the original subcode *Sets or clarifies task demands and expectations*. While the general idea behind the two codes is similar, the new explanation of **Covered** better aligns with what the participants actually did in the study group settings. **Covered** is defined as when a participant discussed the topics or concepts that were included on an assignment or would be covered in an exam or project. Fourth, the subcode of **Current Plan** was developed to represent times when participants discussed what was the current plan moving forward. There was significant evidence in the observations from the study to support the development of this new subcode. Finally, the subcode of *Sets goals and targets* was not observed during the observations. While this category should be included in a list of expected or desired behaviors for metacognitive engagement based on the literature, the behavior of setting a goal or target was not explicitly observed in the current habits of participants. Therefore, this habit is identified as one that should be a focus of potential interventions on developing the metacognitive skills of engineering students.

Under the category of monitoring, there were also several differences between the C.Ind.Le and the NOME. First, the subcodes of **Mental Clarity**, **Comments on Understanding**, and **Checks Understanding** were added to the NOME due to their significant presence in most observations. It is likely that these subcodes were not included in the C.Ind.Le coding strategy because of the developmental differences between 3-5 year old children and undergraduate students. These new subcodes may reflect distinct progress in metacognitive development that is due to age. Second, the subcodes of **Known/Unknown Info**, **Checks Strategy**, and **Checks Answers** were added to the NOME due to their significant presence in most observations. It is likely that these subcodes were not included in the C.Ind.Le coding strategy because these

behaviors relate to problem solving with open-ended problems. Therefore, these behaviors relate more to the engineering context in this study and thus would not be behaviors expected in the context of the C.Ind.Le. Finally, the subcode of **Checks Goal** was added to the coding strategy due to its presence in most observations. It should be noted that *Sets goals and targets* was not an observed behavior in this study. The lack of support for the planning subcode and the addition of the monitoring subcode could be due to the fact that students implicitly set goals for themselves and their study groups but do not explicitly express those goals out loud.

Under the primary code of evaluation, there were two main differences between the C.Ind.Le and the NOME. First, the subcode of **Reasonableness** was added to the coding strategy due to its significant presence in most observations. It is likely that this subcode was not included in the C.Ind.Le coding strategy because this behavior relates to problem solving with open-ended problems. Therefore, these behaviors relate more to the engineering context and thus would not be behaviors expected in the context of the C.Ind.Le. Second, the subcodes of *Suggests and uses strategies in order to solve the task more effectively* and *Applies a previously learnt strategy to a new situation* were unsupported in the data collected for this study. These behaviors were not observed in the data analyzed for this study.

Finally, under the primary code of control, there were two main differences between the C.Ind.Le and the NOME. First, the subcode of **Verbally Repeats** was added to the NOME due to its significant presence in most observations. While the original protocol included the subcode of *Repeats a strategy in order to check the accuracy of the outcome*, during my study, I observed both verbal and non-verbal behaviors that indicated a repeat in strategy. Based on the C.Ind.Le coding strategy, I interpreted the *Repeats* subcode to only refer to non-verbal behaviors.

Therefore, I created the **Verbally Repeats** subcode to complement the **Repeats Strategy** subcode so that both verbal and non-verbal behaviors would be accounted for.

The evidence shows that there are both similarities and differences between the NOME and the C.Ind.Le. The NOME was developed to reflect the context of an undergraduate engineering environment, specifically in naturalistic settings such as study groups. In the next section, we discuss evidence that the NOME is a reliable instrument for coding metacognitive behaviors in undergraduate engineering contexts.

### **4.1.2 Reliability of the NOME**

Using the process to check agreement described in Section 3.6.2.3, I next determined the level of agreement that could be reached among different researchers using the newly developed NOME. It was important to check the level of agreement when using the NOME coding strategy in order to determine if the coding strategy could be reliably used by multiple researchers. If the coding strategy has a high level of agreement, then there is potential for this coding strategy to be used by multiple researchers for future work in metacognition in engineering education. First, agreement in unitizing was calculated. A heading of ‘coded’ means that a particular turn was coded by the researcher. A heading of ‘uncoded’ means that a particular segment was not coded by the researcher. The results from intercoder agreement in unitizing are shown in Table 14. The cells highlighted in green show instances where the two researchers reached agreement. The cells highlighted in yellow represent instances where the two researchers did not reach agreement.

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Table 14 Agreement in Unitizing			
		Researcher #2	
		Coded	Uncoded
Researcher #1	Coded	93	17
	Uncoded	31	47

Agreement was calculated by taking the sum of instances where agreement occurred (cells 1 and 4) divided by the total number of turns in the sample. An agreement level of 74.5% was reached.

Second, absolute level of agreement in the assignment of codes was checked using the process outlined in Section 3.6.2.3. After coding was conducted by two researchers, a confusion matrix was developed. Results of the confusion matrix are shown in Table 15. Cells along the diagonal of the matrix, highlighted in green, show agreement among the primary codes. Cells falling off the diagonal represent disagreement among coding. Cells highlighted in yellow represent patterns of disagreement among coding. Calculating Cohen's kappa ( $k$ ), I found a level of agreement of 0.74.

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		Table 15 Confusion Matrix for Absolute Agreement in Coding							
		2nd Researcher							
		KoP	KoT	KoS	Plan	Monitor	Evaluate	Control	Total
		1st Researcher	KoP	1	0	1	0	1	0
KoT	0		11	0	3	0	0	0	14
KoS	0		0	10	1	2	0	0	13
Plan	0		0	0	16	1	0	1	18
Monitor	0		0	0	2	31	0	0	33
Evaluate	0		1	2	0	3	10	2	18
Control	0		0	0	0	0	0	1	1
Total	1		12	13	22	38	10	4	100

When conducting similar work, Whitebread and colleagues found levels of agreement in unitizing for the development of the C.Ind.Le to be between 66 and 75%. Whitebread and colleagues also found absolute agreement (*k*) when developing the C.Ind.Le to be between 0.72 and 1.0 (Whitebread et al., 2005; Whitebread et al., 2009; Whitebread & Pino-Pasternak, 2013). Whitebread and colleagues noted that their values for agreement were low but cited a primary reason why these levels of agreement should be considered acceptable in the context of this particular type of research: the observed behaviors involved very complex cognitive and social phenomena. Due to the complexity of what was being researched, Whitebread and colleagues cited that more qualitative methods of assessment should be considered for standards of reliability and that future work should focus on the development of new reliability measures for observational studies. In the case of the current study, a level complexity was added due to the

fact that participants were studying complex engineering content at the time of the observations. Though the engineering content being studied was complex, similar levels of agreement (both unitizing and total agreement) were found when compared to the study conducted by Whitebread et al. (2009). Therefore, I find that the levels of reliability attained for the current study are acceptable based on current community standards for reliability.

#### **4.1.3 Supporting Evidence for Need for Observational Methods**

In order to demonstrate the usefulness of observational methods over the use of self-report methods for investigating metacognitive engagement, participants were also asked to self-report a rank of their engagement in metacognitive behaviors for their PSH course. These self-reported rankings were then compared against a ranking of their actual observed behaviors from all the observations in which they took part. Table 16 shows an example of how self-reported rankings were compared with observed rankings for one participant. This example represents a clear mismatch between the observed ranking and the self-reported ranking. A comparison of self-reported behaviors compared to observed behaviors for all participants is found in Appendix F. The column labeled ‘Observed Ranking’ represents the ranking of the behavior that was observed through study group observations. Ranks were assigned by comparing the number of coded turns in each primary code and assigning a rank from 1 to 5, where 1 represents the behavior engaged in the most and 5 represents the behavior engaged in the least. The column labeled ‘Self-Reported Ranking’ represents the actual ranking of behaviors reported by the participant. Cells highlighted in green show a match between the two rankings while cells in red represent a mismatch.

Table 16 Match of Self-Reported and Observed Metacognitive Behavior (Example)

LIB	Becca	
	Observed Ranking	Self-Reported Ranking
Knowledge of Persons\Self	3	3
Knowledge of Persons\Others	4	2
Knowledge of Persons\Universals	5	4
Knowledge of Task	2	5
Knowledge of Strategy	1	1
Control	4	2
Evaluation	2	3
Monitoring	1	4
Planning	3	1

I compared the observed rankings against the self-reported ranking for each of the eleven participants that participated in interviews. Based on this comparison, I found that there were 29 instances (31%) where the self-report and the observed behavior rankings matched while there were 64 instances (69%) where the self-report and the observed behavior rankings did not match. Further, I found that participants were able to more accurately report their engagement in metacognitive knowledge (48% match between observed and self-report) versus metacognitive regulation, where there was only a 14% match between self-reported behavior and observed behavior in the areas of planning, monitoring, evaluation, and control. The results of this activity further support that self-report measures cannot accurately represent metacognitive engagement and thus supports the need for observational methods in the study of metacognition.

**4.2 Observable Metacognitive Behaviors of Undergraduate Engineering Students in Naturalistic Settings**

Evidence from the observations showed that participants utilized knowledge of strategies at a higher rate than knowledge of persons or tasks. Participants also used monitoring strategies

at a higher rate than planning, evaluating, or control when working on homework assignments and studying for exams. A number of specific behaviors were identified as being used at a higher rate than other behaviors. Also, several behaviors from the original metacognitive coding strategy (C.Ind.Le) were not observed in this study. Specifically, there was no evidence of participants using knowledge of universals, setting goals, suggesting strategies in order to solve a problem more effectively, or applying a previously learned strategy to a new task. The following section explores these behaviors in greater detail. As a reminder, these behaviors map back to Whitebread’s modified framework discussed in Chapter 2 and shown in Figure 15.

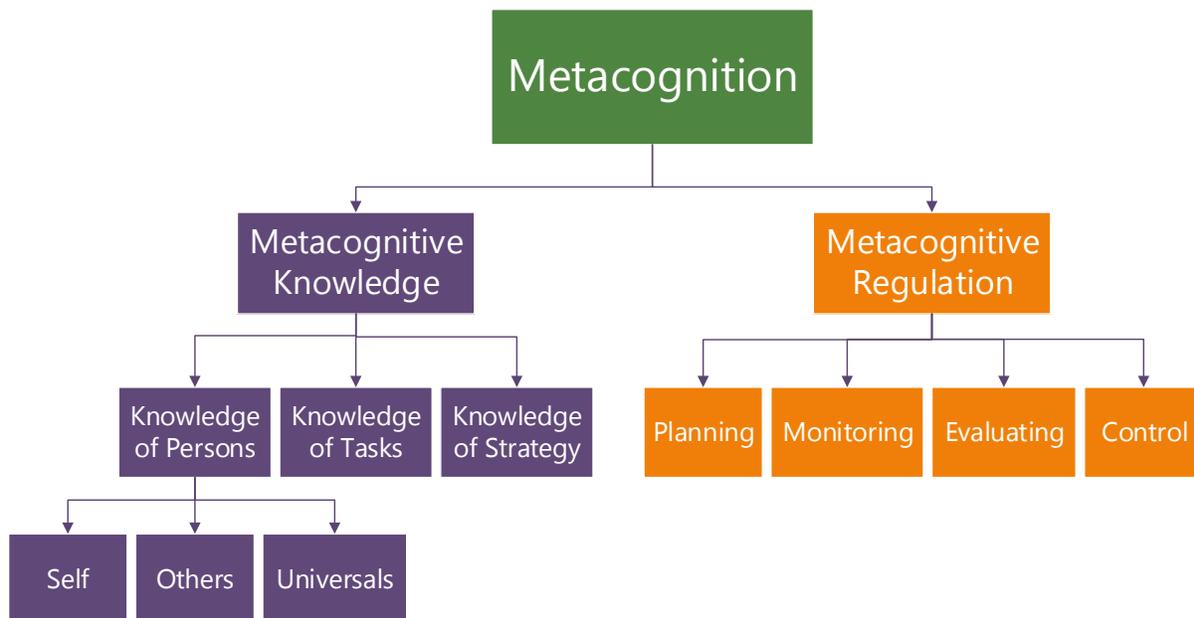


Figure 15 Theoretical Model of Metacognition

#### 4.2.1 Observed Metacognition

In discussing what the metacognitive behaviors of undergraduate students look like while studying, I first take a high level view of what habits look like over the course of the academic term by examining the metacognitive behaviors of all the participating study groups over the course of all observations. Figure 16 displays a numerical summary of the metacognitive and

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non-metacognitive engagement of all participants during the observations selected for analysis.

The rates reported in Figure 16 were calculated using Equations 1-5 from Chapter 3 and

represent the average rate of engagement over all nine observations conducted for this study.

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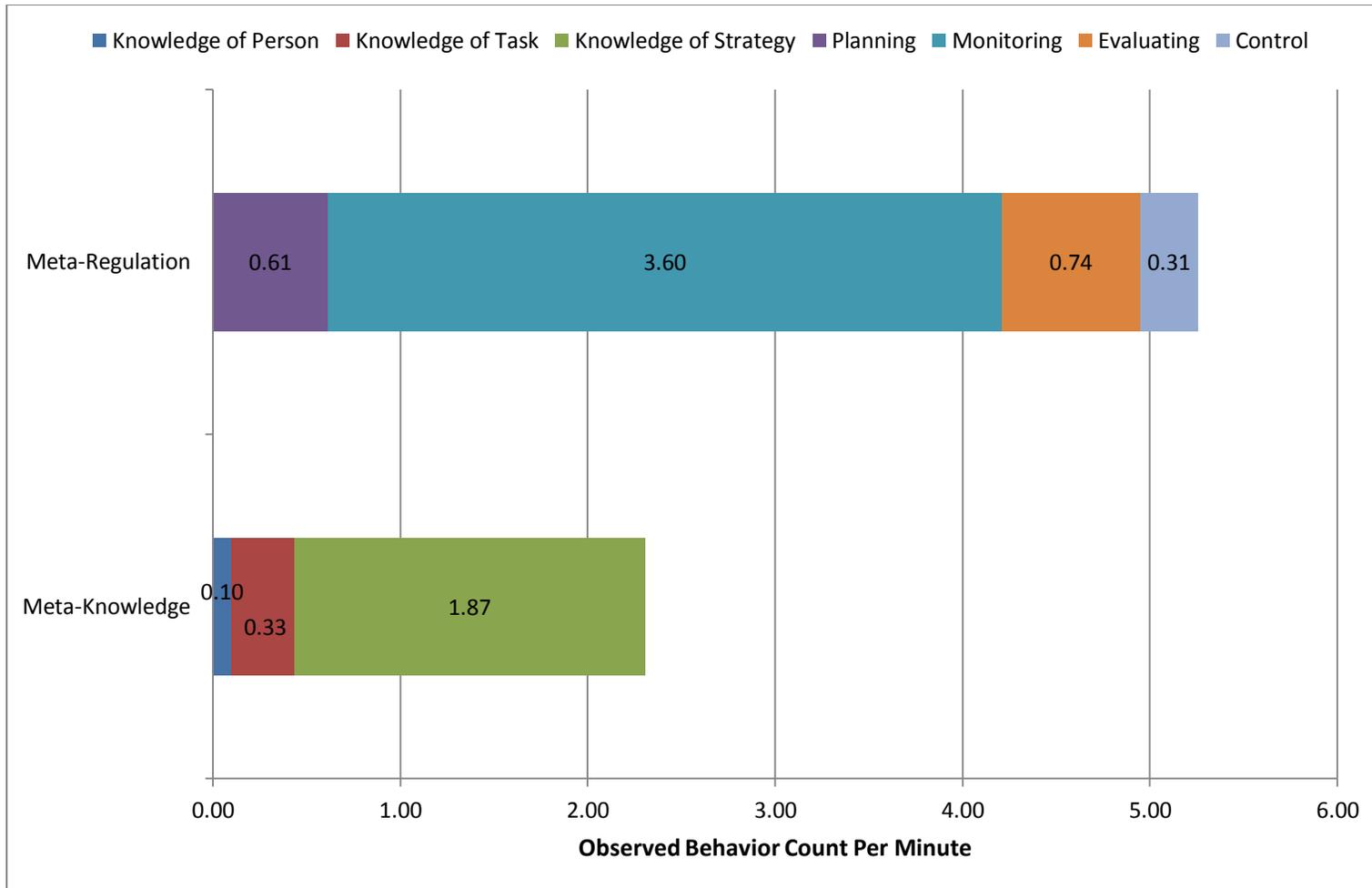


Figure 16 Metacognitive Knowledge Habits of All Study groups over Academic Period

Overall, Figure 16 shows that metacognitive regulations activities were observed at a rate of about 5.25 observed behaviors per minutes (bpm) while metacognitive knowledge behaviors were observed at a rate of 2.3 bpm. Predominantly, metacognitive knowledge on-task discussion was focused in the area of knowledge of strategies (1.87 bpm) while a minimal amount of the discussion was focused on knowledge of persons (0.10 bpm) or knowledge of tasks (0.33 bpm). Metacognitive regulation was focused on the area of monitoring (3.6 bpm). The remainder of metacognitive regulation discussion was spent between planning (0.61 bpm) and evaluation (0.74 bpm), with minimal discussion or behavior related to control activities (0.31 bpm).

To better understand how the students are engaging in each one of these metacognitive areas, I looked at the subcode level to understand what actions made up each of these metacognitive areas. I first provide a discussion of behaviors related to metacognitive knowledge and then move into a discussion of the behaviors that make up metacognitive regulation.

### **4.2.2 Metacognitive Knowledge**

Evidence of the use of metacognitive knowledge occurred at a rate of 2.3 observed behaviors per minute over all observations. I identified specific behaviors that showed evidence of the use of metacognitive knowledge. In the following section, I discuss these specific behaviors related to knowledge of persons, knowledge of tasks, and knowledge of strategies. Based on the data, participants engaged in certain behaviors more often than others.

#### ***4.2.2.1 Knowledge of Persons***

As a reminder, knowledge of persons refers to the knowledge that a person has about their own or another person's knowledge, skills, and abilities in learning or completing a task. Knowledge of persons is typically broken into three categories: knowledge of self, knowledge of others, and knowledge of universals. Knowledge of self refers to the knowledge that a person has

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about himself or herself in regards to their knowledge, skills and abilities in completing a task. In contrast, knowledge of others refers to the knowledge that a person has about another person's knowledge, skills, and abilities in completing a task. Finally, knowledge of universals refers to knowledge that a person has about universals of a person's cognition. Recall that knowledge of universals was not evident in this study and was thus not included in the NOME coding strategy. Therefore, knowledge of universals is not discussed further in this section.

In this section, I review the types of behaviors that reflect participants' use of knowledge of persons. Based on the data from my study, I found that participants used knowledge of persons in different ways and some types of knowledge of persons were used at a higher rate than others when studying in study groups. Specifically, participants used information regarding their own knowledge, skills, and abilities at a higher rate than information about others' knowledge, skills, and abilities when studying together, as shown in Figure 17.

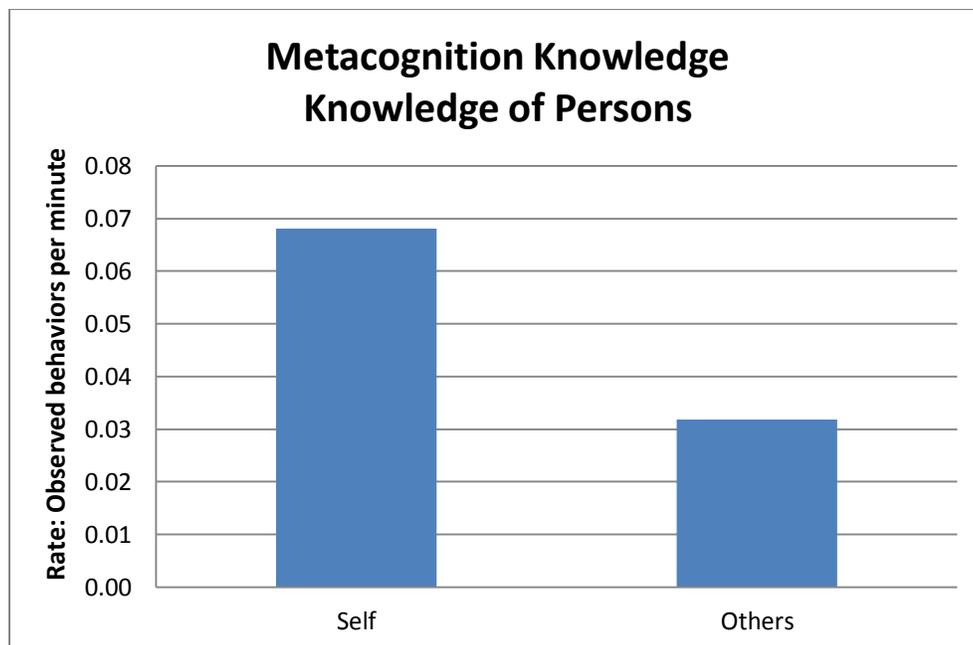


Figure 17 Observed activities associated with MK – Knowledge of Persons

Figure 17 shows that participants expressed knowledge about their own learning and capabilities at a higher rate than knowledge about others' learning or capabilities.

*Self:* Participants tended to focus their discussion about their own knowledge by discussing what they could and could not do or how smart or unintelligent they were. For instance, after the rest of the study group decides to use a strategy to solve the homework that Jenny had suggested earlier in the evening, Jenny smiles, points to herself, and makes the following statement to the others in the group:

*That's what I was trying to say before. It's like says where I just have these moments and it's like the greatest part of my day. And I can go back and [friend name]'s like 'How was studying?' and I was like 'I was the smartest for a minute. And then for the rest of the three hours I was sitting in the corner quietly hoping some dude would tell me what to do.'*

In this statement, Jenny discusses the knowledge that she has about her own capabilities and understanding of the material. Jenny displays her knowledge of her self by stating that, in many cases, she does not feel as capable as the other members of her group. In this scenario, her knowledge of her self was challenged when Jenny provided a correct solution to the group. In that moment, she found herself to be smart. Thus, Jenny had different conceptions of her knowledge of herself. At times, Jenny's knowledge of her self reflected that she was believed smart. At other times, Jenny's knowledge of her self reflected that she believed she was not smart or not as capable as other members of her group.

In a similar manner, when William discussed the quiz that was taken in class earlier in the day, he made the following comment to the others in the group:

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*Yeah, I did. I actually got it today and I was like, oh my god! I'm so smart! Why am I in this class?*

In this example, William states that, because he was able to answer the quiz question, he felt very smart and thus did not need to be in the class anymore. In this quote, he displayed his knowledge of self by stating that he understood the material and was thus, smart.

*Others:* Participants discussed knowledge of others by talking about the capabilities of other students in terms of grades, their ability to explain a concept in terms that the participants can understand, or their general ability to perform better in a class than others. Many times this information was used to determine if another person would be an acceptable person to ask for help. In terms of OFF, knowledge of others was used to determine if fully worked homework solutions from certain students should be used as study or homework aids. For example, as OFF began to gather fully worked homework solutions for their study session, they discussed how one particular student may not be someone they want to pull solutions from. As they began to pull a set of homework solutions from a particular student, Terry asks the question “Does [student name] have good grades?” Leonard responds with “I assume [student name] does alright.” In this situation, the knowledge that the student in question had good grades helped the study group move forward with using this particular student’s fully worked solutions.

In another example, LIB was preparing to study for an exam in the PSH course. As part of their study tactic, they obtained fully worked exams from previous course sections from a learning support center on campus. These full worked examples were from previous students and thus were graded. LIB had obtained several worked exams dating back several years. As the members decide which fully worked exam they should use to study from, Benjamin asked the following question: “How’d they do? Eighty three.” Benjamin and the rest of LIB used the

information about the grade received on the exam in order to determine if that exam should be used to study from. Both of these examples demonstrate how participants discussed others' grade point averages as a way of determining their ability and knowledge level.

Participants also demonstrated the use of knowledge of others by discussing how other students had the ability to explain concepts in terms that everyone can understand. For example, during one evening, OFF invited an older student to come to the study session to help explain concepts and answer questions. As the study group waited for the older student's arrival, they joked about how this older student would probably tell them that all of the homework problems were easy. As the discussion progressed, Leonard said, "No, he's actually pretty good at explaining things." Leonard stated that this older student knew enough about the subject matter and had a strong ability to explain things in a way that others can understand.

*Universals:* The use of knowledge of universals was not observed in this study.

### ***4.2.2.2 Knowledge of Tasks***

Knowledge of tasks refers to knowledge that a person has about different elements of a task and my data show that this includes the categories of task difficulty and comparisons across tasks. Overall, participants used information regarding the difficulty of task at a higher rate than information about similarities or difference between the task they were working on and other tasks when studying together, as shown in Figure 18.

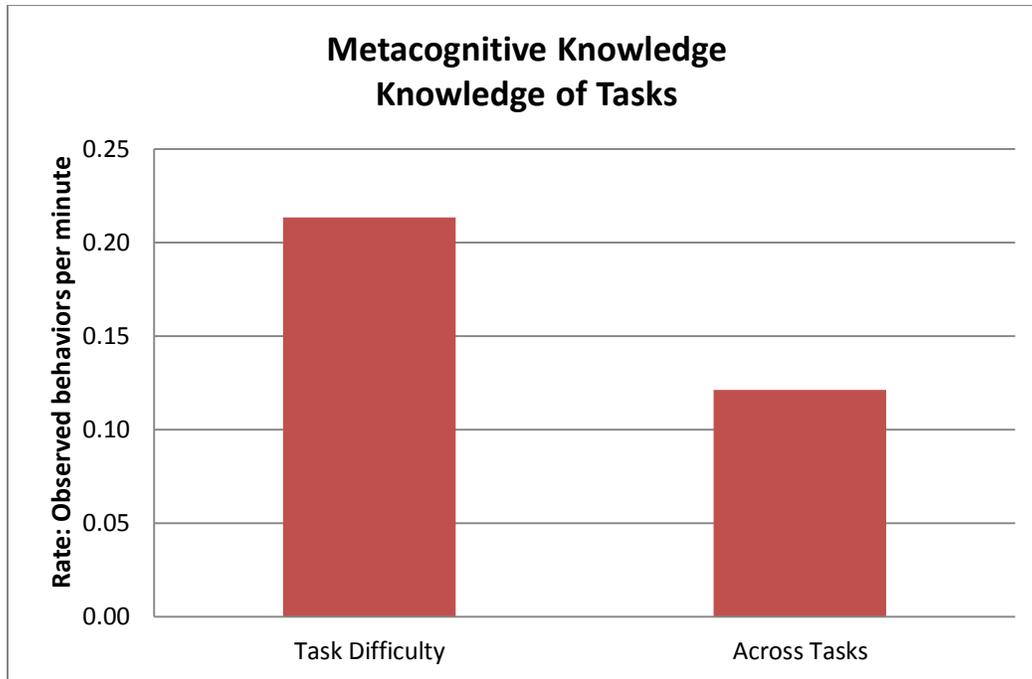


Figure 18 Activities associated with MK – Knowledge of Tasks

*Task Difficulty:* When discussing task difficulty, participants tended to make general statements about how difficult or easy a certain task looked without expanding on what informed this particular judgment. For example, when discussing a problem that a few in the group are about to start, Adam comments, “I’m looking at it now and it looks pretty tough.” Adam provides no other information to discuss why this particular problem looks difficult. On some occasions, participants discuss difficulty level in conjunction with the length of time or amount of work it will take to solve a particular problem. For instance, when discussing with Chris about one of the homework problems he has already completed, Wilson states, “The first one was that simple. It took me fifteen.” In this example, Wilson discusses the level of difficulty of the problem in terms of the length of time it took him to complete that particular problem. During another observation, Leonard remarks that “I was kind of hoping this would be like, easy and we’d be done but, ahh...I guess not.” Again, in this example, Leonard discussed the level of difficulty of a problem in conjunction with the length of time it would take to complete the problem. In this specific

example, Leonard states that the problem that he was working on was difficult and taking longer to complete than he originally expected.

*Across Tasks:* When comparing across tasks, participants tended to focus on comparing the problem to be solved with problems that were solved by the instructor in class, another homework problem in the problem set, or another portion of the same homework problem. For example, when starting the second homework in the homework set, Jenny asks, “Is this going to be the exact same thing?” referring to the homework problem that had just been completed. In response to Jenny’s question, Benjamin responds “Yeah, it’s pretty much the exact same problem.” In this example, both Jenny and Benjamin compare the current problem to the problem just completed and determine that the problems are similar in approach. When working on a different homework assignment, as Jenny starts to look at the problem statement, Jenny states, “This is literally like the exact same problem we did in class.” In this example, Jenny compares the current problem against a problem that was worked in an in-class session and determines that the two problems are similar in nature.

#### ***4.2.2.3 Knowledge of Strategies***

Knowledge of strategies refers to the knowledge a person has about the strategies used to perform a task. Based on my data, knowledge of strategies includes knowledge related to explaining procedures and evaluating the effectiveness of certain strategies. In general, participants used information regarding the actual strategies that should be used to complete a task at a higher rate than information about the effectiveness of different potential strategies when studying together, as shown in Figure 19.

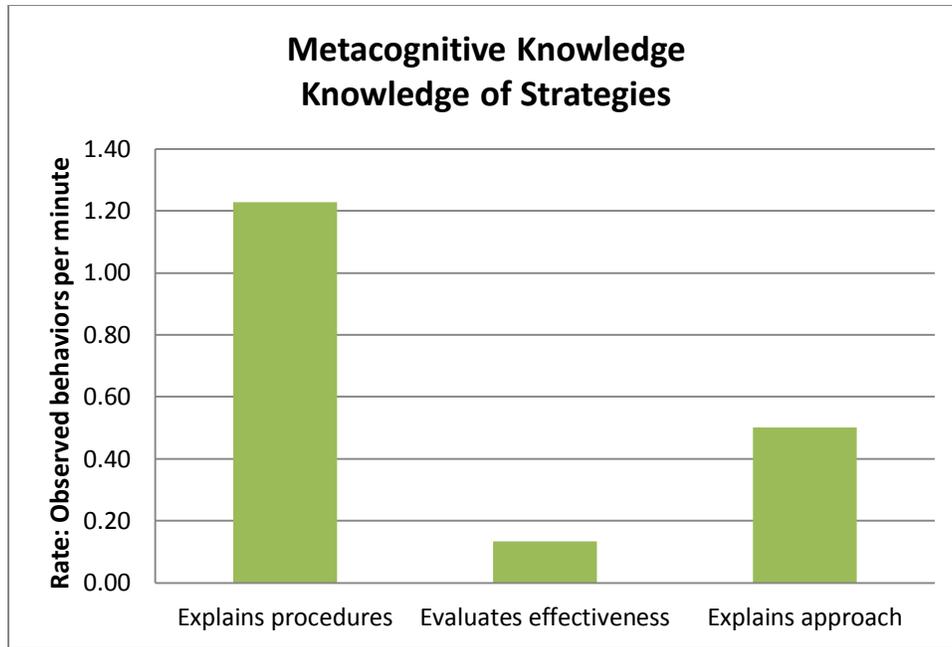


Figure 19 Activities associated with MK - Knowledge of Strategies

*Explains procedures:* Explaining the procedures used was the activity overwhelmingly associated with discussing metacognitive knowledge. When explaining procedures used, participants would explain a set of procedures to be used in order to accomplish a specific task or meet a certain goal. When explaining the procedures, participants told other participants how they should proceed with a task. For this behavior, participants used language that does not take personal responsibility for the actions (i.e. no use of ‘I’ or ‘we’). For example, when working on a homework assignment related to conservation of mass, Wilson explains to Chris how many equations are involved in this particular portion of the assignment. “There's two conservations of mass, one for each system. There's four species, four species, one, two, three, four (motions his finger at each number) times the two systems. That's eight. There's six stream composition equations.” Wilson explains that a certain number of each type of equation is required to complete this particular problem. *Explaining procedures* in the category of knowledge of

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strategies should not be confused with knowledge of tasks because this subcode's focus is on the procedures associated with completing a task and not on the task itself.

*Evaluates effectiveness:* Another way that participants displayed use of knowledge of strategies was through the discussion of the effectiveness of particular strategies. When participants discussed the effectiveness of particular strategies, they spoke in terms of how well a certain strategy obtained a certain goal. Some discussions centered on the quality to which a certain strategy would meet a goal. For example, Jenny discusses her strategy for studying for exams and says, "I study better for tests not by myself necessarily but just like alone..." In this case, Jenny shares that a more effective strategy for her to study for exams is to study alone. In other situations, participants pointed out that a strategy used by another student would not reach the intended goal. For example, when speaking with Wilson about a strategy he is using to solve one of the homework solutions, Chris states, "You are just doing it wrong." In this statement, Chris told Wilson that the approach that he was taking to solve a particular problem was incorrect.

*Explains approach:* Explaining an approach is similar to explaining a procedure in that it focuses on explaining the process used for a particular task. The major difference between *Explains approach* and *explains procedures* is that explaining an approach is directly connected to the person speaking. The language used in this behavior uses 'I' or 'we' and is used to explain how a specific individual proceeded in completing a specific task. For example, while working on a homework problem, Michael asked the question, "So, what do we have to do with the percentages?" In response to Michael's question, Benjamin's explains:

*We figure out how many kilograms of like fruit solids are coming in per hour based on the flow rate. And then that will tell us umm how much umm how much fruit solid and all the other stuff we have at the end inside*

*the jam. And then based on that it has to be equal going out so we can figure out what the flow rate needs to be to keep up with the production.*

In this way, Benjamin is explaining the procedure he used for determining the percentages provided in the problem statement to accomplish the task.

### **4.2.3 Metacognitive Regulation**

Evidence of the use of metacognitive regulation occurred at a rate of 5.25 observed behaviors per minute for all observations. For this study, I identified specific behaviors that showed evidence of the use of metacognitive regulation. In the following section, I discuss specific behaviors related to planning, monitoring, evaluation, and control strategies. Based on the data, participants engaged in certain behaviors at a higher rate than others.

#### ***4.2.3.1 Planning***

Planning refers to any behavior related to the selection of procedures necessary for performing the task, individually, or with others. In general, participants held discussions on making a plan at a higher rate than they discussed the current plan or the homework format when studying together, as shown in Figure 20.

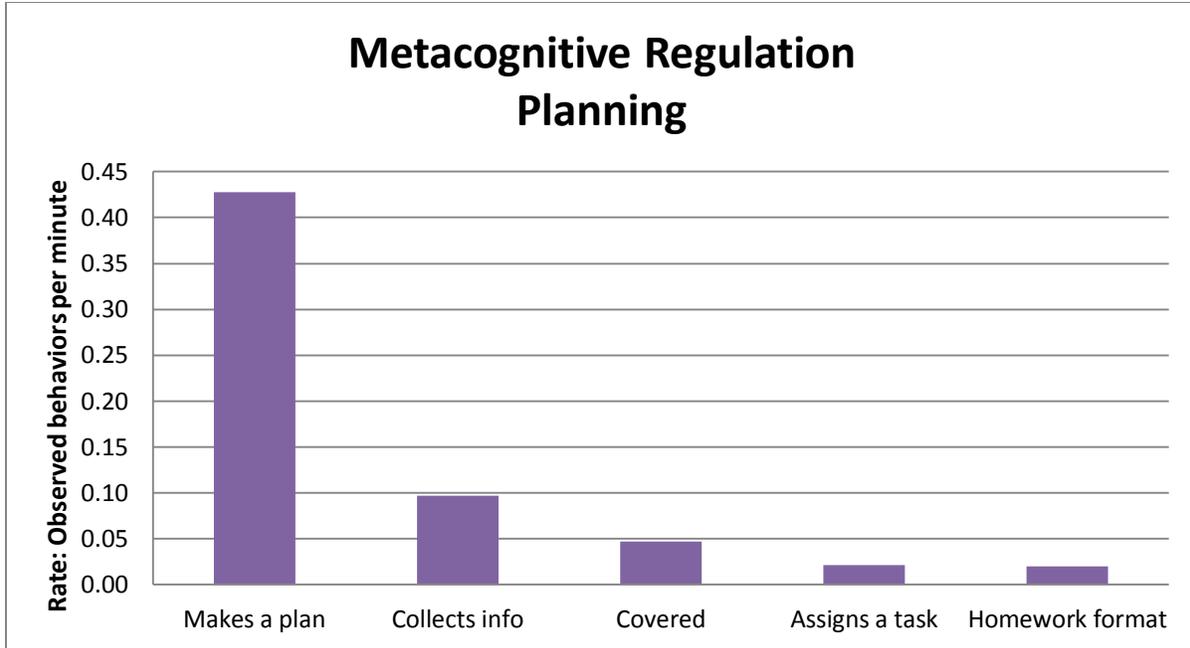


Figure 20 Activities associated with MR – Planning

*Makes a plan:* A ‘makes a plan’ action occurred when one or multiple participants talked about making a plan to accomplish a goal or complete a task. These conversations were sometimes very detailed in construction and involved multiple steps. For example, when developing a plan for completing part of a homework problem, Benjamin states, “Umm...I mean...yeah, we...we could add up all of the masses for fruit, sugar, and pectin and therefore solve for how much water is leaving. Although I guess we don’t really have to do that.” In this example, Benjamin creates a step by step plan for how to solve for how much water is leaving the system. Other times, very general plans were made in order to complete a task. For instance, when discussing a plan to solve a system of equations, William says, “Just put it in the...put it in the Maple [software program].” In this example, William provides a plan of putting all the equations in Maple in order to solve the system of equations for the homework assignment. William does not provide a step by step plan of how to input the equations into Maple but instead provides the general plan to use Maple to solve the system. ‘Makes a plan’ is different from knowledge of tasks and

strategies in that there is an action associated with making a plan, while knowledge of tasks and strategies only exhibit the use of knowledge.

*Collects info:* During the planning process, participants engaged in collection actions in order to collect information and resources needed to accomplish their goals. Information was collected in order to determine how the planning process should be approached. For instance, at the beginning of a study session, Benjamin asks “Alright, so what’s number 7?” Benjamin was seeking information to understand what the problem assigned entailed in order to start the planning process. Resources were also collected that were needed to successfully complete the task. Resources included things like books and notes (Jenny: “Ok. Let me grab my book.”; Michael: “Maybe, did he [professor] post an example yet?”) as well as fully worked solutions or answers (Chris: “We need someone else’s answers.”; William: “3.37. I’m gonna see if [student name] has it.”).

*Covered:* When students discussed what would be covered, they had discussions related to what information or concepts might be covered on an upcoming exam. These discussions typically surrounded what topics were to be covered on an exam so that a plan for studying could be developed. If participants did not believe that information would be covered on an exam, they typically did not put that information in their plan for further study. For example, on an evening when studying for an upcoming exam was the group’s primary focus, the group focused a significant amount of time creating the sheet of notes they were allowed to take in with them to the exam. During that preparation time, Michael asked “We don’t have anything with rotation, right?” in order to determine if he needed to put rotational equations on his equations sheet.

*Assigns a task:* Assigning a task typically occurred when one student started asking other students to take on certain parts of the plan that was created. In one example, Wilson and Chris

were working on a homework problem and Wilson realized that there may be two different ways to solve that particular problem. Wilson then says to Chris, “Chris, you do it your way and I’ll do it my way. We’ll see if we get the same answer.” Wilson assigns Chris the task of taking one approach while Wilson will take the alternate approach to determine if both approaches reach the same end.

*Homework format:* For the PSH course, students were required to submit all homework assignments using a specific homework format. An example of this homework format is shown in Figure 21. The homework format required students to state information that was known from the problem statement, write an explanation of what information was to be found, draw a picture or system diagram of given information, and then provide an explanation of the strategy that is used in approaching the problem. By requiring students to use this homework format, the instructors of this course were providing a structure for students to plan out their homework problems.

Early observations recorded discussions of how to follow the homework format as students adjusted to engaging in this formal planning process. For example, at the beginning of one study session, OFF reminded each other of the components of the homework format. William asks, “What do we have to write? The find. The given...” As the academic term progressed, discussions of the homework format diminished as this process became more automatic.

Problem #	Date	Name
<p>Known: The mass and weight are given for an object.                      Find: Local acceleration of gravity in <math>\text{ft}/\text{s}^2</math>                      • Mass in <math>\text{lb}_m</math> and weight in <math>\text{lb}_f</math> at a location where <math>g = 32.2 \text{ ft}/\text{s}^2</math></p>		
<p>Given:  <math>m = 10 \text{ lb}_m</math>  <math>W = 9.8 \text{ lb}_f</math></p>		
<p>Analysis:                      Strategy: <math>\rightarrow</math> Because both <math>m + W</math> are given, we should be able to use definition of <math>W</math>                      By definition <math>\rightarrow W = mg</math>                      so <math>g = \frac{W}{m} = \frac{9.8 \text{ lb}_f}{10 \text{ lb}_m} = 0.98 \frac{\text{lb}_f}{\text{lb}_m}</math> local gravitational field strength                      Need to convert units to <math>\text{ft}/\text{s}^2</math> - acceleration</p>		
<p>Approach #1</p> $g = 0.98 \frac{\text{lb}_f}{\text{lb}_m} \left[ \frac{32.2 \text{ lb}_m}{\text{slug}} \right]$ $= 31.6 \frac{\text{lb}_f}{\text{slug}} \left[ \frac{1 \text{ slug} \cdot \text{ft}/\text{s}^2}{1 \text{ lb}_f} \right]$ $= \underline{\underline{31.6 \text{ ft}/\text{s}^2}}$		<p>Approach #2</p> $g = \left( 0.98 \frac{\text{lb}_f}{\text{lb}_m} \right) \left[ \frac{32.2 \text{ lb}_m \cdot \text{ft}}{\text{lb}_f \cdot \text{s}^2} \right]$ $= \underline{\underline{31.6 \text{ ft}/\text{s}^2}}$
<p>local acceleration of gravity <math>g = 31.6 \frac{\text{ft}}{\text{s}^2}</math></p>		

Figure 21 Homework Format Example from PSH Textbook  
 (Textbook not cited as the citation would identify the research site for this study)

Sets goals and targets: In the observations, I did not observe instances where participants were setting goals for the study session or the course.

**4.2.3.2 Monitoring**

Monitoring refers to any behavior related to the on-going on-task assessment of the quality of task performance and the degree to which performance is progressing towards a desired goal. Overall, participants check strategies or answers with one another at a higher rate than commenting on memory retrieval or mental clarity when studying together, as shown in Figure 22.

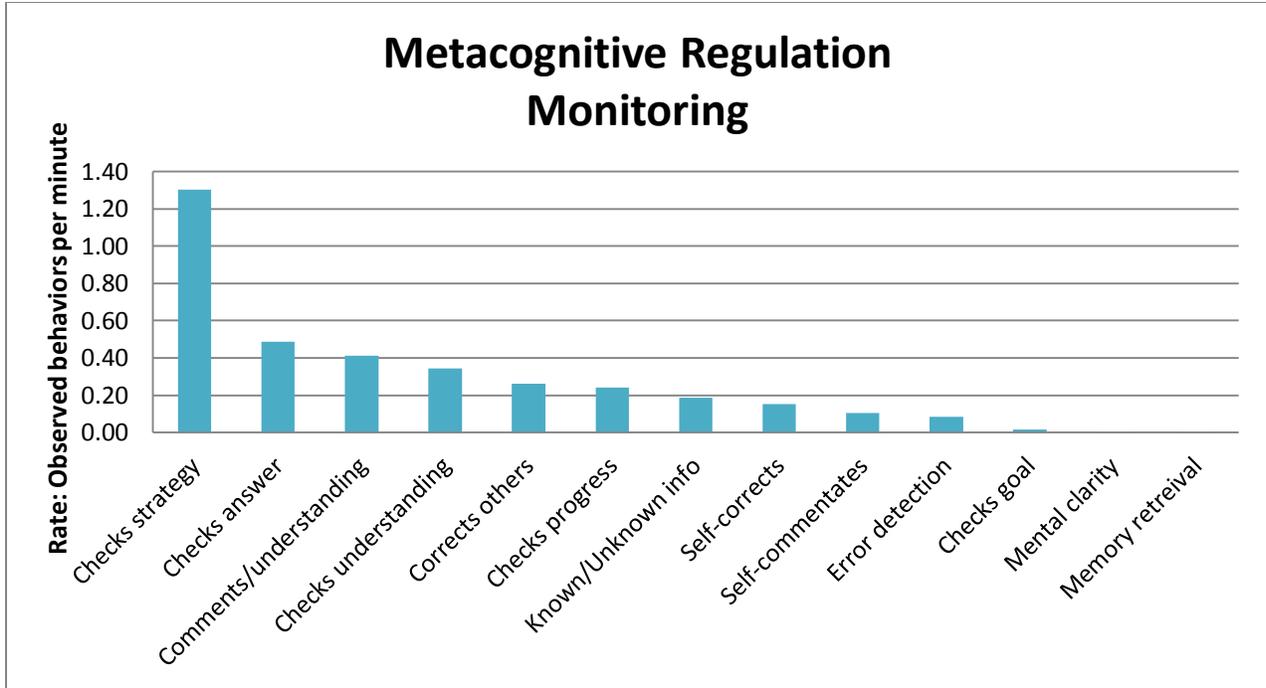


Figure 22 Activities associated with MR – Monitoring

*Checks strategy:* Many times, participants had an idea about what strategy that they should attempt to use to solve part of a problem for a homework assignment. Still, when there was doubt in their mind as to whether this was the appropriate strategy to implement, a participant might ask another study group member if that strategy was the correct one to select in order to solve the problem. While the knowledge of the strategy to use is also a part of the metacognition model, this checking process is what is called ‘checks strategy.’ For example, as Michael starts a problem, he asks Benjamin, “So, mass flow rate is, well m1 equals 1000 kilograms per hour, right?” Michael thinks that the first mass flow rate in the problem should equal 1000 kilograms per hour but is hesitant. So, he checks this idea or strategy with Benjamin before proceeding on with the problem.

*Checks answer:* Participants frequently engaged in the practice of checking a final answer or intermediate answer with another member of the group. Participants checked answers in order to determine if they had successfully completed part of the task in order to move on to another

segment. For example, when finishing a problem that they were working on, Wilson asks Chris, “Did you get 0.109%” While this activity may sound evaluatory in nature because the check occurs at the end of solving a problem, this process is indeed a monitoring activity. In the same interaction just described, Wilson finishes the statement by saying, “Did you get 0.109%? Chris, our numbers don’t match up.” The process of checking the answer leads J to make the evaluatory statement that Wilson and Chris had not successfully completed the problem because they did not achieve matching answer. The monitoring process of checking answers led Wilson to an evaluation statement, causing Wilson and Chris to return to the process of monitoring in order to find the mistake that occurred.

*Comments/understanding:* In the process of working on a homework problem or listening to the explanation of a certain concept, many times participants would reach a point where they knew that they understood or did not understand the discussion that was occurring. For example, while looking at a fully worked homework solution from another student, William states, “I don’t understand what [student]’s doing, exactly.” Later in the same observation, as William listens to an explanation from David about a particular procedure, William says, “I understand you now David.” These comments on understanding signal that either the participant can move on because understanding has been reached or the participant needs to pause and find more help because understanding has not been achieved.

*Checks understanding:* In order to reach a point where a participant can determine if they (or another study group member) understands or does not understand, sometimes a participant may check their own understanding or the understanding of another group member. For example, when Jenny begins to describe her process of coming to a solution, she says, “That’s what I have...nine thirty...nine thirty eight...divided by 2032.5. Times 100 is 46.2.” Benjamin then

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asks “Nine thirty eight divided by what?” Benjamin asks this question in order to check Jenny’s understanding of what exactly she included in her calculations. From this question, Jenny realizes that she has transposed numbers and that is the mistake in her calculation. Participants may also check their understanding in order to ask for clarification about a topic or strategy. Checks understanding should not be confused with comments on understanding (the previous subcode). When a participant commented on understanding, they would comment on whether they understood or did not understand a particular topic. When checking understanding, a participant would ask a question in order to check if they understood a particular topic.

*Corrects others:* While discussing specific strategies that had been used, participants often engaged in the process of correcting others. Participants corrected others by showing them a step in their process or strategy that was incorrect or would not successfully complete the task. For instance, when working with David on a species accounting problem, William finds that David has not properly labeled all of his variables in one of his equations. So William points out “Two...there should be another two in here.” David sees the mistake and then fixes his equation.

*Checks progress:* In order to stay on track towards the progress of completing assignments or to determine if help might be available, participants would check on their own progress or on the progress of other study group members. For example, Terry asks “Are you guys drawing your systems or what?” A few turns later, Terry asks “What’s our system?” By asking if others had drawn their systems, Terry was able to ask for help from those who had already accomplished the task. When checking progress, the participant is focused on checking and identifying at what point they personally or another member of the group are in completing the task at hand. This action is different than checking a strategy because when checking a strategy, the participant is

focused on determining if a particular strategy is the appropriate one to use to complete a particular part of a task.

*Known/Unknown info:* During the process of solving a problem, participants, at times, needed to check back to be reminded of what information was given in problem statement and what information was not provided. At times, this checking process impacted the direction taken by the study group members when solving a problem while at other times, a direction or path was confirmed through this checking process. For example, while working on a problem dealing with conservation mass, Adam asks if others in the group are assuming that the system is at steady state to which David responds, “Yeah, it said it in the problem.” By checking back to the information in the problem statement, David confirmed to Adam that the approach he was taking was the appropriate strategy due to the fact that the system in question was operating at steady state. If that information had not been given in the problem or if the study group members had not gleaned that information from the problem statement, Adam would have potentially changed the strategy that he was using to solve this problem.

*Self-corrects:* While many participants engaged in the practice of correcting other group members, they also engaged in the practice of correcting themselves when a mistake was detected. In the case of self-corrects, an individual realizes that a mistake has occurred and has an implementable strategy for correcting the mistake. For example, as Michael checks an answer with Benjamin he states, “I got fifty five. Oh shoot, that’s not right, that’s not right. Wrong number.” Michael proceeds to fix the ‘wrong number’ and achieve an answer match with Benjamin.

*Self-commentates:* Many of the practices described so far have been collaborative practices that involve one participant interacting with another participant in order to engage in monitoring

activities. The process of self-commentating is strictly an individual behavior that participants engage in to support their own monitoring activities. When a participant self-commentates, they verbalize the mental thought process they are engaged in. Self-commentating supports cognitive activity as it helps the participant keep track of the process they are engaged in in a different way than keeping these processes as internal thoughts. For example, as LIB works on a homework problem one evening, Michael and Jenny finish up a discussion about a portion of the assignment. Michael then begins to speak quietly to himself and makes the following comment:

*So dmsys over dt goes out, zero steady state (crossing out terms on paper) equals the same of mass flow minus the sum of mass flow. So the sum of mass flow in equals the sum of mass flow out. So we have 1000 kilograms per hours plus 1.3 times 1000. (inaudible).*

In this example, as Michael begins to work individually, he verbalizes the steps he is engaging in. He likely verbalizes his steps in an effort to help himself keep track of what he is doing, thus engaging in a monitoring process.

*Error detection:* Many participants engaged in correcting themselves and others during study group sessions. When correcting self or other, participants detected an error and had a viable alternative solution offer in place of the incorrect strategy attempted. While many times, viable alternative solutions were available, there were times where participants realized there was some sort of mistake in a strategy or solution but did not know exactly what the mistake was or how to correct it. In these cases, an error was detected without a clear plan for correction. For example, when Jenny attempts to check a strategy with Benjamin, she realizes that the strategies are not matching up and states, “Wait, what? I put something down wrong.” Thus, error detection is

different than a self-correction because the error detection identifies that a mistake has occurred but lacks a clear plan to correct the mistake.

*Checks goal:* In order to ensure that the study group was making progress towards the correct goal, participants would check back to the intended goal of a problem. This ensured that study groups were not straying in developing their strategy for solution. For example, as Michael discusses a strategy he wants to pursue on a homework problem, he stops, leans over to check Jenny's paper and asks, "What are we finding?" When he receives an answer, he continues developing his strategy to solve the problem. In this example, Michael took a pause from making progress on developing a strategy in order to determine if he was moving in the direction of the goal for this particular problem. Michael had to make sure that he knew what he was solving for before he could continue developing his strategy. When checking a goal, participants are focused on referring back to the original goal or set of goals developed for a specific task. This behavior is different than checking their progress because checking progress is focused on determining where a participant in the process of achieving a particular goal for a task.

*Mental clarity:* At times, participants would realize that they were having problems concentrating or focusing on the task at hand. By commenting on mental clarity, participants were monitoring their mental state. For example, Jenny stated that she was very happy that another group member was very focused that evening "Cause I'm finding it a little hard to concentrate."

*Memory retrieval:* Though not prominent in the data, some participants would share when they were attempting to recall information that had been discussed at alternate times by other group members or instructors. For example, when trying to recall information the instructor had given

on a particular homework assignment, Benjamin stated, “I’m trying to remember what he said about that.”

**4.2.3.3 Evaluation**

Evaluation refers to any behavior related to reviewing task performance and evaluating the quality of performance. Specifically, participants discussed their progress on certain tasks at a higher rate than the reasonableness of a solution or strategy when studying together, as shown in Figure 23. It should be noted that a major difference between many monitoring and evaluation strategies is whether a participant is seeking information or is making a conclusion. For monitoring behaviors, participants tend to focus on seeking some sort of information in order to determine if they are on track towards a goal. In contrast, evaluation behaviors focus more on displaying that a determination has been made that the goal has been achieved to some standard. Evaluation behaviors tend to focus more on the result of achieving the goal and whether the process for achieving the goal was appropriate, effective, and efficient.

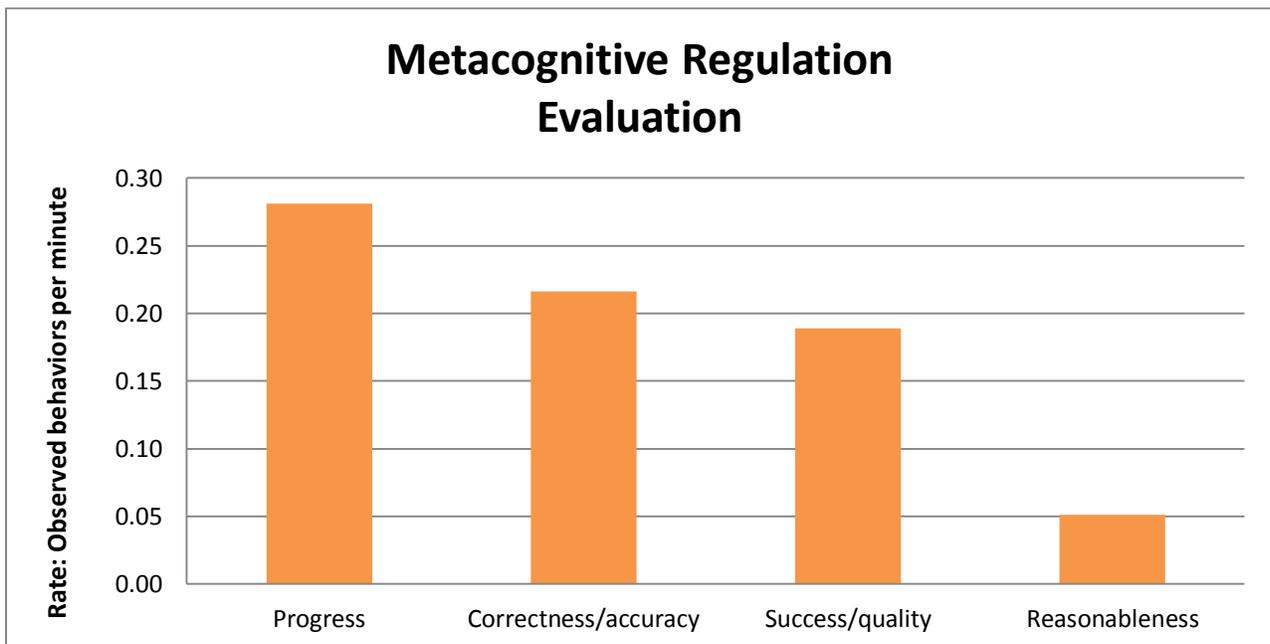


Figure 23 Activities associated with MR - Evaluation

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*Progress:* Participants spent a significant amount of discussion time evaluating their progress toward a goal or in completing a task. Progress evaluations typically focused on discussing where a participant was in reaching a goal. For example, while working on a homework problem Chris asked Wilson if he had finished writing down the homework problem. Wilson responded by saying, “I’m working on it.” In this example, Wilson evaluates by commenting on the progress that he has made in writing down the problem. It should be noted that Chris engaged in a monitoring strategy of ‘checking progress’ by asking Wilson if he had written down the problem.

While many times, comments of progress were meant to provide a marker towards how close a participant was to completion, there were instances where comments of progress were celebratory in nature. For example, as he completed a problem, David exclaimed “Yes! Adam, look. I did one!” In this case, the comment of progress from David was to show that he had completed a certain task. The evaluation strategy of commenting on progress should not be confused with the monitoring strategy of checking progress. When engaging the monitoring strategy of checking progress, a participant is inquiring about where a participant is in the process of completing a particular task. When engaging in the evaluation strategy of commenting on progress, a participant is making a definitive statement about the progress they have made on a particular task. Commenting on progress is a different activity than checking progress because commenting on progress provides an estimate of how close or far a participant or group is to reaching a goal or provides evidence that a goal has been achieved. When participants engage in checking progress, they are seeking information to help them determine where they are in the span of reaching a goal.

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*Correctness/accuracy:* Participants also engaged in evaluation behaviors by discussing the correctness or accuracy of an answer or strategy. One way in which correctness or accuracy were signified by responding positively or negatively to questions regarding a check of a strategy or answer. For example, Jenny asks the question, “So, then for the sugar solution we do 1.3 times 1000...” to which Benjamin responds, “Mhmm.” This positive response indicates that the strategy that Jenny has suggested is in fact correct. Another way in which participants discussed correctness or accuracy were in statement made about whether a strategy produces a desired or expected outcome. For example, as Chris works on a unit conversion for a problem, he states “Hmm. Kelvins doesn’t cancel out the way it’s supposed to.” In this statement, there is an expected outcome that the unit, Kelvin, will cancel out in a certain way. The strategy that Chris used does not produce this outcome and is therefore deemed to be incorrect.

*Success/quality:* Another way in which participants engage in evaluator behavior is through discussions of success or quality. These comments are not directly tied to discussions of whether an answer or strategy is correct or accurate. Instead, they infer that a certain strategy or answer is successful at reaching some goal, though the intended goal is typically not correctness or accuracy. For example, after finding an answer to a homework problem, Wilson looks at Chris’s paper at states “Our numbers aren’t matching up.” In this case, there is an evaluation of not reaching success but this statement is not measured against a correct standard. Instead of the goal being to reach the correct answer, the goal was to reach matching answers. Jenny makes a similar statement during a different observation when she says to her group, “Ok, I got a much different number than you.”

*Reasonableness:* Evaluation also occurred when the participants discussed the reasonableness of a certain answer achieved. Statements of reasonableness typically showed that answers achieved

were out of the range of what the participant expected. For example, Michael states “That’s really, really, really, really fast” and then “That’s not realistic.” At another point in the same observation, as Becca discusses the units for a particular answer, Becca states “Kilowatts. That’s reasonable.” Comments of reasonableness predominantly showed no explicit sign of justification for why an answer was or was not reasonable.

There were examples of times when participants wanted to make evaluations of reasonableness of answers but discussed how they did not have all the information necessary to make a reasonableness judgement. For example, when working on a homework problem involving a jet engine, Becca attempted to make reasonableness judgments but was aware of her lack of knowledge that inhibited her ability to make a reasonableness judgment. The conversation with Becca and Benjamin was as follows:

*Becca: So, when you do this timsing by a thousand...cause I think you have to...like cause your units do not cancel out unless you times by a thousand in there. Somewhere. And when you do that, that's when you get a huge velocity.*

*Benjamin: Ok. But it is a jet engine so...*

*Becca: Is that like a reasonable...*

*Benjamin: That's a very reasonable velocity.*

*Becca: Oh, it is?*

*Benjamin: Yeah.*

*Becca: So, I'm not crazy.*

*Benjamin: No.*

*Becca: See, if I had just known that could be a reasonable velocity...*

*Jenny: Well, also you could have saved it and asked [professor]. If for anything else, that would take two seconds.*

*Becca: Yeah, except that it, you use that for every other calculation. So...*

*Jenny: It's really easy to do it and like change the one number.*

*Benjamin: Ok, so then...*

*Becca: So that is a reasonable number for a jet engine?*

*Benjamin: Yeah.*

*Becca: I don't know things like this. Make sure you get the same number as me.*

In this example, Becca discusses how she had difficulty determining if the answer she calculated for the homework problem was reasonable because she did not know enough about jet engines. Benjamin, who had more knowledge of jet engines speeds, told Becca that her answer was, in fact, reasonable. Becca’s lack of knowledge about jet engines, and not her lack of metacognitive skill in evaluation, led to her inability to make a reasonableness judgment in this case. If Becca had been given information about the normal speeds of jet engines, she may have been able to engage in a reasonableness behavior that would have helped her determine if she had reached the goal of adequately solving the homework problem.

**4.2.3.4 Control**

Control refers to any behavior related to a change in the way a task was conducted as a result of cognitive monitoring. In general, participants showed evidence of changing strategies or asked for help from others at a higher rate than referring to representations or repeating strategies when studying together, as shown in Figure 24.

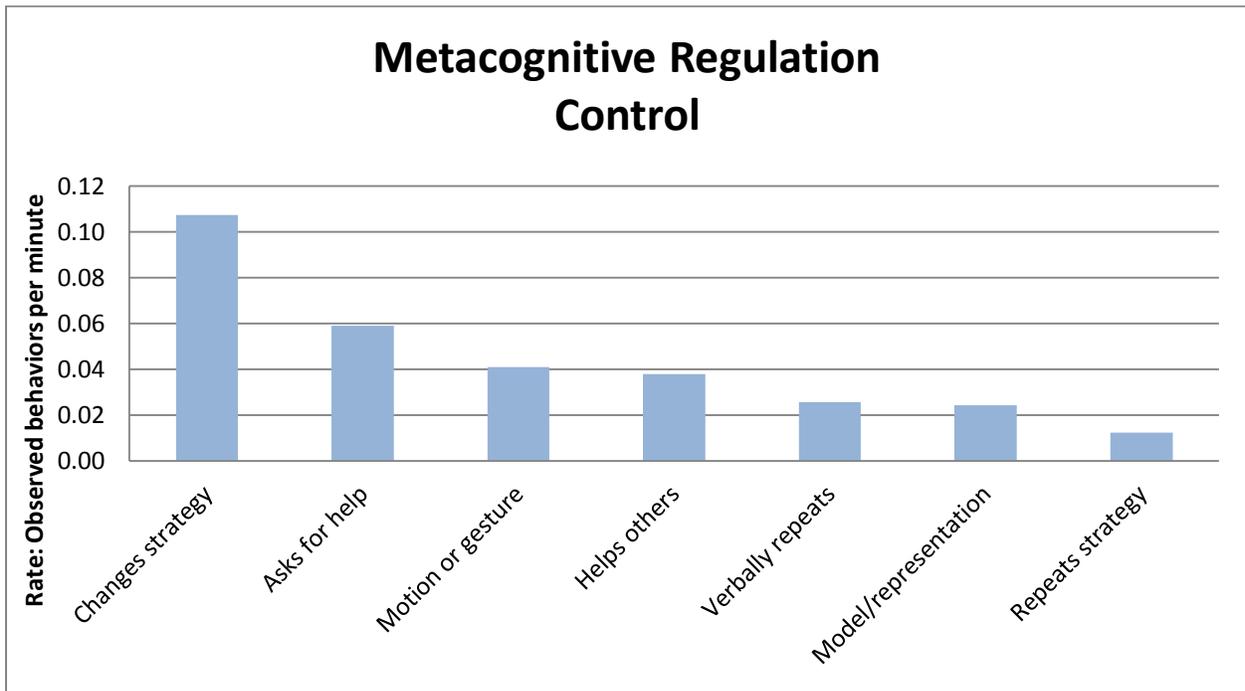


Figure 24 Activities associated with MR - Control

*Changes strategy:* Participants engaged in a control strategy when they showed evidence of changing a strategy due to some sort of monitoring activity. A change in strategy was most notably shown when a participant would erase something (an equation, variable or diagram) from their paper and write something new. This action was more of a non-verbal action though it could sometimes be connected to a verbal response by a participant.

*Asks for help:* Another control strategy occurred when one participant would ask for the help of another participant. A request for help typically occurred when a participant determined that there was an error in their current strategy or found that the answer they achieved did not match the answer of another in the group. For example, when Jenny asks Benjamin what he got for an answer and finds that their answers do match, she says “Ok, so I need to see what you changed because I have negative seven thousand two hundred and fifty point nine. (Takes Benjamin’s paper) Ok.”

*Motion or gesture:* A non-verbal motion or gesture can signify that a participant is engaging in a control strategy. For a motion to be considered a control strategy, it should be used in order to support the cognitive activity of a participant. For example, when Michael is working through a problem involving canceling out certain factors and taking into account geometry, the following happens: “The x-components cancel out (moving hands opposite from one another) in each direction so they have both y’s going down. So you just do what the fifteen times... (uses hands like he is measuring geometry).” In both cases, A uses his hands to represent a motion that aids his understanding of what he talking about.

*Helps others:* While many times, participants look for help from others, at other times participants also offer help to others. This offer of help shows a need for a change in strategy just as a request for help shows a need for change. For example, Michael offers helps to Jenny by

saying “Let me see this (takes Jenny’s paper).” Michael takes Jenny’s paper in order to find the mistake that Jenny believes she has in her strategy.

*Verbally repeats:* In order to check that a word, phrase or strategy was understood, some participants would verbally repeat themselves in order to check comprehension. This process was done both individually and collaboratively, meaning sometimes a participant would repeat a phrase to themselves to check their own comprehension while other times a participant may repeat a phrase to check the understanding of others in the group. For example, Jenny was checking an answer she obtained with Benjamin and Michael but the answers between the three were not matching. Michael found that Jenny was transposing a number which was causing an incorrect calculation. In order to make sure that she was correct, Jenny repeated the series of numbers outloud, “Two three zero two. Goodness gracious team.” Verbally repeating a strategy is different than checking a strategy in that the purpose of verbally repeating a strategy is to determine if a specific word, phrase, or strategy was understood, either by the individual themselves or by someone else in the group. Checking a strategy involves determining if a particular strategy in question is the correct strategy to use in a specific situation.

*Model/representation:* Participants also created and used models and representations in order to support their cognitive activity while working towards completing tasks. The representations included graphical pictures of systems or a series of equations located to a common space. The whiteboard was a popular place for LIB to create representations that were used by the group. Different group members would take turns drawing pictures or writing equations on the board that were used to explain different parts of the task. The pictures and equations for typically left on the whiteboard for a period of time so that they could be used for reference later in the study group session.

*Repeats strategy:* At times, participants felt the need to repeat a strategy (either verbally, on paper, or on the calculator or computer) in order to determine if the task had been successfully completed or if understanding had been reached. For example, when Jenny and Benjamin do not agree on the final answer to a problem, Jenny says “Let me redo my calculations really fast (punches numbers in calculator).” Jenny repeats her strategy in order to determine if she had made a mistake in her calculations.

*Suggests and uses strategies in order to solve the task more effectively:* The behavior of suggesting strategies to solve a problem more effectively was not observed as a part of this study.

*Applies a previously learnt strategy to a new situation:* The behavior of applying a previously learnt strategy was not observed in this study.

The behaviors of participants described in the previous section represent the metacognitive engagement of the undergraduate engineering participants over the course of an academic term. With these behaviors identified, I next looked at how groups engaged in metacognition during different observations and how different contextual factors potentially impacted this engagement.

#### **4.2.4 Metacognition at the Individual Observation Level**

I also looked at metacognitive behaviors on an individual observation basis rather than the holistic representation presented earlier in Figure 16. Table 17 displays the metacognitive behaviors observed during each observation of the study. These results are displayed as a rate of engagement in the observed behavior per minute (as described in Section 3.7). Cells highlighted in green show rate values that lie one standard deviation or more above the average rate for that particular behavior for all observations. Cells highlighted in orange show rate values that lie one

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standard deviation or more below the average rate for that particular behavior for all observations.

Observation #	Knowledge of Person	Knowledge of Task	Knowledge of Strategy	Planning	Monitoring	Evaluating	Control
2	<b>0.26</b>	0.42	1.57	1.19	<b>4.21</b>	0.98	0.37
3	0.07	0.31	1.30	0.33	2.87	0.48	0.15
4	0.10	0.25	1.09	0.36	3.62	<b>1.36</b>	<b>0.50</b>
6	0.12	0.25	1.81	1.32	2.67	<b>0.33</b>	<b>0.49</b>
7	<b>0.01</b>	<b>0.09</b>	<b>2.39</b>	0.19	4.00	0.47	<b>0.46</b>
11	<b>0.25</b>	<b>0.52</b>	1.30	<b>1.89</b>	<b>1.53</b>	0.45	0.20
13	<b>0.03</b>	0.19	1.42	0.27	4.12	0.48	0.22
15	0.12	<b>0.51</b>	1.59	0.54	2.51	<b>1.41</b>	0.18
16	0.12	0.44	<b>0.82</b>	0.42	3.63	0.95	<b>0.14</b>
(> 1 SD from Mean)							
(< 1 SD from Mean)							

From Table 17, the data from my study shows that study groups engage in metacognition differently in different observations. In fact, we see distinct differences in metacognitive engagement in all the behavioral categories. For instance, Observations 2 and 11 show a much higher display of knowledge of person behaviors while Observations 7 and 13 show a much lower display of knowledge person behaviors. Observations 4, 6, and 7 show a much higher engagement in control strategies while Observation 16 shows a much lower engagement in control strategies. While looking at each observation individually offers some insight on the differences in metacognitive engagement, it is critical that we look at the context of each of these observations to begin to understand some of the patterns that we see in metacognitive engagement. The next section provides descriptions of different contextual differences in the study group sessions while providing comparisons of observed metacognitive behavior.

### **4.3 Patterns in Regulatory Behavior in Light of Contextual Factors**

In the following section, I discuss several contextual factors that potentially had an impact on how different study groups engaged in metacognitive behaviors. Specifically, I discuss the potential impact of learning environment, learning resources, study group schedule, purpose of meeting, and impact of workload on metacognitive engagement. It is important to note that the following discussion is only intended to show patterns in metacognitive engagement when compared to patterns in observed behaviors in the observations. This discussion is not intended to suggest that there is a causal link between metacognitive engagement and any of the observed factors discussed. While statistical analyses were conducted for the observational data for each contextual factor, the statistical analyses was not intended to imply that there are direct correlations between the contextual factors and observed behaviors. In fact, due to the small sample size for this study, the statistical analyses for this study provide little evidence that there is any statistical significance among the data set. Instead, these contextual factors are highlighted in the discussion in order to provide evidence for the need for future research in each of these areas to better understand contextual factor.

#### **4.3.1 Differences Among Study Groups**

Before looking at potential differences in metacognitive engagement among different contextual factors, it is first important to determine if there was a difference in how individual study groups engaged in metacognitive behaviors. Figure 25 shows a comparison of metacognitive engagement for each study group involved in this study. There were no statistically significant differences for any of the metacognitive behaviors among different study groups. However, the following potentially practical differences should be noted:

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- LIB engaged in a higher rate of monitoring behaviors than both ON and OFF (3.5 vs 3.3 behaviors per minute (bpm))
- ON engaged in a higher rate of evaluation behaviors than both LIB and OFF (1.1 vs. 0.6 bpm)
- LIB engaged in a higher rate of control behaviors than both ON and OFF (0.4 vs. 0.2 bpm)
- ON engaged in a higher rate of discussion of knowledge of task than both LIB and OFF (0.5 bpm vs. 0.2 and 0.3 bpm, respectively)
- LIB and OFF engaged in a higher rate of discussion of knowledge of strategy than ON (1.6 and 1.4 bpm, respectively, vs. 1.1 bpm)

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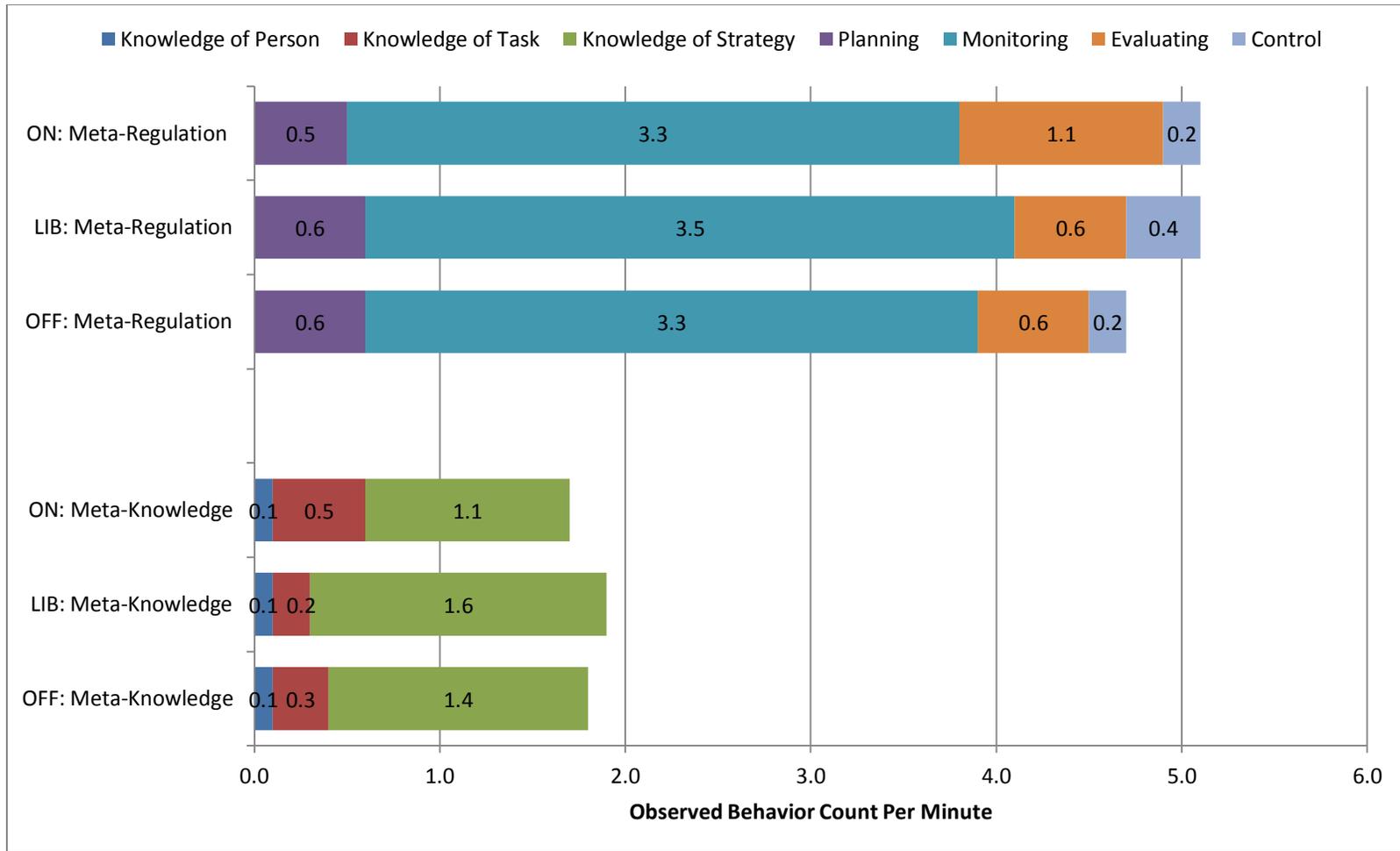


Figure 25 Metacognitive Engagement: Different Study Groups

### 4.3.2 Learning Environment

Study session location for each of the study groups was varied. Based on a comparison of metacognitive engagement in the different study location, the selection of learning environment may be related to different patterns in metacognitive engagement in the study groups. In this section, I will discuss the two major differences between the learning environments chosen by the study group. These differences include whether the study locations were set apart locations or common area locations. I define a set apart location as a learning environment that is set up in a way that distractions are minimized, either from non-study group members or other distracting influences. A learning environment can be set apart by a physical barrier, such a door or partition, as well as being physically located away from potential distractions, such as human traffic. I define a common area location as a learning environment that is situated near a location where traffic from non-study group members is common or where other distracting influences are located in close proximity. A common area location typically does not have a physical barrier or partition to separate the study group from distractions.

*Set Apart Location:* LIB conducted all study sessions in a reserved study room in the campus library. The library on campus offered four study rooms that could be reserved for several hour blocks of time. For each study group meeting, Jenny would reserve a study room and send a notice to the group as to the time and location of the meeting. Two of the available study rooms were small rooms that would accommodate up to four students at a time, as shown in Figure 26. These study rooms had a round table with four rolling chairs. Another study room was a medium sized study room, as shown in Figure 27. This study room had a rectangular table with six rolling chairs. The final study room was equipped as a large study room, as shown in Figure 28. This study room had a large rectangular table that could accommodate up to ten students.

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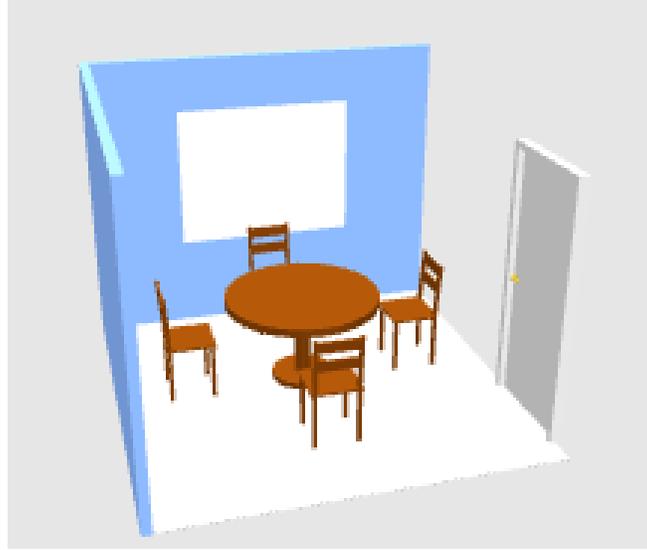


Figure 26 Library: Small Study Room

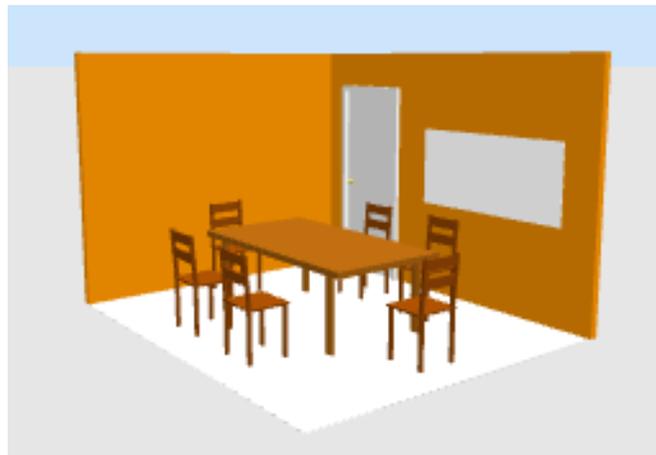


Figure 27 Library: Medium Study Room

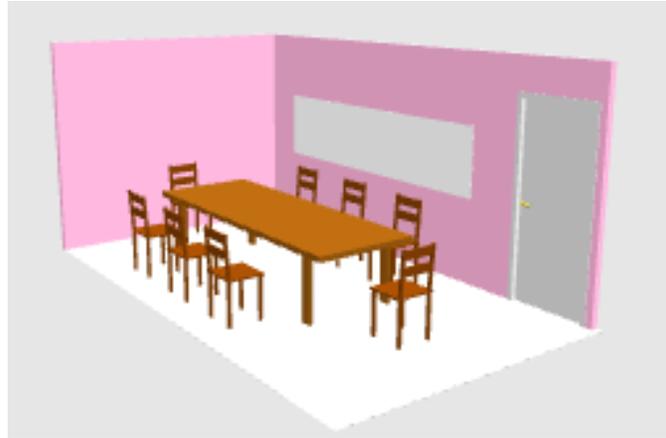


Figure 28 Library: Large Study Room

Each room was also equipped with at least one white board on the back wall. The small study rooms were equipped with one white board while the medium and large study rooms each had two whiteboards. Finally, each room was closed off from the rest of the library. While there were windows that looked into the interior of the library, there was a physical door to each study room that closed so as to reduce noise from the common areas in the library. This door also served as a barrier between the study group and other students in the library. While there were occasions where non-study group members would stop by the study room to hold a conversation or ask a question, these interruptions were minimal when compared to the distractions that OFF and ON encountered in their learning environments.

*Common Area Location:* OFF conducted all study sessions in the dining room of the off-campus house where they lived, as shown in Figure 29. This dining room was located on the main floor of the house and was adjacent to the house's kitchen. Studying occurred at the dining room table which was a large rectangular table that could easily accommodate 8-10 students studying. There were three door entrances to the study room as well as a screen door that faced to the front of the house. Two of the doors were adjacent to the common meeting room for the house. The third door was adjacent to the house's kitchen. During study sessions, there was frequent traffic in the

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common room and in the house's kitchen. House residents would make their way to the kitchen for an evening snack or bottle of water. As they made their way to and from the kitchen or common room, it would not be uncommon for someone to stop and ask the study group what they were working on or to have another conversation. Interruptions by house members were common and frequent.

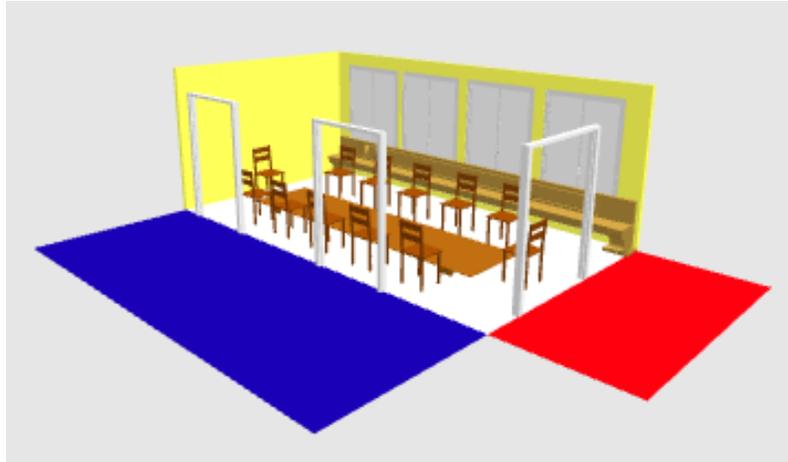


Figure 29 Fraternity House: Dining Room

ON held their study sessions in two different locations in their dorm. If available, study sessions were conducted in the study lounge located on the floor of their dorm, as shown in Figure 30. This was a large room containing three tables. One table was a large rectangular table with seating for eight. A second table was a small rectangular table with seating for four. The final table was a small circular table with seating four. The room also contained two whiteboards at either end of the room. This study room was located at the end of the hallway. While there was a door adjacent to the hallway, this door remained open during the study session. Interruptions from students living in the hallway were frequent as they checked to see who was working on what assignment and who wanted to go to the cafeteria for dinner. When this study room was not available, studying occurred in the lobby of the dorm floor, as shown in Figure 31. This lobby area connected to adjoining hallways on the floor of the dorm. The lobby was a large open room

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containing two round study tables that each seated four people. The lobby also contained a U-shaped set of couches in front of a television. There was a printer for use by residents of the hall. Finally, there was a ping pong table at the far end of the room. When study sessions occurred in the lobby, interruptions were very frequent. At any time, there may be two separate groups studying at the tables, a group of students conversing at the U-shaped couch, students playing ping pong, students traveling back and forth between the printer and their room, and students either entering or leaving the floor through the lobby.

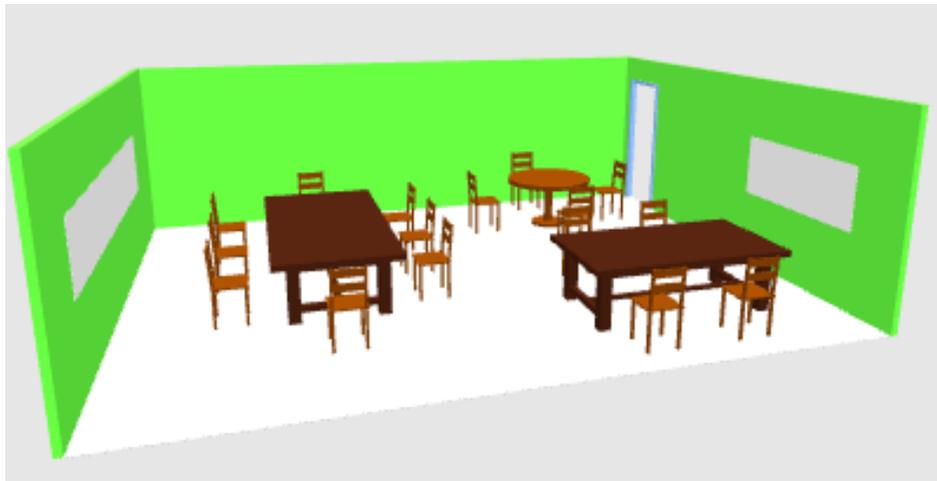


Figure 30 Dorm: Study Room



Figure 31 Dorm: Lobby

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When comparing the metacognitive data between observations in different locations and different levels of on-task time, it is evident that there are differences in the amount of engagement in certain metacognitive categories. Figure 32 displays a comparison of metacognitive engagement in different learning environments. The data shows the following differences:

- A higher rate of monitoring activity in the set apart space when compared to the common space (3.5 vs 3.3 behaviors per minute (bpm))
- A lower rate of evaluation activity in the set apart space when compared to the common space (0.6 vs 0.8 bpm)
- A higher rate of control activity in the set apart space when compared to the common space (0.4 vs 0.2 bpm); this difference is statistically significant ( $p < .10$ ;  $g = 1.15$ )
- A lower rate of discussion of knowledge of tasks in the set apart space when compared to the common space (0.2 vs 0.4 bpm)
- A higher rate of discussion of knowledge of strategies in the set apart space when compared to the common space (1.6 vs 1.3 bpm)

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Figure 32 Metacognitive Engagement: Different Learning Environment (Multiple Teams)

### 4.3.3 Learning Resources

Each study group used an assortment of learning resources as aids in order to complete the homework assignments due for the PSH course. In this section, I'll describe each of one of those main resources and how the participants used them in details. While many resources were used commonly across all study groups, one resource stood out in that it was only used by one study group: the fully worked homework solution. After describing these resources, I discuss the potential impact that using fully worked homework solution has on metacognitive engagement while working on homework assignments.

*Textbook:* As part of the PSH course, students were required to purchase a textbook. This textbook was specifically written for use in this course and was developed by previous and current instructors of the course. The textbook was sold as a loose-leaf note packet in the university bookstore and was available to the students at a small cost. The textbook was organized around the main conservation and accounting principles that were the focus of the course. Each chapter provided discussions of each concept, examples of worked solutions, and practice problems. Appendices for the textbook included a discussion of the problem solving heuristic for the course, a section on how to properly use dimensions and units and supplementary tables and equations.

A section of reading from the textbook was assigned before every class period. This reading was meant to introduce students to the topics that would be covered in that day's class period. At the end of each class period, a set of homework problems was assigned. The homework assigned corresponded to practice problems found at the end of chapter in the textbook.

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In study sessions, study groups tended to use the textbook in order to gain access to the problems assigned for homework. Students would find the problems statements for the homework problems assigned at the end of the corresponding textbook chapter. These problem statements were used to complete the homework format required for the assignment. After the homework format was completed, the textbook was rarely used. If other resources failed to help students solve the homework problems, they would occasionally return to the textbook in order to look for more example problems that might be useful. Otherwise, textbooks were rarely used beyond the planning stages of homework assignments.

*Notes:* Classes for the PSH course were typically lecture based. In order to keep track of information presented in each lecture, different instructors provided students with differing levels of notes during each class period. For some instructors, notes for students included a set of incomplete powerpoint slides that students could use to follow along with the lecture and fill in blank spots when appropriate. Instructors would supplement these powerpoints with extra handouts where students would either follow along as the instructor solved a problem or where students would attempt to solve a problem and the instructor would provide feedback on that attempt. Other instructors provided a full package of notes and problems to be worked during the class period to the students at the beginning of each class. Though instructors took different approaches to the development and distribution of notes during class periods, the structure and function of class notes was similar across the four instructors observed. Course notes would provide conceptual descriptions of the phenomena under study. Instructors would then work a series of example problems to demonstrate the concepts in practice.

Study groups used course notes as a main resource for working on homework assignments. Notes were predominantly used because they offered worked solutions that students

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could use as examples when working on homework assignments. Students would determine what was required in a particular homework problem and then find a comparable worked solution in order to use as a reference when solving. Students would also use notes to reference equations that should be considered for use in homework solutions. All three study groups used the course notes to work on homework assignments.

*Common representations:* Participants and study groups also used common representations as resources for accomplishing tasks. The common representations were typically created by group members. LIB used the whiteboard available in the study rooms as places to locate common representations. One participant would draw a picture or write equations on the whiteboard in order to explain a strategy or concept. These representations would then be left on the whiteboard for a period of time for the group to use or refer back to at different times during the study session. OFF and ON typically used their own homework assignments or pieces of paper for creating common representations. Papers would either be passed around the table or participants would huddle around the paper in order to hold a discussion.

*Fully worked homework solutions:* A resource that was used by only one study group for working on homework was the use of fully worked homework problems by previous students. This resource was available specifically to OFF. These fully worked and graded homework solutions were collected from house members after they completed a specific course. These solutions were available to students currently taking a course as a study aid. While many fully-worked solutions were available for a single problem, these solutions were typically chosen for use based on the grade received for the assignment. Thus, solutions receiving higher grades were used more by study group participants than solutions with lower grades. Part of the preparation process for a study session was collecting solutions from different students. Fully worked

solutions were used in different ways by study group members. At times, fully worked solutions were used to check answers. When a problem was completed, the answer achieved by the students was then checked against the answer developed in the solution. At other times, fully worked solutions were used to prompt which steps should be used to solve a particular portion of the homework problem. Fully worked solutions were a resource used specifically by OFF and were not used by either ON or LIB to work on homework assignments. Fully worked old exams were available to all study groups through the campus's learning support center. LIB did use the resource of fully worked old exams in order to study for exams.

The major difference in resource use among the study groups was in the use or non-use of fully worked solutions for studying. Therefore, I focused on comparing observations where fully-worked solutions were used against observations where fully-worked solutions were not used. As before, the analysis for this condition was limited to observations focused on working on a homework assignment. The decision to exclude Observation 13 was made because the focus for studying for an exam can be very different than the focus for working on a homework assignment. Therefore, observation 13 was excluded from this analysis because it did not represent a time when participants were working on a homework assignment.

When comparing observations where fully worked solutions were used against observations where fully worked solutions were not used, we can see differences in metacognitive behaviors, as shown in Figure 33. The data shows the following potentially practical differences:

- A lower rate of planning activity when not using fully worked solutions when compared to the use of fully worked solutions (0.4 vs 0.6 bpm)
- A higher rate of monitoring activity when not using fully worked solutions when compared with the use of fully worked solutions (3.6 vs 3.3 bpm)
- A higher rate of evaluation activity when not using fully worked solutions when compared with the use of fully worked solutions (0.8 vs 0.6 bpm)

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- A higher rate of control activity when not using fully worked solutions when compared with the use of fully worked solutions (0.3 vs 0.2 bpm)
- A higher rate of discussion of knowledge of strategy when not using fully worked solutions when compared with the use of fully worked solutions (1.5 vs 1.4 bpm)

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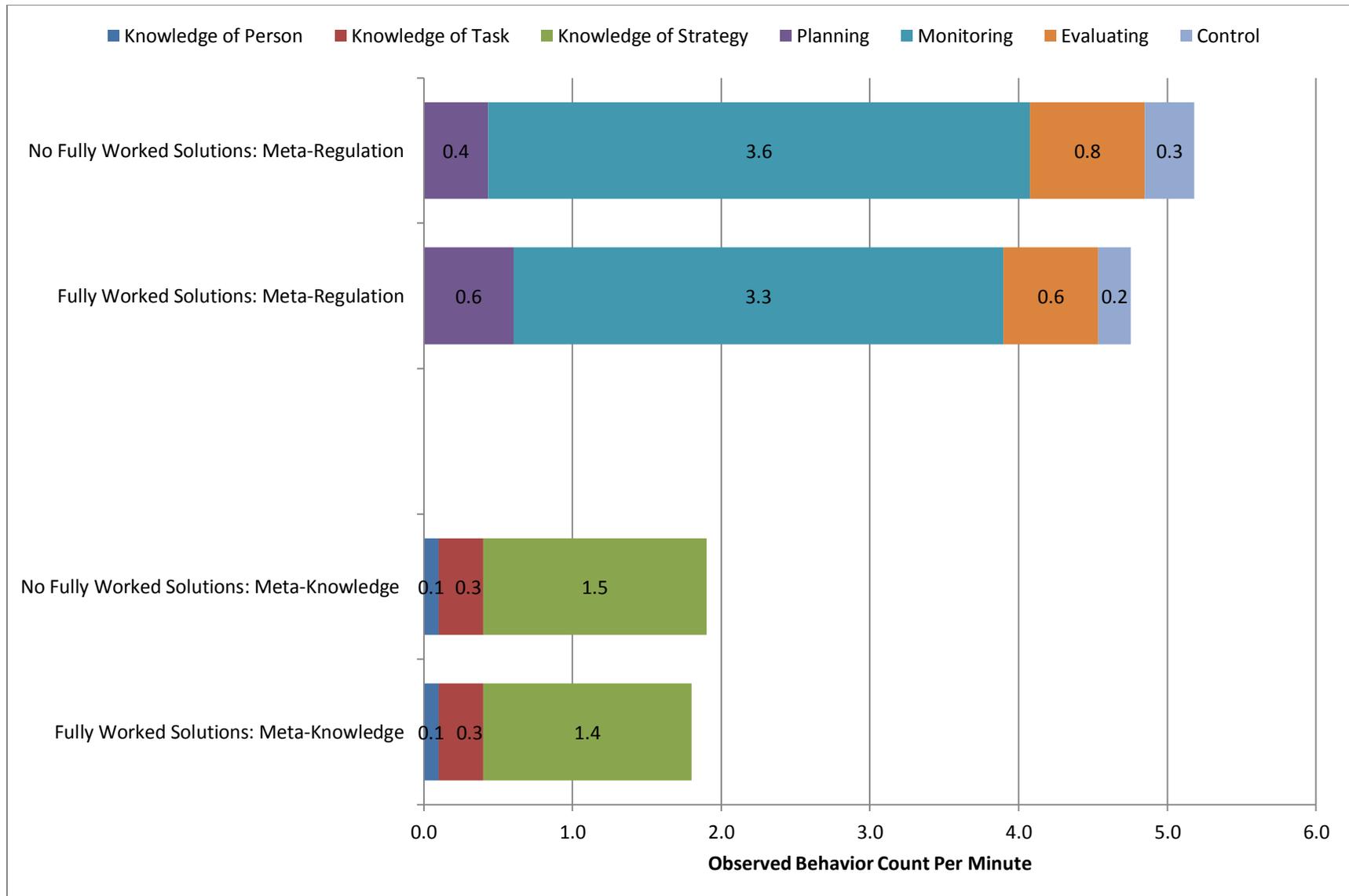


Figure 33 Observed Metacognitive Behaviors Compared to Resource Use

#### 4.3.4 Study Session Schedule

Study sessions were scheduled by group members. Different groups took different approaches to scheduling study sessions. Based on a comparison of metacognitive engagement with different study group schedules, the data from study shows that the study group schedule may be related to different patterns in metacognitive engagement in the study groups. In order to illustrate contextual differences, I discuss how metacognitive engagement differed between two observations where LIB changed their typical study group schedule.

*Two Days Before vs. One Day Before:* As stated earlier, homework assignments for the PSH course were due on Tuesday and Friday of every week unless that day coincided with a scheduled exam for the course. The study groups took different strategies for working on homework assignments in relation to when the assignment was due. LIB arranged their study group schedule so as to start working on a homework assignment two days before it was due, while OFF and ON typically worked on the homework assignment the night before it was due. The study group communicated that they did not like to wait until the last minute to work on a homework assignment. On a typical evening with LIB, the study group would work one problem at a time until either the problem was completed or the study group determined that they could not solve to problem without further assistance. While working, each member of LIB would work on their own paper but the nature of the work was very collaborative. Much of the discussion time was spent checking and explaining different strategies that could be used to solve parts of the homework problems. The study group did not move on to a new problem until everyone in the group had completed the problem. If the study group decided they could not solve a particular problem without help, they decided to attend the office hours of their professor in order to ask questions. After attending office hours and asking for help, the study group would

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then reconvene to finish the problems, either directly after office hours or the evening before the assignment was due. On one occasion (Observation 16), LIB waited until the night before an assignment was due to start working on the problems. The beginning of the observation followed the standard format of working on one problem at a time in a collaborative nature. As the evening progressed, the study group began to engage in a different strategy. The study group formed into smaller groups and took the 'divide and conquer' method where the smaller groups worked on different problems so that the larger group had all the problems solved and the solutions could be shared amongst each other in order to have a complete assignment turned in. It was observed that the intentions for completing the assignments shifted from understanding the processes needed to solve a problem to completing an assignment for credit. While this behavior was observed for LIB, it was out of character for the rest of the observations spent with this study group. Divide and conquer was not an observed behavior for the ON study group, though it was an observed behavior on a few occasions with the OFF study group.

I looked for patterns in metacognitive behavior with different study group schedules by comparing observations when studying occurred two nights before a due date and observations when studying occurred one night before a due date. It should be noted that the analysis for this condition was limited to observations focused on working on a homework assignment. The decision to exclude Observation 13 was made because the schedule and focus for studying for an exam can be very different than the schedule and focus for working on a homework assignment. In an attempt to compare similar situations, the observation focused on study for an exam (Observation 13) was excluded from this statistical analysis. Figure 34 shows a comparison of the metacognitive behaviors observed when studying two nights before a due date when compared to studying one night before a due date. The data shows the following differences:

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- A higher rate of evaluation activity when studying two nights before when compared to studying one night before (0.8 vs 0.7 bpm)
- A higher rate of control activity when studying two nights before when compared to studying (0.5 vs 0.2 bpm); this difference is statistically significant ( $p < 0.1$ ;  $g = 4.21$ )
- A lower rate of discussion of knowledge of tasks when studying two nights before when compared to studying one night before (0.2 vs 0.3 bpm)
- A higher rate of discussion of knowledge of strategy when studying two nights before when compared to studying one night before (1.7 vs 1.3 bpm)

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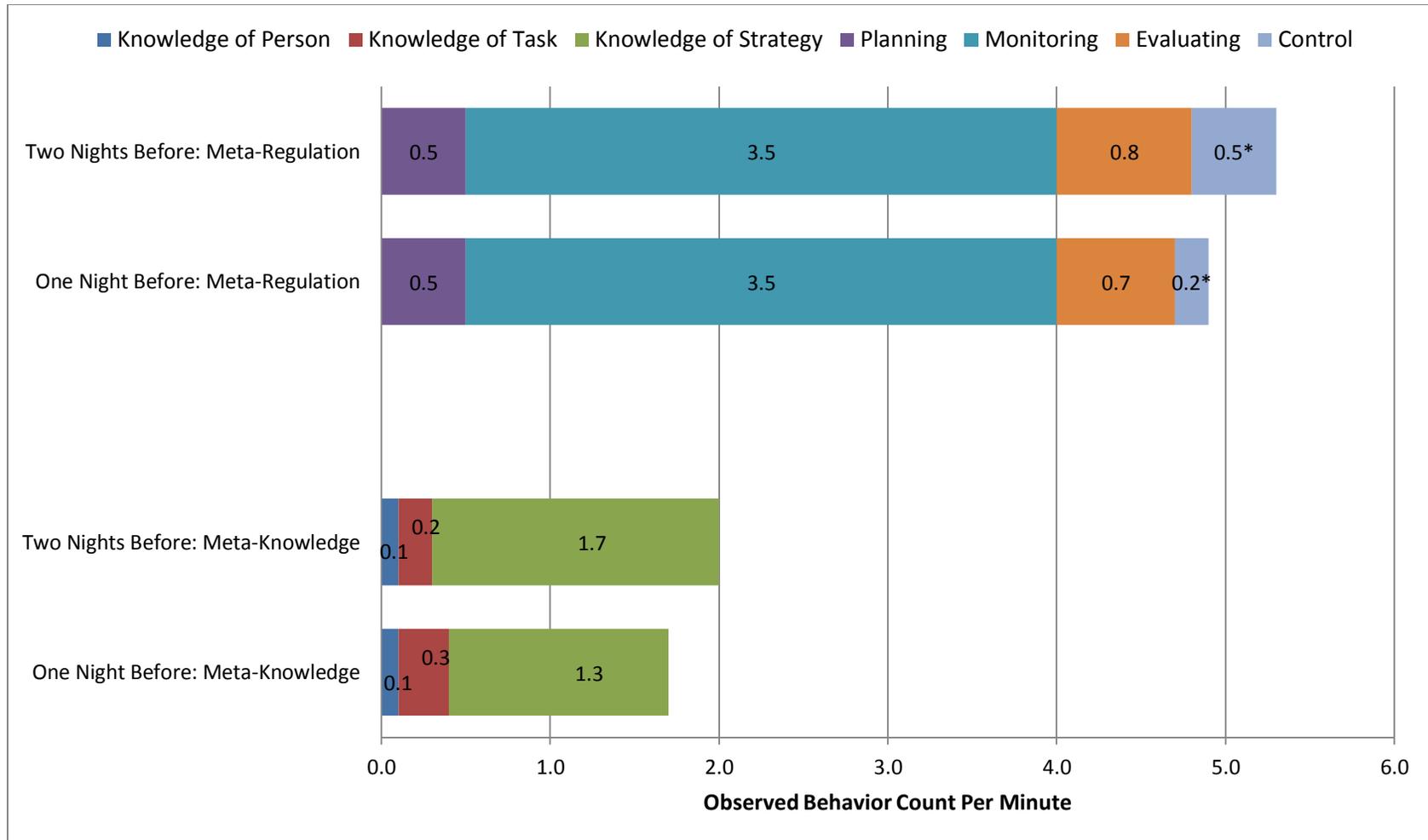


Figure 34 Metacognitive Engagement: Difference in Study Session Schedule (LIB)

#### 4.3.5 Purpose of Meeting (Homework vs. Study for Exam)

Much of the activity observed involved working on homework assignments for the problem solving course. In fact, all observations except for observation 13 involved study groups working on homework assignments. For LIB, observation 13 focused on preparing for the second exam in the course covered conservation of linear and angular momentum principles. In this section, I discuss the difference in approach that LIB took when studying for exams when compared to working on homework assignments. Then I discuss potential impacts that the purpose of a study session have on metacognitive engagement.

For LIB, a typical homework study session involved working each homework problem until an answer was achieved or the study group determined that they needed help from the professor. LIB would use worked examples from class, class notes, and (in some cases) the textbook as resources for completing the homework assignment. While each participant would solve the homework problems on their own paper, working on homework was a very collaborative effort. Participants would discuss the strategy they should use for achieving an answer to the assigned homework. Work would continue until a consensus was reached as to what the final answer should be. Only when all group members obtained a final answer did the study group move on to a new problem.

LIB's approach to studying for an exam was very different than working on homework assignments. The study group started the exam study session by working on the equation sheet that they were allowed to bring into the exam room with them. Each member worked through their set of notes and wrote down equations they thought would be helpful on the exam. At times, a study group member might ask the other members if they thought a certain concept would be covered on the exam. If the group did not think a topic or concept would be covered,

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they would not write equations for that concept on their sheet. After finishing their equation sheets, the study group moved on to reviewing the exam preparation packet provided by a student center on campus. This packet consisted of worked exams from the course from previous years that current students could use for practice. The study group had collected several different old exams from the student center on campus. Benjamin, Michael, and Jenny looked through the packet, at times discussing whether they understood a certain approach taken on the completed exam. At one point, Michael moved to the white board to put a solution to one of the problems on the board. Michael wrote a partial solution a particular problem and discussed with Benjamin a few points to make sure they understood. After it was determined that everyone understood that problem, Michael started to review another problem in order to put that problem on the whiteboard. Michael, Benjamin, and Jenny discussed how they were not worried about this exam and thought that they were prepared. Jenny noted that she would review her notes and homework individually before the exam the next day. After 90 minutes, the study session ended. During this study session, no problems were worked fully to a solution. Instead, fully worked solutions were discussed verbally by the study group members.

By looking at observations where students are working on homework and studying for exams, I looked at ways different meeting purposes may be related to different patterns in metacognitive engagement. Figure 35 shows a comparison of the metacognitive behaviors observed when studying for an exam when compared to working on a homework assignment.

The data shows the following differences:

- A higher rate of planning activity when studying for an exam when compared to working on a homework assignment (1.9 vs 0.5 bpm)
- A lower rate of monitoring activity when studying for an exam when compared to working on a homework assignment (1.5 vs 3.5 bpm)
- A lower rate of evaluating activity when studying for an exam when compared to working on a homework assignment (0.4 vs 0.7 bpm)

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- A lower rate of control activity when studying for an exam when compared to working on a homework assignment (0.2 vs 0.3 bpm)
- A higher rate of discussion of knowledge of persons when studying for an exam when compared to working on a homework assignment (0.2 vs 0.1 bpm)
- A higher rate of discussion of knowledge of tasks when studying for an exam when compared to working on a homework assignment (0.5 vs 0.3 bpm)
- A lower rate of discussion of knowledge of strategies when studying for an exam when compared to working on a homework assignment (1.3 vs 1.5 bpm)

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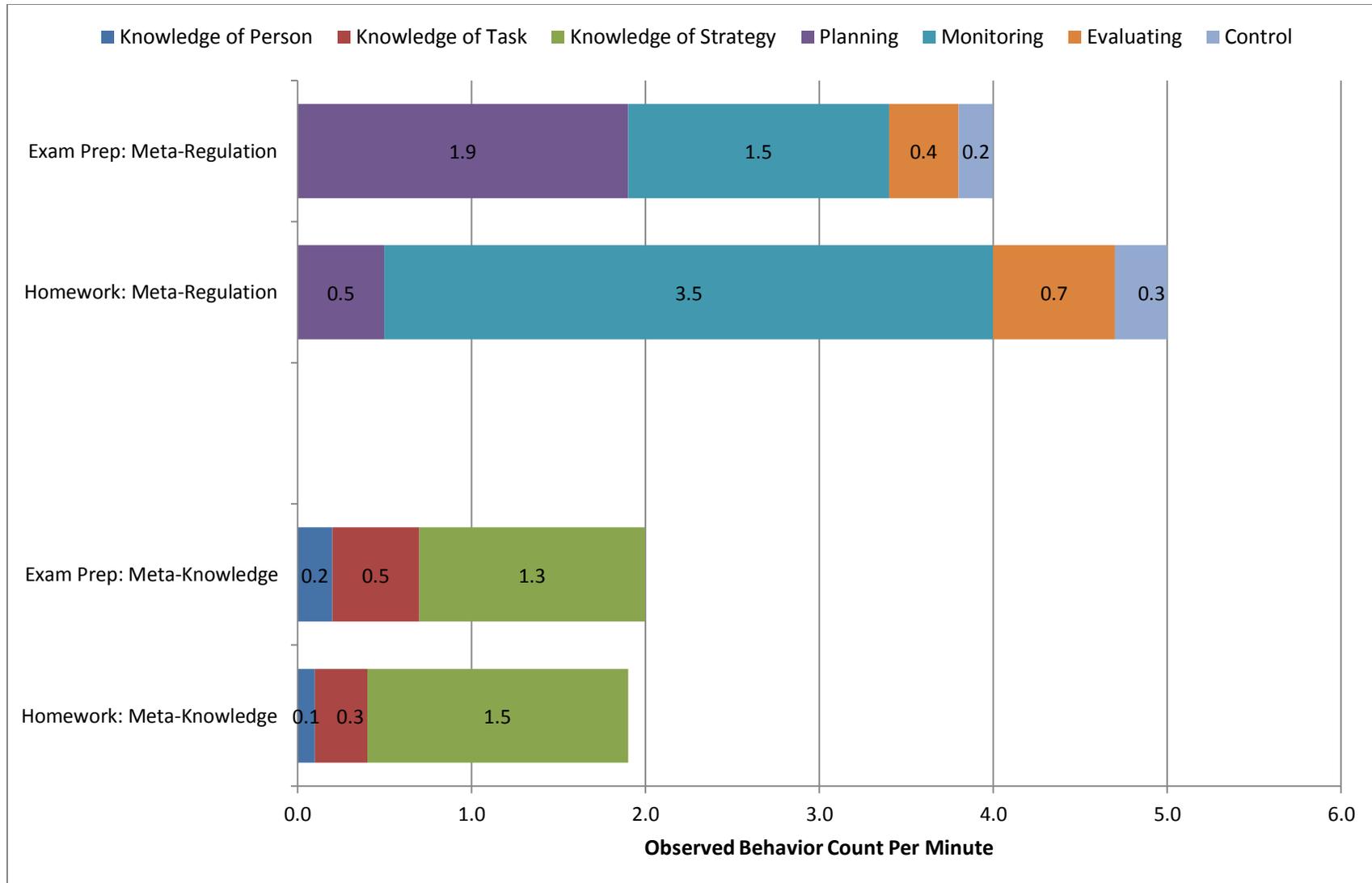


Figure 35 Observed Metacognitive Behavior Compared with Different Meeting Purposes

#### 4.3.6 Impact of Workload

In this section, I discuss the impact that a heavy workload potentially has on metacognitive engagement. Specifically, I discuss how study groups with a typical high level of metacognitive engagement see shifts in their metacognitive engagement on days when their workload is increased dramatically.

A typical study session for LIB was described in an earlier section. During most typical study sessions, the homework assignment was completed by all study group members. On a few occasions, the study group would find it necessary to ask their professor for help in order to complete one of the homework problems. Even when the study group had to ask for help, only one or two of the homework problems were the focus of a help session.

These typical study sessions occurred either after a full day of classes or after a weekend break. Observation 6 represents an atypical study session where LIB attempted to work on a homework assignment after taking 3 exams in one day. On the day the observation occurred, all study group members had taken an exam in the PSH course as well as differential equations and an electrical system course. The study group members entered the study group session with a different attitude than was normally observed. The group members seemed very tired and not as mentally alert. It was noticeable that one study group member had recently been crying. As they started work, many members made comments about being ‘brain dead’ or ‘exhausted.’ The group members started the first homework problem but after only a few minutes seemed to relay that they were stuck and could not make progress. At one point Michael asks, “What’s the next one?” to which Jenny replies, “Yeah, cause I don’t know what’s going on.” Benjamin states, “Yeah, we may as well go to the next one.” A very similar cycle repeats for all four homework problems. The study group spent time setting up each of the four homework problems assigned

but makes little progress on any problem. After an hour of working, the study group abandons working on homework for the PSH course, plans to go ask the instructor for help the next morning, and attempts to work on a homework assignment for another course. After speaking with the professor, the study group reconvened for observation 7 to finish the homework assignment that was due. During this observation, all four homework problems were completed.

I looked at the metacognitive behaviors of typical study sessions and compared them to the metacognitive behaviors observed during higher work load study sessions. It should be noted that, for this analysis, only observations for LIB were included. It would be difficult to provide an accurate comparison of workload between groups without asking for input from the study groups. Therefore, the analysis was limited to observations conducted with LIB. Figure 36 shows a comparison of the metacognitive behaviors observed when participants when subjected to a heavy workload when compared to when participants were subjected to a normal workload. The data shows the following differences:

- A lower rate of planning activity for the higher workload when compared to the normal workload (0.5 vs 0.6 bpm)
- A lower rate of monitoring activity for the higher workload when compared to the normal workload (2.7 vs 3.6 bpm)
- A lower rate of activity for the higher workload when compared to the normal workload (0.2 vs 0.3 bpm)
- A lower rate of discussion of knowledge of strategy for the higher workload when compared to the normal workload (1.1 vs 1.9 bpm)

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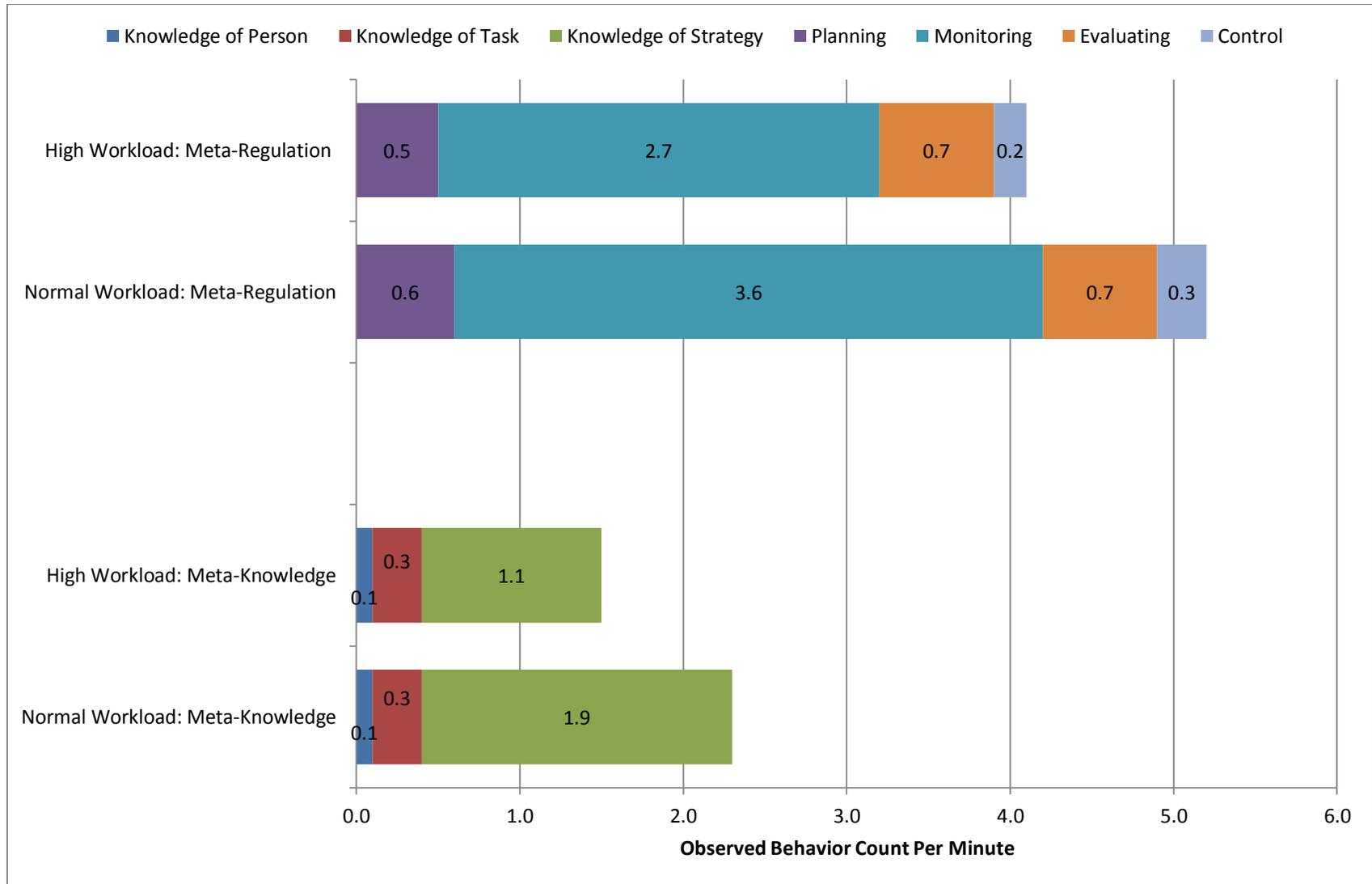


Figure 36 Observed Metacognitive Behavior at High Work Load

#### 4.4 Summary of Chapter 4

The purpose of my research was to answer the question “*How are engineering students engaging in metacognition when they are studying together in study groups?*” In order to answer this overarching research question, three research questions were developed (add table #). As part of this study, the NOME coding strategy (add table #) was developed in order to provide a methodological approach for identifying the metacognitive behaviors of undergraduate engineering students in naturalistic settings, thus answering the first research question. To answer the remaining questions, observations of nine study group sessions were coded using the NOME coding in order to develop a rich description of what metacognitive behaviors look like in these naturalistic settings. Overall, evidence supported that monitoring strategies and knowledge of strategies were the metacognitive behaviors engaged in at the highest rate by participants. Specifically, participants relied heavily on checking strategies, checking answers, and explaining strategies with other members of the study group. Several contextual factors were identified as potential influences on metacognitive engagement in these study group sessions. These factors include learning environment, study session schedule, learning resources, purpose of meeting, and impact of workload.

Conclusions based on these findings are presented in Chapter 5. Implications of the findings relative to research in engineering education and metacognition are discussed. Implications to practice for instructional faculty and students are also discussed. Finally, Chapter 5 provides a summary of the contributions of this study, areas of future work, and a closing statement.

## 5 Chapter 5: Discussion and Conclusions

The discussion contained in this chapter draws on my findings in conjunction with current literature in order to answer the research questions for which this study was designed. In this chapter, I discuss what was found in the data and how these findings align with and extend our current understandings of metacognition in literature. Based on my findings, I provide implications for research and practice. My implications for research pertain both to research in metacognition as well as research in engineering education. For example, the use of participant observations for data collection allow for a new subset of research questions to be explored both in metacognition as well as engineering education. Implications for practice include implications for educational practitioners as well as engineering undergraduate students. Primarily, I discuss the role that educational practitioners and students play in the appropriate selection of study strategies in order to maximize benefits in learning. Finally, I provide recommendations for future work in order to expand our understanding of how students engage in metacognition in engineering contexts and how to develop and support metacognitive behaviors.

### 5.1 Answering the Primary Research Question

Recall that the purpose of this study was to 1) to develop a methodological approach that would allow for the identification of metacognitive engagement in naturalistic settings for undergraduate engineering students, 2) to understand what metacognitive behaviors students engage in when studying together in a group and 3) to understand pertinent contextual factors that support metacognitive engagement. While there are many methodological choices that could have been made in order to understand engagement in naturalistic settings as well as a large number of contextual factors that impact student learning, I was able to consolidate the information from this study in order to answer this study's overarching research question: *How*

*are engineering students engaging in metacognition when they are studying together in study groups?*

Participant observations were useful in identifying the metacognitive behaviors of engineering students while studying in naturally formed study groups. Through video and audio recording these study sessions, I was able to develop an observational coding strategy that could identify and classify the types of metacognitive behaviors in which students were engaging. Participant observations were also useful in identifying relevant contextual factors that are tied to engagement in metacognition while studying in study groups.

Through the observations, I developed a rich picture of the metacognitive engagement of engineering students in the PSH course studying in study groups. Specific habits have been identified that provide detail on how students engage in metacognition when engaging in a course that is focused on teaching a problem-solving heuristic. In general, participants spent the majority of metacognitive regulation discussions engaged in monitoring activities. Participants also spent the majority of metacognitive knowledge discussions focused on knowledge of strategies. Participants spent the least amount of their discussions around knowledge of their own and others learning and abilities (knowledge of persons).

The contextual factors of learning environment, learning resources, study group schedule, study group purpose, and workload were linked to differences in metacognitive engagement. These factors align with factors identified as salient in self-regulated learning literature but extend our understanding of how these factors potentially link to metacognitive engagement. In combination, the results show:

- The need for using observational methods was supported by evidence that the participants of this study could not accurately report their metacognitive activity over the period of the study when compared with their observed behaviors.

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- In the area of knowledge of persons, participants committed more of their discussions to knowledge about their own personal learning and thinking and less on knowledge about others' learning and thinking.
- In the area of knowledge of tasks, participants committed more of their discussions to the difficulty of tasks and less to discussion of similarities and differences across different tasks.
- In the area of knowledge of strategies, participants committed more of their discussion to explaining procedures used in different tasks and less to knowledge about evaluating the effectiveness of certain strategies.
- In the area of planning, participants committed more of their discussions to making a plan for a task than collecting information or resources, discussing what information would be covered in an assignment or exam, assigning different tasks, or working on the assigned homework format for the course.
- In the area of monitoring, participants spent the majority of their discussions on checking strategies and answers with others in the study group. Little discussion was devoted to checking back to goals, discussing mental clarity and discussing memory retrieval.
- In the area of evaluating, participants spent the majority of their discussions on commenting on progress made toward a goal and discussing the correctness or accuracy of a particular strategy or answer. The reasonableness of certain answers or strategies was the least used evaluatory strategy.
- In the area of control, participants most commonly showed activity regarding the change of a strategy by erasing from their paper and writing new equations or variables. The least used control strategy was to repeat a strategy in order to check its effectiveness.

Several behaviors originally identified in Whitebread's observational work were unsupported in the data for this study. Those behaviors included discussions of knowledge of universals, the planning activity of setting goals and targets, and the evaluation activities of suggesting and using strategies in order to solve the task more effectively and applying a previously learnt strategy to a new situation. There are multiple reasons why these behaviors may have been unsupported by the data for this study.

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It is not surprising that discussions of knowledge of universals were not represented in this data set. Of all the components that comprise the theoretical framework of metacognition, knowledge of universals is the least widely cited and discussed. In fact, pivotal articles such as a review of metacognitive literature for the introduction of the journal, *Metacognition and Learning*, by Veenman et al. (2006), an article by Pintrich (2002) on the role of metacognitive knowledge in learning and teaching, and an article by Krathwohl (2002) suggesting the addition of metacognitive knowledge to Bloom's taxonomy all fail to provide any discussion on knowledge of universals. It is possible that there is not a clear definition of this component of the theoretical framework as well as a clear understanding in how this component fits in with the rest of the framework.

While goal setting behaviors were not observed in the context of this study, this does not mean that students were not engaging in goal setting behaviors. It is very possible that students had implicit goals set that they were not verbally communicating to the study group. It is also possible that goal setting discussions were occurring amongst study group members in settings other than the study group sessions. Because my observations focused primarily on study group sessions, it is possible that these discussions were occurring in class, through email or phone conversations, or in other environments that I did not have access to.

In regards to the evaluation activity of suggesting and using strategies in order to solve the task more effectively, it is possible that this behavior is related to the development of expertise in a particular content area. Due to the fact that the participants were novices to the engineering concepts in the PSH course, they may not have developed enough knowledge about the concept to suggest alternate strategies. Therefore, this behavior may not be observable until significant expertise is developed.

Finally, in regards to the evaluation strategy of applying a previously learnt strategy to a new situation, it is possible that the context of the PSH course at STFC impacted engagement in this particular behavior. The purpose of the PSH course was to teach a specific problem-solving heuristic in the domain of conservation and accounting principles. Though some of the students had been exposed to key concepts in previous courses (e.g. Newton's Second Law of Motion in a previous physics course), the instructors required students to use the accounting principle, and not previous strategies, to solve linear momentum problems. Therefore, the specific structure of the course limited participants' abilities to apply previously learned strategies to the PSH course, which is an evaluation strategy.

In summary, the results of this study provide evidence that engineering students are engaging in metacognition while studying engineering content in study groups. Though there is evidence of engagement, there is also evidence that students are engaging in certain practices more than others and potentially engaging in critical practices minimally. As discussed in the following sections, these results both agree with and expand the current literature in metacognition in education. Specifically, this work provides supporting evidence for the use of new assessment methodology in studying metacognition, provides a more in depth picture of what metacognitive engagement looks like in educational settings, including engineering education settings, and provides evidence for the need for further research on the impact that context plays in metacognitive engagement. While the findings of this study are discussed in the following sections, a summary version of findings and implications is located in the appendix section.

### 5.1.1 Assessment Methods for Studying Metacognition

There is continued debate in research on metacognition as to what are the appropriate methodological approaches for studying this phenomenon (Baker & Cerro, 2000; Veenman et al., 2006). My research further supports the need for new methodological approaches in the study of metacognition in education. Specifically, the results of my study support the use of observations for the study of metacognition, support the use and development of other qualitative methods, and provide evidence against the use of only self-report methods. My research also extends the observational work originally started by Whitebread and colleagues in looking at metacognition in naturalistic settings (Whitebread et al., 2009; Whitebread & Pino-Pasternak, 2013). Though his original work focused on assessing the abilities of small children, my work expands Whitebread's efforts to bring observational methods to the forefront as an effective method in the study of metacognitive engagement. It is important to note that observational methods for studying metacognition require a significant amount of resources, are time intensive, and require a well-trained research team in order to make the types of interpretations that are necessary in order to code for metacognitive behaviors. For researchers who choose to use observational methods for a study, time, resources, and training must be built into the research procedure. These challenges should not prevent researchers from using observational methods, as I conducted this study predominantly on my own. With proper preparation, observational methods can be a worthwhile and exciting approach for studying metacognition.

My study supports the need for continued development of different approaches in investigating metacognitive behaviors by showing that observational methods can effectively identify metacognitive engagement in naturalistic settings. My findings in this regard are consistent with assessment and research design literature in metacognition. For example, Baker

and Cerro (2000) discussed the need for alternative measures of identifying metacognition due to several issues, as I previously outlined in Table 2 of Chapter 2. A significant concern for self-reporting is that students do not have the ability to accurately report behaviors they have previously engaged in or the level or frequency that they engage in such behaviors because the behaviors themselves are subconscious in nature (Schellings & Hout-Wolters, 2011). Many researchers have pointed to the need for methodological approaches that do not rely solely on participants to self-report their behaviors (Baker & Cerro, 2000; Richardson, 2004; Winne & Nesbit, 2009). My research further supports the claim that students do not have the ability to fully self-report their metacognitive behaviors. In my study, I found that participants self-reports of their engagement of metacognitive behaviors did not match with their observed engagement in metacognition. This is further proof that self-report methodology is not an appropriate way to ask participants about their metacognitive engagement. Therefore, my research, and specifically the development of the NOME coding strategy, supports this need as observational methods allow for the identification of metacognitive behaviors without the need for students to self-report.

Further, Cromley and Azevedo (2011) and Schellings (2011) contend that self-reports that are task-centered instead of focused on general behaviors provide more accurate measurements of metacognitive engagement. If this is true, then the current research could support continuing research in determining if there are more valid and reliable forms of self-report measures for metacognitive engagement. Conducting mixed methods research combining observational methods and task-centered self-report methods could bring the metacognition research community closer to a final agreement on these methodological issues.

The qualitative descriptions of metacognitive behaviors developed in this study provide a basis not only for further development of observational methods but also for the development of

other qualitative measures to investigate metacognition. For instance, in their work on studying the cognitive engagement of engineering students' problem solving in statics, Litzinger et al. (2010) used think-aloud protocols to study aspects of students' metacognitive engagement in regards to their problem solving abilities. Litzinger et al. coded transcripts of think-aloud protocols for metacognitive engagement as part of his study and found significant impacts due to metacognitive engagement on problem solving abilities. For researchers interested in pursuing future work to build on the work of Litzinger et al., it would be necessary to understand what types of behaviors are classified as metacognitive in order to properly analyze think-aloud data. By combining Litzinger's think-aloud methods and my observational coding strategy, researchers would have the ability to continue this important work in engineering education.

### **5.1.2 A Picture of Metacognitive Engagement in Education**

The specific metacognitive behaviors identified through my observations of participant groups also builds upon the work of researchers such as Whitebread (Whitebread et al., 2005; Whitebread et al., 2009; Whitebread & Pino-Pasternak, 2013), Bryce (Bryce & Whitebread, 2012), Volet (Volet, Summers, et al., 2009; Volet et al., 2013), and Rogat (Rogat & Linnenbrink-Garcia, 2013). These researchers have approached the task of qualitatively exploring the metacognitive behaviors of different populations in order to better understand how people engage in these habits. While research in the area of qualitative descriptions of metacognition is minimal, we are beginning to develop an understanding of what metacognition looks like at different stages of development as well as in different contexts and content areas. For example, we have information on the metacognitive habits of young children (Whitebread), middle school children (Rogat), undergraduate veterinary students (Volet) and now undergraduate engineering students (McCord). The field of observational studies on metacognitive engagement is quite

small and needs further expansion to better understand how metacognitive behaviors may be linked at different developmental stages as well as in different contexts and content areas. Specifically, my work contributes to this area as now we have two distinct studies that look at metacognition in an undergraduate context but with different content focuses: veterinary medicine and engineering. My work is distinct from Volet's work in that I focused in the development of the methodological approach for identifying metacognitive behaviors in naturalistic settings while Volet focused more on the collaborative nature of metacognitive engagement. Future work can begin to compare metacognitive engagement in these two content areas to determine if certain disciplines require different metacognitive skills.

My research findings also align with the focus in pedagogical development on developing metacognitive regulatory skills. In my study, I found that, overall, participants engaged in metacognitive regulation activities at a higher rate than metacognitive knowledge activities. Previous pedagogical approaches that were intentionally created to develop metacognitive skills have focused more on developing metacognitive regulation skills like planning, monitoring, evaluation, and control. In the context of the PSH course, components of the course design focused on engaging students in planning and monitoring activities. These components included a homework format and a standard form of the accounting principle that would help students plan their problem solving process. The use of the 4 Q's (see Section 3.4.2) potentially supported engagement in monitoring activities. It is possible that students engage in more regulation activities because pedagogies have focused more on developing these skills and less on developing metacognitive knowledge. Due to the fact that metacognitive knowledge is also important in learning, can be accurate or inaccurate, and can be very resistant to change (Veenman et al., 2006), future work should focus on developing pedagogical interventions with

the purpose of building accurate metacognitive knowledge. One example of a pedagogical intervention created for the purpose of developing accurate metacognitive knowledge in students comes from the field of language studies. With this pedagogical approach, developed by Cotterall and Murray (2009), students are engaged in working directly with language materials, instruction is provided on learning strategies, students keep portfolios of their work, and final grades are determined through a collaborative evaluation process that includes self-assessment activities. The portfolio and self-assessment activities are designed specifically to develop accurate metacognitive knowledge of the learner by engaging them in reflective activities that ask the learner to review their level of understanding and skill on a frequent basis.

#### ***5.1.2.1 A Picture of Metacognition in Engineering Education***

Metacognition is still an emerging topic in engineering education. Thus, there are only a few studies to which I can compare the results of my study. Nonetheless, I believe that my study aligns well with previous studies of metacognition in the past. For example, as stated earlier, Litzinger et al. (2010) found that metacognition plays an important role in how well students problem solve in statics. Litzinger et al. found that participants engaged in more monitoring behaviors than evaluation behaviors while performing think-alouds for statics problems. These findings are in line with the findings of my study in that, in both studies, monitoring activities were identified as the majority activity in metacognitive regulation. It is important to note that Litzinger et al.'s study only investigated engagement in monitoring and evaluation activities when looking at problem solving whereas my study included not only monitoring and evaluation but also knowledge of persons, tasks, and strategies as well as planning and control. Litzinger's study could be expanded in the future, using the NOME coding strategy, in order to understand

the role that metacognitive knowledge, as well as the regulatory activity of planning, plays in problem solving in engineering.

Case, Gunstone, and Lewic (2001) have also explored the metacognitive development of engineering students in a chemical engineering course. In their work, Case et al. found that students initially focused their original metacognitive skills on discipline, time management, and discussing task difficulties. Over time, Case found that engineering students moved away from time-management tasks and moved closer to a final state of selecting strategies and resources in order to meet learning objectives. When comparing the initial state of participants that Case et al. observed in their study to the observed state of participants of the current study, I found that there were similarities between the two groups in that there were significant mental resources dedicated towards checking progress against time standards and discussing task difficulty. As evidenced in my study's analysis of evaluation strategies, participants focused more evaluation discussion on commenting on progress, specifically in terms of the time duration to complete assignments. Participants spent less time focused on their quality or success of reaching learning objectives. This may be due in part to the fact that students were not required to report their own assessment of their learning as part of the PSH course structure. In a study conducted by Morgan (1985), it was found that students that monitored or evaluated their progress based on time or duration to complete an assignment while studying did not significantly improve their end of course examination scores. Instead, students who monitored or evaluated their progress based on defined learning objectives did significantly improve end of course examination scores. Therefore, there is a need to find ways to help these students move closer to evaluation techniques that evaluate progress towards learning objectives and away from evaluation methods that strictly seek to improve time to completion.

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While the results of my study supports the work on metacognition in engineering education, my work also adds new understanding to metacognitive engagement in engineering, specifically in the area of what students are and are not doing. For instance, my study found that students engage in evaluation strategies that look at the reasonableness of solutions at a lower rate than evaluation strategies that focus on estimates of time to completion. One reason for a lack of focus on reasonableness in evaluation could be due to the fact that students do not have adequate previous knowledge about the context of problems given for assignments or examinations. If the context of a problem is not one that students have experienced before, this may limit their ability to determine if an answer is reasonable or not. Therefore, as educational practitioners, we must either select problem contexts that are familiar to our students or provide them with the resources needed to make reasonableness judgments. This finding is specifically applicable to the PSH course from STFC. Because the textbook for the PSH course was written by instructors from STFC, the homework assignments were also written by the instructors. Some of the homework problems were written in a way that the context of the problem was specific to STFC (e.g. using the pond on campus as the context for a conservation of mass problem). While contexts such as these were more relatable to all students at STFC, other contexts, such as problems about jet engines, were only relatable to students who had experience or knowledge with jet engines or the aerospace industry. As shown in the example between Becca and Benjamin, Becca did not have experience with jet engines and this did not have the prior knowledge necessary to make a reasonableness judgment in that context. Becca would have benefited from supplemental materials that helped her learn about the normal operating conditions of jet engines in order to make an appropriate reasonableness judgment.

My study also found that, under the category of planning, students did not explicitly state the goals that they had for a study session or task. Achievement goals are defined as the general goals that students have in regards to the tasks that they are engaging in and are generally viewed in two orientations: mastery and performance (Elliott & Dweck, 1988). Mastery goals are generally focused on learning and understanding while performance goals are generally focused on demonstrating one's abilities. Vrugt and Oort (2008) found a positive relationship between mastery goal orientation and high engagement in metacognitive strategies. Though my participants did not explicitly state goals, they did engage in monitoring by checking back to goals. This implies that students do set goals for themselves and, potentially, their study groups as they prepare to work. Due to the important role of goals in learning, it could be equally important to help students engage in the process of explicitly stating goals for learning in order to impress upon our students the critical nature that those goals have on actual learning outcomes.

It is important to note that many of the findings in the context of engineering may be applicable to other contexts besides engineering. For instance, findings related to approaches to problem solving may not be limited to only engineering but may also be applicable in other problem solving contexts like mathematics and the physical sciences. Due to the controversial nature of whether metacognitive skills are domain general or domain specific (see section 2.1.3.2), it is important for the research community to continue its focus on understanding how generalizable these skills may be with different tasks or content areas.

### **5.1.3 The Impact of Context on Metacognitive Engagement**

Many of the contextual factors in this study have been addressed in recent literature as being critical in student learning. While these contextual factors have been discussed, it is important to note that few, if any, draw a connection between context and metacognitive

engagement. This is an important connection because context may play a critical role in students' ability and willingness to engage in metacognitive practices which I have already highlighted as important in learning.

#### ***5.1.3.1 Learning Environment and Metacognitive Engagement***

The current study highlighted differences in learning environments for each of the participant study groups. Patterns in metacognitive engagement were highlighted that were potentially linked to differences in the learning environments. While there is minimal literature on the connection between learning environment and metacognitive engagement, this finding aligns with the literature in SRL that suggests that the social and physical environment plays a key role in the development and engagement in self-regulated learning (Zimmerman & Schunk, 2001). While noted as having a significant impact on engaging in self-regulated learning, many researchers disagree on the ways in which the learning environment has an impact. For example, SRL researchers who take a volitional view of SRL state that the learning environment has a direct impact on students' volition in learning. In contrast, those researchers that take a Vygotskian view of SRL believe that the learning environment plays a role in so much as it supports the learner's ability to be surrounded and have experiences with more experienced learners. Thus, the learning environment that is structured in a way to work within a student's zone of proximal development is most impactful to learning and engaging in SRL (Vygotsky, 1980). Another view is the constructivist view (or the Piagetian view) that believes that an environment that engages learners in cognitive conflict is an environment that supports SRL (Zimmerman & Schunk, 2001). From numerous perspectives, the learning environment plays a critical role in supporting learning and components of self-regulated learning. My study provides evidence that there is potentially a similar impact on metacognitive engagement due to the

structure of the learning environment. Therefore, future research should continue to focus on the impact that environmental structure can have on learning, especially in the area of metacognitive engagement.

#### ***5.1.3.2 Learning Resources and Metacognitive Engagement***

In the current study, an important difference in the resources used by participant study groups was in the use of fully worked out solutions as a major study aid. Through my research, I found that student groups that used fully worked solutions tended to engage in fewer metacognitive behaviors, specifically in the areas of monitoring and evaluation. Chi et al. (1989) conducted a study looking at how physics students engaged with fully worked solutions while working physics problems. Chi and colleagues found that stronger problem solvers tended to use the fully worked solution in order to check a strategy that was already devised by the student. In contrast, weaker problem solvers tended to check the fully worked solution in order to find a solution for the problem they were working on. Weaker students also engaged in fewer self-explanation strategies than did stronger problem solvers. While Chi and colleagues made no explicit connections to metacognitive engagement, it is possible to infer between the two studies that the use of fully worked solutions for finding a solution to a problem contribute to engagement in fewer metacognitive strategies because students are not required to question their level of knowledge when the solution is provided for them. This may speak to the lower engagement in monitoring strategies for participants of this study who used fully worked solutions as a homework aid.

In regards to lower levels of evaluation strategies used by participants, literature on student achievement goals may provide some insight as to why students engage in lower or higher rates of evaluation behaviors because several studies have been conducted to look at the

connection between students' achievement goals and engagement in metacognition. If students using fully worked solutions have performance goal orientations and thus use the fully worked solutions in order to complete assignments and obtain higher grades, then this could explain why there is lower engagement in metacognitive strategies. Specifically, the use of fully worked solutions provides students not only with a worked solution, but answers and scores for those solutions. If students are aware of the correct final solution to a problem, their evaluation engagement may be limited to evaluating whether the answer they developed matches the given answer. The need for looking at the reasonableness of a solution or strategy in light of other engineering knowledge is not as necessary to 'successfully' complete the problem, if success is considered (from a performance approach) to be achieving the correct answer in order to get the highest possible score on an assignment.

The use of common representations for study purposes was also noted as a resource that some teams utilized during their study sessions. The use of common representations, and specifically the use of whiteboards, in collaborative settings has been studied in order to improve the effectiveness of team interactions (Kim, 2013). While a quantitative comparison of common representations was not possible in this particular study, future work could be conducted using a similar methodological approach to Kim in order to determine the impact of using common representations on metacognitive behaviors. Specifically, study groups could be placed in different physical environments that offer different spaces for common representations to determine how they interact with the common representations and how their metacognitive engagement changes in each setting.

### ***5.1.3.3 Workload and Metacognitive Engagement***

In the current study, there are two potential examples of competing goals that caused a shift in how study groups approached achieving those goals. First, I revisit the session where participants had taken multiple exams in one day. During this session, the goal of completing the homework assignment was forced to compete against the goal of mental and physical rest. Next, I showed a similar competition of goals when I discussed the scenario of working on a homework assignment one night before the assignment was due. In this situation, the study group was faced with a goal of understanding the material covered that was in competition with finishing all components of the assignment in order to turn the assignment in on time. When discussing the goals of study groups, it is also important to note that students typically juggle multiple goals at one time. While some goals may line up with one another, there are many times when these goals compete against one another, thus requiring students to make prioritizing decisions about how these goals will be reached. Fryer and Elliot (2008) note that much of the literature on goal orientation focuses on studying students' goals one at a time. But in students' actual contexts, they are faced with numerous competing goals. While this research suggests the need for further understanding of how context impacts metacognitive engagement, it is also critical we understand how context impacts the goal orientation of students, as there may be a link between goal orientation and metacognitive engagement.

### ***5.1.3.4 Study Group Purpose, Study Group Schedule, and Metacognitive Engagement***

As I showed in this study, metacognitive engagement looked different when study groups worked on homework assignments versus when they studied for exams. There are a few possible explanations for the differences that we see between these two scenarios. First, the differences in metacognitive engagement could be due to the effects of spacing in learning. Spacing or spaced

practice refers to distributing learning over a period of time in order to increase retention and is one of the most studied phenomena in educational literature (Toppino & Cohen, 2010) (Hintzman, 1974). In general, studies of the spacing on learning have shown positive impacts on learning retention. So, students that engage in spaced learning tend to have higher rates of retention of information. If LIB engaged in spacing their learning while working on homework assignments each week, then the need to engage in learning activities while studying for an exam would be less than if learning had not occurred during homework sessions. Therefore, metacognitive engagement would look very different for exam preparation, where learning was not necessary, when compared to homework study sessions, where learning actually occurred. While effective spacing could be one reason for the difference in metacognitive engagement during homework and exam study sessions, there is an alternative explanation. It is possible that a difference in metacognitive engagement during an exam study session could be due to a failure or inaccurate assessment of metacognitive knowledge. When Isaacson and Fujita (2006) studied the connection between metacognitive knowledge and test performance, they found that students with higher levels of metacognitive skills were more likely to know whether they understood the material to be tested and thus could choose appropriate strategies to enhance their performance on exams. In the context of the current study, it is possible that, while studying for their exam, LIB had inaccurate knowledge about their own understanding and abilities and thus chose study strategies that were not suited for their actual level of knowledge. Thus, inaccurate knowledge could potentially lead some students to not study as much for an exam because they believe they know the material well enough when, in all actuality, they do not.

*5.1.3.5 Study Habits: Tying Together Environment, Resource Use, Schedule, Purpose and Workload*

In general, I saw a diverse set of study habits used by the students participating in this study. Many of these strategies, like using fully worked solutions as homework aids, studying in high traffic and distracting learning environments, scheduling time to work on assignments close to the assignment deadline, and not fully working problems while preparing for an exam, were concerning to me as an observer. At times, I questioned whether these were the most effective strategies for these study groups to be using at the time. Winne and Nesbit (2009) noted that even high achieving university students have been shown to engage in learning strategies and study habits that are distinctly in contrast to what the literature would suggest is the most efficient and most effective. Other educators and researchers have also shown concern with the study skills preparation of engineering students.

Several studies have been conducted to look the study habits of undergraduate engineering students and have found deficiencies in areas such as time-management, self-testing, and concentration (Bernold, Spurlin, & Anson, 2007), as well as positive impacts on performance when students are less distracted and more inquisitive in their question asking (Blumner & Richards, 1997). And yet, with research in engineering education pointing to a need for more effective study skills, we see little effort in the community to develop sound practices for addressing these deficiencies. In a discussion on successful engagement in metacognition, Winne and Nesbit (2009) state that a major challenge to successful engagement is that students have not been taught about what the research community has learned about effective learning and study strategies. In essence, students have not learned how to learn mainly because we, as educators, have not taught them how to learn. Therefore, significant resources, both from the

research and practitioner communities, need to be dedicated to teaching effective study habits to students.

## **5.2 Study Implications**

The results of my research have implications both for research and educational practice. Implications for research involve the use of observational methods for further study of metacognition in educational settings and a specific need for more research in the area of cognition and metacognition in engineering education. Implications for practice include the necessity of developing interventions to help students develop more effective study strategies.

### **5.2.1 Implications for Research: Metacognition**

There is currently great debate in the world of metacognition research on methodological approaches that should and should not be used in the assessment of metacognitive engagement. My study further supports that notion that observational strategies are an emerging methodological approach that can be successfully used in the study of metacognition. As observational methods continue to develop, the research community could engage in collaborative efforts to triangulate the results using different methodological approaches. This type of mixed-methods work could continue to help the metacognition research community gain better understanding on this very complex thought process.

It is also critical that the education research community commit more time and effort into understanding how context plays a role in metacognitive engagement. Just as there is an active call for studying SRL in context (Perry, 2002), a similar call should be instituted for the study of metacognition. This study has highlighted a few of the contextual areas where this research can start (learning environment, learning resources, study group schedule, study group purpose, and workload). But the worlds of formal and informal learning are dynamic and ever changing. It is

likely that a number of other contextual factors could play significant roles in how our students engage in metacognition.

### **5.2.2 Implications for Research: Engineering Education**

There is currently limited research in the area of metacognition in the engineering education community. As critical as metacognition is in the area of problem solving and conceptual learning, it is critical that we understand how metacognition can help our engineering students learn difficult content more effectively. While we can learn much from the fields of physics and mathematics education, it is critical that we focus specific resources in understanding how metacognitive behaviors are different in engineering content areas. Researchers like Case (2001), Litzinger (2010), and Lawanto (2010) have started the conversation surrounding metacognition in engineering education but more of the community needs to follow suit.

My study has provided a rich description of what metacognitive engagement looks like in an engineering context. In connection with that engagement, I identified several contextual factors that potentially impact that engagement. It is critical that we focus resources on understanding how to develop the metacognitive strategies of our engineering students. Specific energy should be focused on how to develop the study strategies of our students in order to require metacognitive evaluation that is connected to evaluating learning against objectives during studying instead focusing on limiting effort or reducing time to complete assignments. While the pedagogical approach used by the PSH course potentially engaged the participants of this study in more metacognitive strategies than traditional problem-solving courses, there was not explicit instruction on how to improve overall study skills. An intentional effort on

discussing effective study strategies with the students of the PSH course may add to the engagement that was seen through the use of the problem-solving heuristic alone.

The current study focused on contextual factors that occurred as part of the study sessions. While a number of contextual factors were identified in the context of the study sessions, this study did not focus on connecting contextual factors identified in the study sessions to contextual factors from inside the classroom. It is quite possible that the structure of the PSH course as well as individual teaching styles of the instructors could be linked to how students approach conducting study sessions. Future work should focus on linking context inside the classroom with context outside of the classroom.

### **5.2.3 Implications for Practice: Instructional Faculty**

First, this study provides evidence that engineering students are in fact engaging in metacognitive behaviors while study engineering content in study groups. Observations of these study groups show students engaged in a very active form of learning. Activities that engage students actively provide more opportunities for students to display the metacognitive behaviors that they engage in to solve problems.

Second, this study highlighted the need to help students determine more effective study habits and strategies. As Winne and Nesbit (2009) showed, many high achieving students were shown to use strategies that were in stark contrast to effective strategies defined in the literature. The expectation that students should just ‘know how to learn’ is as preposterous as an expectation that, without training, students should know how to solve calculus problems. Prior to entering university, most undergraduate engineering students have had little to no exposure to engineering content. Many students come to a university with experience only in mathematics and the physical sciences. As discussed earlier, there are distinct disciplinary differences between

mathematics, the physical sciences, and engineering. Specifically, engineering requires students to focus more on the application of knowledge. Therefore, learning and study strategies for engineering courses are potentially different than what many students may have experienced in their high school math and science courses. In addition, undergraduate engineering students begin their engineering courses with brains that are not fully developed. Therefore, the first few years are marked with developmental changes that may impact students' abilities to engage in certain strategies. Due to these disciplinary and developmental influences, we need to take an active role in teaching students about effective learning and study strategies that have been identified in the literature.

Third, this study provided evidence that certain strategies were used more than others. As educators, we must identify the types of strategies that are important to specific learning outcomes for our students. For instance, engineering students need to be able to determine if an answer they develop is reasonable (evaluation strategy) in the context of the problem they are working on. Once these strategies are identified, we need to provide students with the necessary resources to engage in those strategies. If making reasonableness judgments is important for our engineering students, then we must provide students with the information necessary to make reasonableness judgments or, at the very least, teach them to find the information needed to justify reasonableness judgments.

Fourth, this study provided evidence that there are other contextual factors that potentially impact metacognitive engagement. For example, a student's academic workload potentially has an impact on their willingness or ability to engage in metacognitive behaviors. In the specific example from the study, the study group had taken three examinations in one day. There are contextual factors that we, as instructional faculty, do have the ability to manage.

Asking students to take three examinations in one day seems to be an unfair workload. Clear communication with other instructors who teach like students can potentially move students away from unduly stressful situations and instead will allow them to perform and function at more optimal levels for learning and assessment.

### **5.2.4 Implications for Practice: Students**

The selection of study strategies have a potential impact on how students engage in metacognition. Recall the models of self-regulated learning posed by Butler and colleagues in Figure 3 (Butler et al., 2011). The selection of and adjustment of strategies for learning are a critical component of these self-regulated learning models. It is critical that students play an active role in the selection of strategies that they use for studying in their study group sessions. Following models of self-regulated learning, students should actively identify the goals that they have in certain learning situations. Once goals have been identified, students should select appropriate strategies in order to achieve the goals they set.

### **5.3 Dissemination of Results to Research Site and Participants**

As I spent a significant amount of time at STFC with the faculty and research participants, I viewed the research site and participants as a final set of special stakeholders for this study. On May 15-16, 2014, I traveled back to STFC in order to disseminate the results of this research study to the participants, the instructors of the PSH course, and interested faculty and students of STFC. During this two day trip, a series of meetings was held with study groups and instructors. A seminar was also held to disseminate the results to the larger community.

The participating study groups (OFF, LIB, and ON) were all invited to have personal meetings with me during my visit to STCFM. Both LIB and ON were interested in hearing the results of the research study. Thus, on May 15 and 16, I was able to meet with the LIB and ON

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study groups in order to share the results of my study and discuss implications for their groups. I started each session by reviewing the general purpose for my study, reviewing the definition of metacognition, and then providing a brief overview of the behaviors that I saw the students engage in as well as the behaviors I expected to see but did not. I focused my discussion on relating to the study groups that, while many of the behaviors that I saw were positive, there were several behaviors, such as goal setting, evaluation based on time to completion, and judgments of reasonableness, that needed improvement. I then facilitated a discussion among the group members to have them reflect on the study skills they were currently using, how effective those study skills were, and then had them generate a list of areas they would like to work on for the upcoming fall term. I received positive feedback from both the LIB and ON study groups. Many members of the LIB study group communicated to me that they had already made significant changes to how they studied and approached learning since the fall term. In fact, several communicated that if I came back to repeat the study, I would observe very different behaviors. The ON study group also communicated that, based on the new classes they were taking, they were approaching their study sessions differently. They were selecting new study habits for these classes based on the structure of the course and the difficulty level of the content being presented. I took this to be very encouraging feedback from both teams as it seemed as if they were choosing to change their behaviors because what they were doing was not working. This revelation of a change in strategies does not negate the results presented in this study. Instead, the revelation that the groups had to change their working strategies in order to be more effective and efficient is further evidence that these two groups were engaging in metacognitive practices, even while I was gone. By determining that their current learning strategies were not working, these students were monitoring their behaviors and engaging in control strategies in

order to shift towards learning strategies that helped them more effectively reach their goals. I encouraged them to continue this trend, as being willing to change and try new strategies should lead to more effective learning and performance in their studies. While the students expressed that they had changed their learning strategies over the course of my absence, I do not believe that the metacognitive behaviors I observed are invalid. Instead, I believe that the behaviors I observed may provide a picture as to what metacognitive engagement looks like in the early stages of engineering learning. Future work can focus on looking at the development of metacognitive behaviors over time and, in a sense, capture the phenomenon of ‘changing learning strategies’ that the participants were communicating to me in our follow up meetings.

I was also able to meet with most of the instructors of the PSH course while visiting STFC. Again, the results of this study were very well received by these faculty members. I focused this discussion on encouraging the faculty members to think about how to integrate activities to teach their students how to learn into the current curriculum. While there are several pedagogical practices that have been developed to support metacognitive engagement, like those discussed in Section 2.2.3, I did not suggest that faculty members consider changing their entire pedagogical approach in their classes. Instead, I suggested that they read a book called *Creating Self-Regulated Learners* by Linda Nilson (2013), as it provides a number of practical suggestions on integrating activities in the curriculum that should help students develop metacognitive skills and challenge them to think about their own learning. The suggestions made by Nilson are small changes that can be made to current courses that should help develop and support self-regulated learning behaviors, including metacognition. We also discussed whether this type of learning instruction was better taught in the context of an engineering course or whether a separate course should be created to teach students these metacognitive skills. While I did not have a full answer

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to this question, our discussion stimulated conversation on how to best approach teaching students how to learn. We also discussed how making intentional time to stop and allow students to think may support their ability to process the content in class so that students have the opportunity to determine if they have a question and then ask that question during the class period. While I facilitated the discussion among these instructors, much of the conversation was spent with the instructors generating their own ideas for how to approach integrating new techniques into the course structure.

Finally, I gave a seminar presenting my research results to the larger STFC community. The seminar was well attended and even included several students in the audience. While I knew that I would receive a warm welcome in returning to STFC to present my results, I did not expect to be greeted with such excitement over the results of my study. Faculty members asked questions throughout the entire presentation. We had very productive discussions on how and why to engage students in goal setting activities, how to encourage students to make more reasonable judgments, how to push away from time to completion evaluations, and in general how to engage students in thinking about their own learning processes. Faculty members were interested in knowing if there were gender differences in metacognitive engagement as well as ties to performance in the classroom (grades). While I could not provide definitive results on either of these topics, I did assure them that future research could focus on these areas.

While a major goal for my study was to determine if and how students were engaging in metacognitive practices while studying engineering content, another goal, and one of the reasons why this data was collected at STFC, was to help develop a partnership between the Virginia Tech Department of Engineering Education (VT ENGE) and STFC. My experience in the field at STFC as well as the experience of reporting these results out to the community of STFC

solidified in my mind that the goal of building a partnership with STFC was accomplished over the past year. Moving forward, I believe that STFC will be a very beneficial partner site in continuing work for this research area as well as other future research and scholarly teaching collaborations.

### **5.4 Contributions**

My research supported the development of the NOME coding strategy as well as observational methods to identify metacognitive engagement in natural settings. This work can be used to further support work in metacognition as well as engineering education. My work also provided a previously undiscovered picture of metacognitive engagement in an engineering context. This picture, as well as the description of metacognitive behaviors, provides a starting point for pedagogical development in the engineering classroom to develop and support the metacognitive skills of undergraduate engineering students. Finally, my work also further supports pedagogical work in that I have identified a number of contextual factors connected with metacognitive engagement.

### **5.5 Future Work**

From the current study, I suggest six areas of future work: 1) research focused on developing new reliability measures for socially-based observation methods, 2) investigate emotional and motivational regulation using current data in order to situate this work in SRL literature, 3) analyze the interviews conducted for this study in the context of the observational analysis, 4) investigate the level of metacognitive engagement, 5) investigate each contextual factor in more detail, and 6) pursue a longitudinal study of the metacognitive behaviors of K-12 STEM students and working engineers.

First, I suggest that future research focus on further development of reliability measures for the development of socially-based observational methods. This suggestion was made by Whitebread et al. (2009) in his earlier work on developing an observational coding strategy for behaviors in young children. As we move forward using observational methods for studying metacognition in education, it is important that we develop means for providing evidence of the reliability of these methodological approaches.

Second, I suggest that future work focus on investigating the emotional and motivational regulation of the participants of this study and participants of future metacognition studies. In order to be able to situate the results of this study and future studies among the literature in self-regulated learning, it is important that all components of SRL, including emotional and motivational regulation, be included in the analysis of future work. This future work can be explored using data collected for this study.

Third, future work should focus on bringing in the participants' voices in order to better understand why they engage in metacognition in certain ways. While researchers can infer why students engage in certain behaviors over others, explanations of behaviors from students may provide insight as to the types of barriers or supports that students encounter when trying to encounter in metacognition. Many areas of further inquiry were identified during the observations conducted in my study. These areas were probed during the ethnographic interviews that took place during the data collection process. The data from these interviews could provide a starting point for understanding, from the students' perspectives, why certain behaviors are chosen over others.

Fourth, I recommend that future work focus on determining the level of metacognitive engagement in naturalistic settings. This information can provide further information helpful in

developing pedagogical interventions for developing and supporting metacognitive behaviors. Low level metacognitive engagement lacks connection to explicit conceptual justification while high level metacognitive engagement ties discussions directly to conceptual justifications. Volet, Summers, et al. (2009) conducted similar work with college veterinary students to determine that undergraduate students were spending little study time focused on high level metacognitive engagement. Similar work would help the engineering education would allow the research community to understand at what level engineering students are engaging in metacognition.

Fifth, I suggest that future research be dedicated to investigating more deeply each one of the contextual factors identified in the study. By focusing on a contextual factor individually, future work may be able to provide causation evidence showing that these contextual factors are directly tied to metacognitive engagement.

Sixth, I suggest that future research be focused on the development of pedagogical interventions with the specific goal of helping students develop accurate metacognitive knowledge. Previous research has shown that the metacognitive knowledge that students hold can be inaccurate and can be very resistant to change. As metacognitive knowledge is critical in helping students make decisions about how they approach learning activities, it is important that the knowledge that students develop is accurate. Pedagogical interventions to build metacognitive knowledge should focus on making the current knowledge that students hold explicit, engaging students in reflective practices, and aiding students in developing self-assessment measures for determining if the knowledge they hold is accurate and useful.

Finally, I suggest that future work focus on understanding the metacognitive behaviors of K-12 STEM students as well as the habits of practicing engineers. In order to develop pedagogical interventions effectively, we must know how to accurately gauge progress over

time. Therefore, it is important to know what habits we would like to train our engineering students to have. By investigating the metacognitive behaviors of engineers in industry, we can identify a goal in which we would like to move our students towards. It is also important to understand the metacognitive behaviors of students entering our engineering programs. Evidence showing the metacognitive engagement of K-12 STEM students may provide information useful in developing interventions for these students with the intent of strengthening metacognitive skill as early as possible.

### **5.6 Concluding Remarks**

This research study developed out of a desire to better understand how metacognition impacts learnings in engineering education. I embarked on this study with a desire to push the need for research in the cognitive sciences in the engineering education research community. As I progressed through this study, I was encouraged by the excitement and interest that I encountered both in the engineering education community, at places such as FIE and AIChE, as well as STFC, the research site for this study. The response to this work has been overwhelmingly positive. Therefore, I believe that future work will be received in a similar manner. Moving forward, my plan is to continue this line of research while pushing to provide not only research outcomes but also practical outcomes that can be used by educational practitioners. The ultimate goal of this work is to work towards developing pedagogical interventions specifically aimed at developing and supporting metacognition in the engineering classroom. I have a passion for first and second year engineering students and thus I hope to work to develop the thinking skills, including metacognitive skills, of first and second year engineering students in order to prepare them for the difficult content they will face in their engineering curriculums during the third and fourth year and beyond.

**References**

- Alexander, J. M., Carr, M., & Schwanenflugel, P. J. (1995). Development of metacognition in gifted children: Directions for future research. *Developmental Review, 15*(1), 1-37.
- Atkinson, R. K., Sharon, J. D., Renkl, A., & Wortham, D. (2000). Learning from Examples: Instructional Principles from the Worked Examples Research. *Review of educational research, 70*(2), 181-214. doi: 10.2307/1170661
- Avraamidou, L., & Zembal-Saul, C. (2006). Exploring the Influence of Web-Based Portfolio Development on Learning to Teach Elementary Science. *AACE Journal, 14*(2), 178-205.
- Azevedo, R. (2005). Using Hypermedia as a Metacognitive Tool for Enhancing Student Learning? The Role of Self-Regulated Learning. *Educational Psychologist, 40*(4), 199-209. doi: 10.1207/s15326985ep4004\_2
- Baird, J. R. (1986). Improving learning through enhanced metacognition: a classroom study. *European Journal of Science Education, 8*(3), 263-282. doi: 10.1080/0140528860080303
- Bakeman, R. (2000). Behavioral observation and coding. *Handbook of research methods in social and personality psychology. Cambridge University Press, New York*, 138-159.
- Bakeman, R., & Gottman, J. M. (1986). *Observing interaction : an introduction to sequential analysis*. Cambridge [Cambridgeshire]; New York: Cambridge University Press.
- Baker, L. (1979). Comprehension Monitoring: Identifying and Coping with Text Confusions. *Journal of Literacy Research, 11*(4), 365-374. doi: 10.1080/10862967909547342
- Baker, L., & Cerro, L. C. (2000). Assessing Metacognition in Children and Adults. In G. J. Schraw & J. C. Impara (Eds.), *Issues in the Measurement of Metacognition* (pp. 99-146). Lincoln, NE: Buros Institute of Mental Measurement
- Bernold, L. E., Spurlin, J. E., & Anson, C. M. (2007). Understanding Our Students: A Longitudinal-Study of Success and Failure in Engineering With Implications for Increased Retention. *Journal of Engineering Education, 96*(3), 263-274. doi: 10.1002/j.2168-9830.2007.tb00935.x
- Blank, L. M. (2000). A metacognitive learning cycle: A better warranty for student understanding? *Science Education, 84*(4), 486-506. doi: 10.1002/1098-237x(200007)84:4<486::aid-sce4>3.0.co;2-u
- Blumner, H. N., & Richards, H. C. (1997). Study Habits and Academic Achievement of Engineering Students. *Journal of Engineering Education, 86*(2), 125-132. doi: 10.1002/j.2168-9830.1997.tb00275.x
- Borrego, M., Cutler, S., Prince, M., Henderson, C., & Froyd, J. E. (2013). Fidelity of Implementation of Research-Based Instructional Strategies (RBIS) in Engineering Science Courses. *Journal of Engineering Education, 102*(3), 394-425. doi: 10.1002/jee.20020
- Borrego, M., Douglas, E. P., & Amelink, C. T. (2009). Quantitative, Qualitative, and Mixed Research Methods in Engineering Education. *Journal of Engineering Education, 98*(1), 53-66.
- Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn : Brain, mind, experience, and school*. Washington, D.C.: National Academy Press.
- Brown, A. (1987). Metacognition, Executive Control, Self-Regulation and Other More Mysterious Mechanisms. In F. E. Weinert & R. H. Kluwe (Eds.), *Metacognition, Motivation and Understanding* (pp. 65-116). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.
- Bryce, D., & Whitebread, D. (2012). The development of metacognitive skills: evidence from observational analysis of young children's behavior during problem-solving. *Metacognition and Learning, 7*(3), 197-217. doi: 10.1007/s11409-012-9091-2
- Butler, D. L. (1998). In Search of the Architect of Learning: A Commentary on Scaffolding as a Metaphor for Instructional Interactions, Editorial, *Journal of Learning Disabilities*, pp. 374-385. Retrieved from

<http://ezproxy.lib.vt.edu:8080/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=pbh&AN=822846&site=ehost-live&scope=site>

- Butler, D. L. (2002). Qualitative Approaches to Investigating Self-Regulated Learning: Contributions and Challenges. *Educational Psychologist*, 37(1), 59-63. doi: 10.1207/00461520252828564
- Butler, D. L., Cartier, S. C., Schnellert, L., Gagnon, F., & Giammarino, M. (2011). Secondary students' self-regulated engagement in reading: researching self-regulation as situated in context. *Psychological test and assessment modeling*, 53(1), 73-105.
- Butler, D. L., & Winne, P. H. (1995). Feedback and Self-Regulated Learning: A Theoretical Synthesis. *Review of educational research*, 65(3), 245-281. doi: 10.2307/1170684
- Case, J., & Gunstone, R. (2002). Metacognitive Development as a Shift in Approach to Learning: an in-depth study. *Studies in Higher Education*, 27(4), 459-470. doi: 10.1080/0307507022000011561
- Case, J., Gunstone, R., & Lewis, A. (2001). Students' Metacognitive Development in an Innovative Second Year Chemical Engineering Course. *Research in Science Education*, 31(3), 313-335. doi: 10.1023/a:1013113807788
- Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-Explanations: How Students Study and Use Examples in Learning to Solve Problems. *Cognitive Science*, 13(2), 145-182. doi: 10.1207/s15516709cog1302\_1
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, N.J.: L. Erlbaum Associates.
- Corno, L. (2012). Work Habits and Self-Regulated Learning: Helping Students to Find a "Will" from a "Way". In D. H. Schunk, & Zimmerman, B. J. (Ed.), *Motivation and self-regulated learning: Theory, research, and applications*: Routledge.
- Cotterall, S., & Murray, G. (2009). Enhancing metacognitive knowledge: Structure, affordances and self. *System*, 37(1), 34-45. doi: <http://dx.doi.org/10.1016/j.system.2008.08.003>
- Craig, S. D., Chi, M. T. H., & VanLehn, K. (2009). Improving classroom learning by collaboratively observing human tutoring videos while problem solving. *Journal of Educational Psychology*, 101(4), 779-789. doi: 10.1037/a0016601
- Creswell, J. W. (2009). *Research Design: Quantitative, Qualitative, and Mixed Methods Approaches* (Third ed.). Thousand Oaks, CA: Sage Publications.
- Creswell, J. W. (2013). *Qualitative inquiry and research design : choosing among five approaches*. Los Angeles: SAGE Publications.
- Cromley, J., & Azevedo, R. (2011). Measuring strategy use in context with multiple-choice items. *Metacognition and Learning*, 6(2), 155-177. doi: 10.1007/s11409-011-9070-z
- Cronbach, L. J., & Meehl, P. E. (1955). Construct validity in psychological tests. *Psychological Bulletin*, 52(4), 281-302. doi: 10.1037/h0040957
- Davidson, J. E., & Sternberg, R. J. (1998). Smart Problem Solving: How Metacognition Helps. In D. J. Hacker, J. Dunlosky & A. C. Graesser (Eds.), *Metacognition in Educational Theory and Practice* (pp. 47-68). Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.
- De Groot, E. V. (2002). Learning Through Interviewing: Students and Teachers Talk About Learning and Schooling. *Educational Psychologist*, 37(1), 41-52. doi: 10.1207/00461520252828546
- Dodge, Y. (2008a). Kruskal-Wallis Test *The Concise Encyclopedia of Statistics* (pp. 288-290): Springer New York.
- Dodge, Y. (2008b). Mann-Whitney Test *The Concise Encyclopedia of Statistics* (pp. 327-329): Springer New York.
- Dodge, Y. (2008c). Nonparametric Test (Publication no. 10.1007/978-0-387-32833-1\_283). (978-0-387-31742-7). Retrieved 2008/01/01, from Springer New York [http://dx.doi.org/10.1007/978-0-387-32833-1\\_283](http://dx.doi.org/10.1007/978-0-387-32833-1_283)

## THINKING ABOUT THINKING IN STUDY GROUPS

- Dominowski, R. L. (1998). Verbalization and Problem Solving. In D. J. Hacker, J. Dunlosky & A. C. Graesser (Eds.), *Metacognition in Educational Theory and Practice* (pp. 25-46). Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.
- Donald, J. (2002a). Hard thinking: Applying structured knowledge to unstructured problems *Learning to think: Disciplinary perspectives* (pp. 62-95). San Francisco: Jossey-Bass.
- Donald, J. (2002b). Learning to think: A cross-disciplinary perspective *Learning to think: Disciplinary perspectives* (pp. 1-30). San Francisco: Jossey-Bass.
- Elliott, E. S., & Dweck, C. S. (1988). Goals: An approach to motivation and achievement. *Journal of Personality and Social Psychology*, 54(1), 5-12. doi: 10.1037/0022-3514.54.1.5
- Emerson, R. M. F. R. I. S. L. L. (1995). *Writing ethnographic fieldnotes*. Chicago: University of Chicago Press.
- Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist*, 34(10), 906-911. doi: 10.1037/0003-066x.34.10.906
- Flavell, J. H. (1987). Speculations About the Nature and Development of Metacognition. In F. E. Weinert & R. H. Kluwe (Eds.), *Metacognition, Motivation, and Understanding* (pp. 21-30). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.
- Fleiss, J. L., Cohen, J., & Everitt, B. (1969). Large sample standard errors of kappa and weighted kappa. *Psychological Bulletin*, 72(5), 323.
- Fryer, J. W., & Elliot, A. J. (2008). Self-Regulation of Achievement Goal Pursuit. In D. H. Schunk & B. J. Zimmerman (Eds.), *Motivation and Self-Regulated Learning: Theory, Research, and Applications* (pp. 53-76). New York, NY: Lawrence Erlbaum Associates.
- Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*: Aldine de Gruyter.
- Glesne, C. (2011). *Becoming qualitative researchers : an introduction*. Boston: Pearson.
- Grotzer, T., & Mittlefehldt, S. (2012). The Role of Metacognition in Students' Understanding and Transfer of Explanatory Structures in Science. In A. Zohar & Y. J. Dori (Eds.), *Metacognition in Science Education: Trends in Current Research*: Springer.
- Hacker, D. J., Dunlosky, J., & Graesser, A. C. (1998). *Metacognition in Educational Theory and Practice*: L. Erlbaum Associates.
- Hayes, J. R. (1989). *The complete problem solver*. Hillsdale, N.J.: L. Earlbaum Associates.
- Hedges, L. V. (1981). Distribution Theory for Glass's Estimator of Effect size and Related Estimators. *Journal of Educational and Behavioral Statistics*, 6(2), 107-128. doi: 10.3102/10769986006002107
- Hennessey, M. G. (2003). Metacognitive Aspects of Students' Reflective Discourse: Implications for Intentional Conceptual Change Teaching and Learning. In G. M. Sinatra & P. R. Pintrich (Eds.), *Intentional Conceptual Change* (pp. 103-132). Mahwah, NJ: L. Erlbaum.
- Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The physics teacher*, 30(3), 141-158.
- Hickey, D. T. (1997). Motivation and contemporary socio-constructivist instructional perspectives. *Educational Psychologist*, 32(3), 175-193.
- Hintzman, D. L. (1974). Theoretical implications of the spacing effect. In R. L. Solso (Ed.), *Theories in cognitive psychology: The Loyola Symposium* (pp. 77-99). Hillsdale, NJ: Erlbaum.
- Hsiung, C.-m. (2012). The Effectiveness of Cooperative Learning. *Journal of Engineering Education*, 101(1), 119-137. doi: 10.1002/j.2168-9830.2012.tb00044.x
- Iiskala, T., Vauras, M., & Lehtinen, E. (2004). Socially-shared metacognition in peer learning? *Hellenic Journal of Psychology*, 1, 147-178.

## THINKING ABOUT THINKING IN STUDY GROUPS

- Isaacson, R. M., & Fujita, F. (2006). Metacognitive Knowledge Monitoring and Self-Regulated Learning: Academic Success and Reflections on Learning. *Journal of Scholarship of Teaching and Learning*, 6(1), 39-55.
- Jacobs, J. E., & Paris, S. G. (1987). Children's Metacognition About Reading: issues in Definition, Measurement, and Instruction. *Educational Psychologist*, 22(3-4), 255-278. doi: 10.1080/00461520.1987.9653052
- Kim, K. (2013). *Developing Guidelines for Collaborative Spaces Supporting Interdisciplinary Engineering Design Teams*. VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY.
- King, P. M., & Kitchener, K. S. (2004). Reflective Judgment: Theory and Research on the Development of Epistemic Assumptions Through Adulthood. *Educational Psychologist*, 39(1), 5-18. doi: 10.1207/s15326985ep3901\_2
- Kramarski, B., & Mevarech, Z. R. (2003). Enhancing mathematical reasoning in the classroom: The effects of cooperative learning and metacognitive training. *American Educational Research Journal*, 40(1), 281-310.
- Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into practice*, 41(4), 212-218.
- Krause, S., Kelly, J., Corkins, J., & Tasooji, A. (2009). *The Role of Prior Knowledge on the Origin and Repair of Misconceptions in an Introductory Class on Materials Science and Engineering*. Paper presented at the 3rd Research in Engineering Education International Conference.
- Larkin, J., McDermott, J., Simon, D. P., & Simon, H. A. (1980). Expert and Novice Performance in Solving Physics Problems. *Science*, 208(4450), 1335-1342. doi: 10.2307/1684057
- Lawanto, O. (2010). Students' metacognition during an engineering design project. *Performance Improvement Quarterly*, 23(2), 117-136. doi: 10.1002/piq.20084
- Linnenbrink, E. A., & Pintrich, P. R. (2003). Achievement Goals and Intentional Conceptual Change. In G. M. Sinatra & P. R. Pintrich (Eds.), *Intentional Conceptual Change* (pp. 347-374). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Litzinger, T. A., Meter, P. V., Firetto, C. M., Passmore, L. J., Masters, C. B., Turns, S. R., . . . Zappe, S. E. (2010). A Cognitive Study of Problem Solving in Statics. *Journal of Engineering Education*, 99(4), 337-353.
- Lofland, J., & Lofland, L. H. (1995). *Analyzing social settings : a guide to qualitative observation and analysis*. Belmont, Calif.: Wadsworth.
- Luque, M. L. (2003). The Role of Domain-Specific Knowledge in Intentional Conceptual Change. In G. M. Sinatra & P. R. Pintrich (Eds.), *Intentional Conceptual Change* (pp. 133-170). Mahwah, NJ: Lawrence Erlbaum Associates.
- Lynn, P. (2004). Sampling Error *The SAGE Encyclopedia of Social Science Research Methods* (pp. 992-993). Thousand Oaks, CA: Sage Publications, Inc.
- Masui, C., & De Corte, E. (1999). Enhancing learning and problem solving skills: orienting and self-judging, two powerful and trainable learning tools. *Learning and Instruction*, 9(6), 517-542.
- Matusovich, H. M., & McCord, R. (2012). *Work in Progress: Does Motivation Matter for Conceptual Change?: Exploring the Implication of "Hot Cognition" on Conceptual Learning*. Paper presented at the Frontiers in Education Conference, Seattle, WA.
- Matusovich, H. M., & McCord, R. (2013). *Quantitative Analysis on Motivation, Learning Strategies and Conceptual Understanding*. Paper presented at the 2013 AIChE Annual Meeting, San Francisco, CA.
- Maxwell, J. A. (2010). Using Numbers in Qualitative Research. *Qualitative Inquiry*, 16(6), 475-482. doi: 10.1177/1077800410364740
- Mayer, R. E. (1998). Cognitive, metacognitive, and motivational aspects of problem solving. *Instructional science*, 26(1-2), 49-63.

## THINKING ABOUT THINKING IN STUDY GROUPS

- McCord, R., & Matusovich, H. M. (2013). *Developing an Instrument to Measure Motivation, Learning Strategies and Conceptual Change*. Paper presented at the 120th ASEE Annual Conference & Exposition, Atlanta, GA.
- McLean, J. E., & Ernest, J. M. (1998). The role of statistical significance testing in educational research. *Research in the Schools, 5*(2), 15-22.
- Meyer, D. K., & Turner, J. C. (2002). Using Instructional Discourse Analysis to Study the Scaffolding of Student Self-Regulation. *Educational Psychologist, 37*(1), 17-25. doi: 10.1207/00461520252828528
- Meyer, E., Abrami, P. C., Wade, C. A., Aslan, O., & Deault, L. (2010). Improving literacy and metacognition with electronic portfolios: Teaching and learning with ePEARL. *Computers & Education, 55*(1), 84-91. doi: <http://dx.doi.org/10.1016/j.compedu.2009.12.005>
- Miller, R. L., Streveler, R. A., Olds, B. M., & Nelson, M. A. (2003). *What conceptual models do engineering students use to describe momentum transfer and heat conduction*. Paper presented at the Annual Conference of the American Educational Research Association, Chicago, IL.
- Morgan, M. (1985). Self-monitoring of attained subgoals in private study. *Journal of Educational Psychology, 77*(6), 623-630. doi: 10.1037/0022-0663.77.6.623
- Nichols, S., Tippins, D., & Wieseman, K. (1997). A "Toolkit" for developing critically reflective science teachers. *Research in Science Education, 27*(2), 175-194. doi: 10.1007/bf02461315
- Nilson, L. (2013). *Creating Self-Regulated Learners: Strategies to Strengthen Students' Self-Awareness and Learning Skills*: Stylus Publishing.
- Nottis, K. E., Prince, M., Vigeant, M., Nelson, S., & Hartsock, K. (2009). Undergraduate Engineering Students' Understanding of Heat, Temperature, and Radiation.
- Nottis, K. E., Prince, M. J., & Vigeant, M. A. (2008). *Addressing Misconceptions about Heat Transfer in Undergraduate Chemical Engineering Instruction*. Paper presented at the NERA Conference Proceedings 2008.
- Olsen, R. (2004). Self-Selection Bias *Encyclopedia of Survey Research Methods* (pp. 809-811). Thousand Oaks, CA: Sage Publications, Inc.
- Palincsar, A. S., & Brown, A. L. (1984). Reciprocal Teaching of Comprehension-Fostering and Comprehension-Monitoring Activities. *Cognition and Instruction, 1*(2), 117-175. doi: 10.2307/3233567
- Patrick, H., & Middleton, M. J. (2002). Turning the Kaleidoscope: What We See When Self-Regulated Learning is View With a Qualitative Lens. *Educational Psychologist, 37*(1), 27.
- Perry, N. E. (2002). Introduction: Using Qualitative Methods to Enrich Understandings of Self-Regulated Learning. *Educational Psychologist, 37*(1), 1-3. doi: 10.1207/00461520252828500
- Piasta, S. B., & Justice, L. M. (2010). *Cohen's d Statistic*. *Encyclopedia of Research Design*. SAGE Publications, Inc. Thousand Oaks, CA: SAGE Publications, Inc.
- Pintrich, P. R. (1993a). Beyond Cold Conceptual Change: The Role of Motivational Beliefs and Classroom Contextual Factors in the Process of Conceptual Change. *Review of educational research, 63*(2), 167.
- Pintrich, P. R. (1993b). Reliability and Predictive Validity of the Motivated Strategies for Learning Questionnaire (MSLQ). *Educational and psychological measurement, 53*(3), 801.
- Pintrich, P. R. (2002). The role of metacognitive knowledge in learning, teaching, and assessing. *Theory into practice, 41*(4), 219-225.
- Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1991). *A Manual for the use of the motivated strategies for learning questionnaire (MSLQ)*. Ann Arbor, Mich.; [Washington, DC]: University of Michigan ; U.S. Dept. of Education, Office of Educational Research and Improvement, Educational Resources Information Center.

## THINKING ABOUT THINKING IN STUDY GROUPS

- Pintrich, P. R., Wolters, C. A., & Baxter, G. P. (2000). Assessing Metacognition and Self-Regulated Learning. In G. Schraw & J. C. Impara (Eds.), *Issues in the Measurement of Metacognition* (pp. 43-98). Lincoln, NE: Buros Institute of Mental Measurements.
- Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66(2), 211-227. doi: 10.1002/sce.3730660207
- Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of engineering education (Washington, D.C.)*, 93(3), 223.
- Reif, F., Larkin, J. H., & Brackett, G. C. (1976). Teaching general learning and problem-solving skills. *American Journal of Physics*, 44(3), 212-217. doi: <http://dx.doi.org/10.1119/1.10458>
- Richardson, J. T. E. (2004). Methodological Issues in Questionnaire-Based Research on Student Learning in Higher Education. *Educational Psychology Review*, 16(4), 347-358. doi: 10.1007/s10648-004-0004-z
- Rittle-Johnson, B., Siegler, R. S., & Alibali, M. W. (2001). Developing conceptual understanding and procedural skill in mathematics: An iterative process. *Journal of Educational Psychology*, 93(2), 346-362. doi: 10.1037/0022-0663.93.2.346
- Robinson, D. H., & Levin, J. R. (1997). Research news and comment: Reflections on statistical and substantive significance, with a slice of replication. *Educational Researcher*, 26(5), 21-26.
- Rogat, T. K., & Linnenbrink-Garcia, L. (2013). Understanding quality variation in socially shared regulation: A focus on methodology. In S. Volet & M. Vauras (Eds.), *Interpersonal Regulation of Learning and Motivation: Methodological advances* (pp. 102-124). New York, NY: Routledge.
- Rossman, G. B., & Rallis, S. F. (2012). *Learning in the field : an introduction to qualitative research*. Thousand Oaks, Calif.: SAGE.
- Schellings, G. (2011). Applying learning strategy questionnaires: problems and possibilities. *Metacognition and Learning*, 6(2), 91-109. doi: 10.1007/s11409-011-9069-5
- Schellings, G., & Hout-Wolters, B. (2011). Measuring strategy use with self-report instruments: theoretical and empirical considerations. *Metacognition and Learning*, 6(2), 83-90. doi: 10.1007/s11409-011-9081-9
- Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. *Handbook of research on mathematics teaching and learning*, 334-370.
- Schraw, G., Olafson, L., Weibel, M., & Sewing, D. (2012). Metacognitive Knowledge and Field-based Science Learning in an Outdoor Environmental Education Program. In A. Zohar & Y. J. Dori (Eds.), *Metacognition in Science Education: Trends in Current Research*: Springer.
- Sheppard, S. D., Colby, A., Macatangay, K., & Sullivan, W. (2006). What is Engineering Practice? *International Journal of Engineering Education*, 22(3), 429-438.
- Smith, E. E., & Kosslyn, S. M. (2007). *Cognitive psychology : mind and brain*. Upper Saddle River, N.J.: Pearson/Prentice Hall.
- Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005). Pedagogies of Engagement: Classroom-Based Practices. *Journal of Engineering Education*, 94(1), 87-101. doi: 10.1002/j.2168-9830.2005.tb00831.x
- Spradley, J. P. (1979). *The Ethnographic Interview*. New York: Holt, Rinehart and Winston.
- Spradley, J. P. (1980). *Participant Observation*. New York: Holt, Rinehart and Winston.
- Steif, P. S., & Dantzler, J. A. (2005). A Statics Concept Inventory: Development and Psychometric Analysis. *Journal of Engineering Education*, 94(4), 363-371.
- Steif, P. S., Lobue, J. M., Kara, L. B., & Fay, A. L. (2010). Improving Problem Solving Performance by Inducing Talk about Salient Problem Features. *Journal of Engineering Education*, 99(2), 135-142.

- Streveler, R. A., Litzinger, T. A., Miller, R. L., & Steif, P. S. (2008). Learning Conceptual Knowledge in the Engineering Sciences: Overview and Future Research Directions. *Journal of Engineering Education*, 97(3), 279-294.
- Streveler, R. A., Miller, R. L., Santiago-Roman, A. I., Nelson, M. A., Geist, M. R., & Olds, B. M. (2011). Rigorous Methodology for Concept Inventory Development: Using the 'Assessment Triangle' to Develop and Test the Thermal and Transport Science Concept Inventory (TTCI). *The International journal of engineering education*, 27(5), 968-984.
- Tarricone, P. (2011). *The Taxonomy of Metacognition*: Psychology Press.
- Thompson, B. (1996). Research news and comment: AERA editorial policies regarding statistical significance testing: three suggested reforms. *Educational Researcher*, 25(2), 26-30.
- Tonso, K. L. (2006). Teams that Work: Campus Culture, Engineer Identity, and Social Interactions. *Journal of Engineering Education*, 95(1), 25-37. doi: 10.1002/j.2168-9830.2006.tb00875.x
- Tonso, K. L. (2007). *On the Outskirts of Engineering: Learning Identity, Gender and Power via Engineering Practice* (Vol. 6). Rotterdam, The Netherlands: Sense Publishers.
- Toppino, T. C., & Cohen, M. S. (2010). Metacognitive control and spaced practice: Clarifying what people do and why. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 36(6), 1480.
- Toth, E. E., Suthers, D. D., & Lesgold, A. M. (2002). "Mapping to know": The effects of representational guidance and reflective assessment on scientific inquiry. *Science Education*, 86(2), 264-286. doi: 10.1002/sc.10004
- Van Dijk, T. A. (1982). Episodes as units of discourse analysis. *Analyzing discourse: Text and talk*, 177-195.
- Vauras, M., Liskala, T., Kajamies, A., Kinnunen, R., & Lehtinen, E. (2003). Shared-regulation and motivation of collaborating peers: A case analysis. *Psychologia*, 46(1), 19-37.
- Veenman, M. V. J. (2011). Metacognition in Science Education: Definitions, Constituents, and Their Intricate Relation with Cognition. In A. Zohar, & Dori, Y. J. (Ed.), *Metacognition in Science Education: Trends in Current Research*: Springer.
- Veenman, M. V. J., & Beishuizen, J. J. (2004). Intellectual and metacognitive skills of novices while studying texts under conditions of text difficulty and time constraint. *Learning and Instruction*, 14(6), 621-640.
- Veenman, M. V. J., Prins, F. J., & Verheij, J. (2003). Learning styles: Self-reports versus thinking-aloud measures. *British Journal of Educational Psychology*, 73(3), 357-372.
- Veenman, M. V. J., & Spaans, M. A. (2005). Relation between intellectual and metacognitive skills: Age and task differences. *Learning and Individual Differences*, 15(2), 159-176. doi: <http://dx.doi.org/10.1016/j.lindif.2004.12.001>
- Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: conceptual and methodological considerations. *Metacognition and Learning*, 1(1), 3-14. doi: 10.1007/s11409-006-6893-0
- Volet, S., Summers, M., & Thurman, J. (2009). High-level co-regulation in collaborative learning: How does it emerge and how is it sustained? *Learning and Instruction*, 19(2), 128-143. doi: <http://dx.doi.org/10.1016/j.learninstruc.2008.03.001>
- Volet, S., Vauras, M., Khosa, D., & Liskala, T. (2013). Metacognitive regulation in collaborative learning. In S. Volet & M. Vauras (Eds.), *Interpersonal Regulation of Learning and Motivation* (pp. 67-101). Abingdon, Oxon: Routledge.
- Volet, S., Vauras, M., & Salonen, P. (2009). Self- and Social Regulation in Learning Contexts: An Integrative Perspective. *Educational Psychologist*, 44(4), 215-226. doi: 10.1080/00461520903213584
- Vrugt, A., & Oort, F. J. (2008). Metacognition, achievement goals, study strategies and academic achievement: pathways to achievement. *Metacognition and Learning*, 3(2), 123-146.

- Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*: Harvard university press.
- Watson, T. J. (2011). Ethnography, Reality, and Truth: The Vital Need for Studies of 'How Things Work' in Organizations and Management. *Journal of Management Studies*, 48(1), 202-217. doi: 10.1111/j.1467-6486.2010.00979.x
- Weinstein, C. E., & Palmer, D. R. (2002). User's Manual for those administering the Learning and Study Strategies Inventory: H&H Publishing Company, Inc. .
- Wentzel, K. R. (1997). Student motivation in middle school: The role of perceived pedagogical caring. *Journal of Educational Psychology*, 89(3), 411.
- White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction*, 16(1), 3-118.
- Whitebread, D., Anderson, H., Coltman, P., Page, C., Pasternak, D. P., & Mehta, S. (2005). Developing independent learning in the early years. *Education 3-13*, 33(1), 40-50.
- Whitebread, D., Coltman, P., Pasternak, D., Sangster, C., Grau, V., Bingham, S., . . . Demetriou, D. (2009). The development of two observational tools for assessing metacognition and self-regulated learning in young children. *Metacognition and Learning*, 4(1), 63-85. doi: 10.1007/s11409-008-9033-1
- Whitebread, D., & Pino-Pasternak, D. (2013). Video analysis of self-regulated learning in social and naturalistic contexts. In S. Volet & M. Vauras (Eds.), *Interpersonal Regulation of Learning and Motivation: Methodological advance* (pp. 14-44). Abingdon, Oxon: Routledge.
- Winne, P. H., & Hadwin, A. F. (1998). Studying as Self-Regulated Learning. In D. J. Hacker, J. Dunlosky & A. C. Graesser (Eds.), *Metacognition in Educational Theory and Practice* (pp. 277-304). Mahwah, New Jersey: Lawrence Erlbaum Associates, Publishers.
- Winne, P. H., & Nesbit, J. C. (2009). Supporting Self-Regulated Learning with Cognitive Tools. In D. J. Hacker, J. Dunlosky & A. C. Graesser (Eds.), *Handbook of Metacognition in Education* (pp. 319-340). New York, NY: Routledge.
- Yackel, E., Cobb, P., & Wood, T. (1991). Small-group interactions as a source of learning opportunities in second-grade mathematics. *Journal for research in mathematics education*, 390-408.
- Yang, D., Streveler, R. A., Miller, R., & Santiago, A. (2009). Repairing Misconceptions: A Case Study with Advanced Engineering Students on Their Use of Schema Training Modules.
- Zhang, L. J. (2001). Awareness in reading: EFL students' metacognitive knowledge of reading strategies in an acquisition-poor environment. *Language Awareness*, 10(4), 268-288.
- Zimmerman, B. J. (1986). Becoming a self-regulated learner: Which are the key subprocesses? *Contemporary Educational Psychology*, 11(4), 307-313. doi: [http://dx.doi.org/10.1016/0361-476X\(86\)90027-5](http://dx.doi.org/10.1016/0361-476X(86)90027-5)
- Zimmerman, B. J., & Pons, M. M. (1986). Development of a Structured Interview for Assessing Student Use of Self-Regulated Learning Strategies. *American Educational Research Journal*, 23(4), 614-628. doi: 10.2307/1163093
- Zimmerman, B. J., & Schunk, D. H. (2001). *Self-regulated Learning and Academic Achievement : Theoretical Perspectives*. Mahwah, N.J.: L. Erlbaum.
- Zimmerman, B. J., & Schunk, D. H. (2011). *Handbook of self-regulation of learning and performance*. New York: Routledge.

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Appendix A Pilot Study Episode Identification Example

Episodes from Group One Observation					
<i>Episode</i>	<i>Start</i>	<i>End</i>	<i>Total Time</i>	<i>Episode Title</i>	<i>Analysis</i>
1	0:03:13	0:03:59	0:00:46	Prepping	
2	0:04:00	0:05:10	0:01:10	Beginning the Review	x
3	0:05:11	0:05:31	0:00:20	Developmental Math (DM)	
4	0:05:32	0:07:54	0:02:22	Back to Review	x
5	0:07:54	0:08:22	0:00:28	Working on 5-48	
6	0:08:22	0:08:30	0:00:08	DM #2	
7	0:08:31	0:08:49	0:00:18	How I record my HW	
8	0:08:50	0:09:25	0:00:35	Area of a Circle	
9	0:09:26	0:09:45	0:00:19	Drawing a Circle	
10	0:09:46	0:10:05	0:00:19	Duck	
11	0:10:06	0:10:33	0:00:27	Back to 5-48	
12	0:10:34	0:10:44	0:00:10	Internet Meme	
13	0:10:44	0:11:40	0:00:56	PiR2	x
14	0:11:40	0:12:04	0:00:24	Really Bad at Drawing	
15	0:12:05	0:12:15	0:00:10	in2 cause its Area	
16	0:12:16	0:13:51	0:01:35	Pieces?	x
17	0:13:52	0:14:45	0:00:53	Working Independently (WI #1)	
18	0:14:46	0:15:02	0:00:16	Drawing a Table	
19	0:15:03	0:16:13	0:01:10	Drawing and Pizza	
20	0:16:14	0:16:32	0:00:18	WI #2	
21	0:16:33	0:16:50	0:00:17	Take 1/4th	
22	0:16:51	0:17:41	0:00:50	1/4th of Centroid	x
23	0:17:42	0:18:21	0:00:39	WI #3	
24	0:18:22	0:18:43	0:00:21	Checking Answer (CA #1)	
25	0:18:44	0:20:29	0:01:45	WI #4	
26	0:20:30	0:24:27	0:03:57	Did you find Big Axbar and Aybar?	x
27	0:24:27	0:25:03	0:00:36	Make a table next time	
28	0:25:03	0:26:22	0:01:19	Phi Theta Kappa	
29	0:26:23	0:28:16	0:01:53	Is this answer right?	x
30	0:28:16	0:30:11	0:01:55	CA #2	x
31	0:30:11	0:30:39	0:00:28	The Table ?'s	
32	0:30:40	0:30:52	0:00:12	I've always turned in my homework	
33	0:30:52	0:31:17	0:00:25	CA #3	
34	0:31:17	0:31:39	0:00:22	I can do 55	
35	0:31:40	0:32:08	0:00:28	I'm scared about tomorrow	
36	0:32:09	0:32:50	0:00:41	New Problem Starting - Last Problem is 3D	

THINKING ABOUT THINKING IN STUDY GROUPS

37	0:32:50	0:34:53	0:02:03	WI #5	
38	0:34:54	0:35:50	0:00:56	Remind you of Intro to Eng?	
39	0:35:50	0:36:10	0:00:20	Answering your own questions	
40	0:36:10	0:37:05	0:00:55	WI #6	
41	0:37:05	0:39:04	0:01:59	CA #4	x
42	0:39:04	0:40:33	0:01:29	Make a mistake in the y somewhere	x
43	0:40:33	0:42:05	0:01:32	WI #7	
44	0:42:05	0:42:47	0:00:42	How is that possible?	x
45	0:42:47	0:43:10	0:00:23	PiD? PiR2?	
46	0:43:10	0:43:38	0:00:28	WI #8	
47	0:43:38	0:45:05	0:01:27	Someone comes in	
48	0:45:05	0:45:16	0:00:11	Teamwork	
49	0:45:16	0:45:38	0:00:22	We're going to have these done in 5 minutes	x
50	0:45:38	0:46:42	0:01:04	3D Prob Aww	x
51	0:46:42	0:47:23	0:00:41	Fun Fact	
52	0:47:23	0:47:23	0:00:00	WI #9	
53	0:47:43	0:48:04	0:00:21	Ginormous #'s	
54	0:48:04	0:49:13	0:01:09	Something tells me I did something wrong CA#5	x
55	0:49:13	0:49:45	0:00:32	Hope she didn't mind	
56	0:49:45	0:50:30	0:00:45	Volume = Area * Height?	x
57	0:50:30	0:51:18	0:00:48	WI #10	
58	0:51:18	0:52:22	0:01:04	CA #6	x
59				Z axis	
60	0:00:11	0:00:30	0:00:19	Quiet	
61	0:00:30	0:01:07	0:00:37	Centroid Negative?	
62	0:01:07	0:01:58	0:00:51	Proper Eng Format	
63	0:01:59	0:02:45	0:00:46	MM asking questions	
64	0:02:45	0:03:51	0:01:06	Expanding the Triangle	
65	0:03:51	0:13:51	0:10:00	Purpose of the drawing – Noise	
66	0:13:51	0:14:43	0:00:52	2,000,000 mm <sup>3</sup> ?	
67	0:14:43	0:15:13	0:00:30	CA #7	
68	0:15:13	0:15:32	0:00:19	Big #'s?	
69	0:15:32	0:15:51	0:00:19	Coordinates	
70	0:15:51	0:16:32	0:00:41	Homogeneous Body	
71	0:16:32	0:16:59	0:00:27	WI #11	
72	0:16:59	0:18:18	0:01:19	3 Sections	
73	0:18:18	0:18:40	0:00:22	WI #12	
74	0:18:40	0:19:03	0:00:23	CA #8	
75	0:19:03	0:19:22	0:00:19	These are easy	
76	0:19:22	0:19:55	0:00:33	Someone enters	

THINKING ABOUT THINKING IN STUDY GROUPS

77	0:19:55	0:20:22	0:00:27	I'm done - fries	
78	0:20:22	0:21:33	0:01:11	Stupid Questions	
79	0:21:33	0:22:00	0:00:27	Really bad at math	
80	0:22:00	0:22:50	0:00:50	You've made it this far	
81	0:22:50	0:23:45	0:00:55	Forever to draw stuff	
82	0:23:45	0:24:12	0:00:27	WI #13	
83	0:24:12	0:24:40	0:00:28	Your x is negative	
84	0:24:40	0:27:12	0:02:32	Checking Strategy	
85	0:27:12	0:27:35	0:00:23	?	
86	0:27:35	0:29:16	0:01:41	How we write our solutions	
87	0:29:16	0:29:31	0:00:15	This is almost over	
88	0:29:31	0:29:55	0:00:24	Section 2	
89	0:29:55	0:30:27	0:00:32	WI #14	
90	0:30:27	0:30:59	0:00:32	Approximation	
91	0:30:59	0:31:25	0:00:26	Washing Machine	
92	0:31:25	0:33:00	0:01:35	CA #9	
93	0:33:00	0:33:37	0:00:37	sneak	
94	0:33:37	0:34:03	0:00:26	WI #15	
95	0:34:03	0:34:16	0:00:13	CA #10	
96	0:34:16	0:35:05	0:00:49	Big #'s	
97	0:35:05	0:35:45	0:00:40	WI #16	
98	0:35:45	0:36:08	0:00:23	Likes my graph	
99	0:36:08	0:36:47	0:00:39	Math Mode	
100	0:36:47	0:37:15	0:00:28	Huge #	
101	0:37:15	0:38:24	0:01:09	4 more calculations WI #16	
102	0:38:24	0:39:10	0:00:46	Km or mm	
103	0:39:10	0:40:15	0:01:05	WI #17	
104	0:40:15	0:40:56	0:00:41	Sum V	
105	0:40:56	0:41:13	0:00:17	I finish 1!	
106	0:41:13	0:42:31	0:01:18	WI #18 - crap	
107	0:42:31	0:42:56	0:00:25	HW 555	
108	0:42:56	0:45:03	0:02:07	crap it's smaller - CA #11	
		Average	0:00:52		

**Appendix B Original Whitebread et al. (2009) Coding Strategy**

C.Ind.Le Coding Scheme: Verbal and Nonverbal Indicators of Metacognition and Self-Regulation in 3- to 5-Year-Olds

Category Name	Description of Behavior	Example
<b>Metacognitive Knowledge</b>		
<i>Knowledge of Persons</i>		
A verbalization demonstrating the explicit expression of one's knowledge in relation to cognition or people as cognitive processors. It might include knowledge about cognition in relation to:		<i>I can write my name</i>
Self: Refers to own capabilities, strengths and weaknesses, or academic/task preferences; comparative judgments about own abilities	Refers to his/her own strengths or difficulties in learning and academic working skills	<i>I can count backwards</i>
Others: Refers to others' processes of thinking or feeling toward cognitive tasks	Refers to others' strengths or difficulties in learning and academic working skills	<i>I don't know how to sing the song</i>
Universals: Refers to universals of people's cognition	Talks about general ideas about learning	
<i>Knowledge of tasks</i>		
A verbalization demonstrating the explicit expression one's own long-term memory knowledge in relation to elements of the task.	Compares across tasks identifying similarities and differences	<i>They need to put their boots on. And when they put their boots on, they dig a hole.</i>
	Makes a judgment about the level of difficulty of cognitive tasks or rates the tasks on the basis of pre-established criteria or previous knowledge	

THINKING ABOUT THINKING IN STUDY GROUPS

Category Name	Description of Behavior	Example
<i>Knowledge of strategies</i>		
A verbalization demonstrating the explicit expression one's own knowledge in relation to strategies used or performing a cognitive task, where a strategy is cognitive or behavioral activity that is employed so as to enhance performance or achieve a goal.	Defines, explains, or teaches others how she/he has done or learned something	<i>We don't need to use the sticky tape, we can use the glue.</i>
	Explains procedures involved in a particular task	<i>You have to point it up this end so that it is going to grow.</i>
	Evaluates the effectiveness of one or more strategies in relation to the context or the cognitive task.	
<b>Metacognitive regulation</b>		
<i>Planning</i>		
Any verbalization or behavior related to the selection of procedures necessary for performing the task, individually or with others	Sets or clarifies task demands and expectations	<i>I'm going to make a big circle.</i>
	Allocates individual roles and negotiates responsibilities	<i>I know...me and Harry could be the knights and you could be the peasant.</i>
	Sets goals and targets	Child compares two objects before deciding which to use on a task.
	Decides on ways of proceeding with the task Seeks and collects necessary resources	

THINKING ABOUT THINKING IN STUDY GROUPS

Category Name	Description of Behavior	Example
<i>Monitoring</i>		
Any verbalization or behavior related to the ongoing on-task assessment of the quality of task performance (of self or others) and the degree to which performance is progressing towards a desired goal	Self-commentates	<i>I think we've got one left</i>
	Reviews progress on task (keeping track of procedures currently being undertaken and those that have been done so far)	<i>This bit doesn't fit anywhere</i>
	Rates effort on-task or rates actual performance	<i>Hang on, we've got it a bit wrong here</i>
	Rates or makes comments on currently memory retrieval	Child stops mid-way through an action (placing puzzle piece), pauses and redirects action to place it somewhere else.
	Checks behaviors or performance, including detection of errors	
	Self-corrects	
	Checks and/or corrects performance of peer	
<i>Control</i>		
Any verbalization or behavior related to a change in the way a task had been conducted (by self or others), as a results of cognitive monitoring	Changes strategies as a result of previous monitoring	<i>Can you help me do it?</i>
	Suggests and uses strategies in order to solve the task more effectively	<i>Let's have a practice.</i>
	Applies a previously learnt strategy to a new situation	Child points to spots on a die as he counts
	Repeats a strategy in order to check the accuracy of the outcome	Child looks at a physical model (example: word on a whiteboard) repeatedly while completing a task
	Seeks help	Child points at computer screen or interactive whiteboard to indicate where another child should click the mouse
	Uses nonverbal gesture as a strategy to support own cognitive activity	
	Copies from or imitates a model Helps or guides another child using gesture	

## THINKING ABOUT THINKING IN STUDY GROUPS

Category Name	Description of Behavior	Example
<i>Evaluation</i>		
Any verbalization or behavior related to reviewing task performance and evaluating the quality of performance (by self or others)	Reviews own learning or explains the task	<i>He's done really well</i>
	Evaluates the strategies used	<i>We learnt how to cut, and how to stick things together</i>
	Rates the quality of performance	Child rotates scissors in hands while opening and closing them before initiating cutting activity
	Observes or comments on task progress	
	Tests the outcome or effectiveness of a strategy in achieving a goal	
<b>Emotional and motivational regulation</b>		
<i>Emotional /motivation monitoring</i>		
Any verbalization or behavior related to the assessment of current emotional and motivation experiences regarding the task.	Express awareness of positive or negative emotional experience of a task	<i>That wasn't very bad</i>
	Monitors own emotional reactions while being on a task	<i>It's a bit sad</i>
		<i>I don't want to be a peasant</i>
<i>Emotional/motivational control</i>		
Any verbalization or behavior related to the regulation of one's emotional and motivational experiences while on the task.	Controls attention and resists distraction or returns to task after momentary distraction	<i>Mine is going to be a lovely one</i>
	Self-encourages or encourages others	Child looks towards activity of others in the classroom, then re-focuses on task at hand and resumes activity
	Persists in the face of difficulty or remains in task without help	

## THINKING ABOUT THINKING IN STUDY GROUPS

### Appendix C Pilot Study Coded Episode Example

	Who		Individual or Group?	Orientation and Depth		Indicator and focus	Social nature and function in context
		Episode 2					
1	J	(???) How you do these things is...	I	K	L		This is the beginning of the study session between John and Steven. Steven missed the last class and so at the beginning of the session, John works to review what was gone over in class for Steven so that they can begin to work on the homework that has been assigned. As John reviews, he stands in front of Steven and reviews from his notes and the text book.
2	J	I'll go over roughly what we did now...	I	K	L	KofS, Plan	
3	J	so, he explained two different methods. One using integration which is bad. Like, seriously bad.	I	K	L		
4	S	S: Is that by parts? like...	G	K	L		
5	J	No..it's not integration by parts but its uh you have to use several different (???) so weird.	I	K	H		
6	J	We should have to use it for the problems, excuse me, that we have.	I	K	H	KofS	
7	J	But the integration part is easy but its just weird trying to get to that part.				KofT	
8	J	So, the prob...the example he gave was problem 47. And it was , yeah. They give you all the dimensions and everything so you don't have to find anything. But..you first start out...	I	K	H		
9	J	cause the objective is to find the centroid,	I	K	H	KofT, Plan	
10	J	which is the center of gravity of it. From what I understand...So, that means you first go out by finding the area...you have to split it into easy sections...I mean you could find the area of the whole thing	I	K	H		
11	J	but it's really difficult.	I	K	H	KofT	
12	S	S: <i>It'd be easier to have a rectangle and triangle.</i>	G	K	H	KofT	
13	J	J: <i>Because it's a rectangle and triangle you obviously split it into different sections.</i>	G	K	H	KofS	
14	J	Sorry, I am used to teaching developmental math while I was helping with them (laughs)	G	K	H		
15	S	S: (laughs)	G	K	H		
16	J	J: So, I'm like going in baby steps at this point. I know, yeah.	G	K	H		

## Appendix D Interview Protocol

Based on the observations that I've done so far, there are some things that I've noticed that I just wanted to ask you a little bit more about. Most of these questions pertain to what happens with your group. Feel free to ask me questions or tell me one of my questions doesn't make sense.

### GROUP

- Why do you work in a group?
  - Are there any other reasons?
- Do you always work in a group for this class or do you ever work individually? I see you work in a group. Do you also work individually?
  - When?
  - Why?
  - How is working in a group different from working individually?
- (For groups that are mixed instructors): Tell me about working in a group that has people from different classes.
- Most of what I've been watching you do to this point is working on homework problems. What other types of studying do you do? How is studying different when working on homework and preparing for an exam?

### RESOURCES

- Based on what I've seen, it looks like your group uses the following resources:

LIST:

- Are there any that I'm missing?
- I'm interested in your use of example problems for ConApps. Why are example problems helpful?
  - What would you do if you didn't have example problems in ConApps?
  - What about Esys? What resource do you use most?
- Think about the notes and the example problems that you get in ConApps. Is there something that could be done to improve on these resources to be more helpful to your learning?
  - Probe for gaps in examples

## THINKING ABOUT THINKING IN STUDY GROUPS

- I've noticed that sometimes you're group works from a common space like a whiteboard or a common piece of paper. Tell me more about putting something up on the whiteboard or on a common space. How do you think that process is helpful
- I've also noticed that you all frequently check your answers with each other. Why do you do this? How is checking answers with peers helpful?
  - Sometimes the professor gives you the final answer to your homework solutions. Is this helpful? How?
  - Every now and then, you have a full solution to a homework problem. Is this helpful? Why?
  - Which situation do you think you learn the most in? (no answer, check answer with peers, check answer with answer from prof, check solution against another solution) Why?

### PROBLEM FORMAT

- Sometimes, you all start to set up a problem and then you say something like "I have no idea how to start this problem."
  - What if no one in your group knows how to start a problem? What do you do?

### PROBLEM CHARACTERISTICS

- Something else I've noticed when observing is that sometimes you all will say something like "Oh this problem is really easy." Or "Crap, this problem is really hard."
  - How do you look at a problem and determine if it's easy or hard?
  - Does how you classify the problem affect how you approach solving it? If so, how?

### VIEW OF KNOWLEDGE

- As I've observed, I've noticed that you all ask a lot of questions of each other while you study. Do you ask questions during class? Why or why not?
  - Are there questions that you have during class that you don't ask? If so, why?
- I heard someone say one evening "My professor wrote the textbook in this class." If your professor, wrote the textbook, do you think that would impact whether you asked question in class or not? Why?

### MOTIVATION

- What is your overall sense of motivation in ConApps?
  - Grades
  - Learning
  - Being an engineer
  - Take it because I have to –
    - How this class connects to anything else
    - Is it different from Esys?

### CONFIDENCE

## THINKING ABOUT THINKING IN STUDY GROUPS

- What is your level of confidence in your ability to do well in ConApps? 1-10.
  - How does your confidence level impact your thought process while you study?

### **METACOGNITION**

- When I come and observe, I am looking for whether you are engaging in metacognition or not. Are you familiar with the term metacognition?

Metacognition is a person's knowledge and regulation of their learning processes. We can think of it this way: (provide categories of metacognition – or maybe the framework tree with short definitions)

Let me ask you: Do you think that you use metacognition when you study? Can you give me some examples?

Think about how you study. If you had to rank these boxes in order from what you use the most to what you use the least, could you do that?

Why did you rank these in this way?

THINKING ABOUT THINKING IN STUDY GROUPS

**Appendix E Full Study Coded Episode Examples**

Example of Coding: LIB Observation 3 (Middle of problem)

Observed Behavior	Analysis		
	Explanation	Primary Code	Subcode
S: Now we need to find water and jam, right?	S asks about the strategy that she should use to complete the task.	monitoring	checks strategy
R: We need to find how much of each thing is in the mixture. Like how much mass.	R explains the procedure they should use to complete the task.	knowledge of strategy	explains procedures involved in a
S: Ok.			
R: And then from there we can do percentages. For the composition. So...	R continues to explain the procedures needed to complete the task.	knowledge of strategy	explains procedures involved in a
S: So is this a bit like when we were doing the umm ideal gas law last time.	S compares the procedures used in this task to a previous task.	knowledge of task	compares across different tasks
R: Yeah, a little bit. It's just not a gas this time.	R cites differences in this procedure when comparing to a previous task.	knowledge of task	compares across different tasks
S: Yeah.			
A: So we take the percentage times that amount?	A asks about the strategy that he should use to complete the task.	monitoring	checks strategy
R: Uh yeah.	R comments that the strategy that A suggests is correct	evaluation	comments on correctness/accuracy
A: To fill in the mixture portion.	A asks about the strategy that he should use to complete the task.	monitoring	checks strategy
R: Mhmm.	R comments that the strategy that A suggests is correct	evaluation	comments on correctness/accuracy
S: Ok, so...			

## THINKING ABOUT THINKING IN STUDY GROUPS

Example of Coding: ON Observation 8

Observed Behavior	Analysis		
	Explanation	Primary Code	Subcode
Q: No.			
J: You're going to lose points for not writing it down.	J states that Q has not properly accomplished the task because he has correctly developed the equations.	evaluation	comments on success/quality of performance
Q: I don't need that whole thing.	Q considers what J has said and decides that Q's strategy is effective at completing the task.	evaluation	evaluates the effectiveness of one or more
J: Yes you do. It's [problem solving course]. I'm not even kidding.			
Q: I wrote it. I wrote it.	Q states that he has successfully completed a portion of the task.	evaluation	comments on progress
J: Ok. great.			
Q: This is it. I'm just doing it piece by piece instead of...see how that has a whole thing that adds up to the no change in rate. Basically, I'm doing every piece. Like I'm doing that one then that one then that one then that one (points to the sheet). Separately.	Q explains the procedures that he has used to complete the task.	knowledge of strategy	defines, explains to others how she/he has done something
J: Ok.			
Q: It all works.	Q states that the procedures that he has used are effective at completing the task.	evaluation	comments on success/quality of performance
J: It's not about working cause it's going to work.	J states that the strategy will work.	evaluation	comments on success/quality of performance
Q: Right...but it...it works out the [problem solving course] way. Maybe I should put some variables in but I think....I think [teacher] would understand.	Q states that the strategy will work then makes a plan to make the strategy more effective.	evaluation	comments on success/quality of performance; making a plan

# THINKING ABOUT THINKING IN STUDY GROUPS

## Appendix F: Self-Reported Behaviors Compared with Observed Behaviors

OFF	Daniel		Adam		Leonard		Terry		Match	Unmatch	Total
	Observed Rank	Self-Reported Rank									
Knowledge of Persons\Self	2	1	4	1	4	1	4	3			
Knowledge of Persons\Others	4	4	3	2	3	2	3	4			
Knowledge of Persons\Universals	5	5	5	4	5	5	5	5			
Knowledge of Task	3	3	2	4	2	3	2	2			
Knowledge of Strategy	1	2	1	3	1	4	1	1			
Control	4	1	4	1	4	1	4	3			
Evaluation	2	1	2	3	2	3	3	3			
Monitoring	1	1	1	2	1	2	1	2			
Planning	3	1	3	4	3	4	2	1			
LIB	Becca		Gary		Benjamin		Micheal		Jenny		Total
	Observed Rank	Self-Reported Rank									
Knowledge of Persons\Self	3	3	2	3	3	2	3	1	3	3	
Knowledge of Persons\Others	4	2	2	5	4	4	4	4	4	4	
Knowledge of Persons\Universals	5	4	2	4	5	5	4	5	5	1	
Knowledge of Task	2	5	2	2	2	3	2	3	2	2	
Knowledge of Strategy	1	1	1	1	1	1	1	2	1	1	
Control	4	2	3	1	4	1	3	1	4	1	
Evaluation	2	3	2	4	2	3	4	3	3	3	
Monitoring	1	4	1	3	1	3	1	4	1	4	
Planning	3	1	4	2	3	2	2	2	2	2	
ON	Wilson		Chris		Total						
	Observed Rank	Self-Reported Rank	Observed Rank	Self-Reported Rank							
Knowledge of Persons\Self	3		3	5							
Knowledge of Persons\Others	4		4	3							
Knowledge of Persons\Universals	5		4	4							
Knowledge of Task	2		2	2							
Knowledge of Strategy	1		1	1							
Control	4	3	4	2							
Evaluation	2	1	2	3							
Monitoring	1	4	1	1							
Planning	3	2	3	4							

THINKING ABOUT THINKING IN STUDY GROUPS

<b>Appendix G: Findings for Thinking About Thinking Study</b>		
<b>Finding</b>	<b>Explanation/Credibility</b>	<b>Implications/Suggestions</b>
Assessment Methods for Study Metacognition		
The development of the NOME coding strategy provides support for the use of observational methods for identifying metacognitive behavior in naturalistic settings	Supported by the work of Whitebread (2009)	Future research should focus on studying metacognition in different contexts and disciplines. This type of research could help us understand how metacognitive habits generalize across contexts and domains.
Support that participants cannot fully self-report metacognitive behaviors	Supported by Veenman (2011), Printrich et al. (2000)	There is still significant concern that self-report methods cannot accurately represent the actual behaviors of participants. This research further supports that claim.
<i>Emergent Behaviors</i>		
Homework Format	Emerged due to context of class	
Current Plan		
Mental Clarity, Comments on Understanding, Checks Understanding, Verbally Repeats	Emerged due to developmental differences between 3-5 years olds and undergraduate students	
Known/Unknown Info, Checks Strategy, Checks Answers, Covered, Reasonableness	Emerged due to differences in context between play and engineering	
Checks goals		
<i>Unsupported Behaviors</i>		
Knowledge of Universals	Minimal discussion in current literature	
Set goals or targets	Student goals may be implicit or discussed in other contexts	

## THINKING ABOUT THINKING IN STUDY GROUPS

Suggests and uses strategies in order to solve the task more effectively	Limited knowledge of content may have limited engagement	
Applies a previously learnt strategy to a new situation	Context of PSH course may have limited engagement	
A Picture of Metacognitive Engagement in Education		
This study identified specific metacognitive behaviors observed in a naturalistic setting in an engineering context.	Builds upon the work of researchers such as Whitebread (Whitebread et al., 2005; Whitebread et al., 2009; Whitebread & Pino-Pasternak, 2013), Bryce (Bryce & Whitebread, 2012), Volet (Volet, Summers, et al., 2009; Volet et al., 2013), and Rogat (Rogat & Linnenbrink-Garcia, 2013).	These descriptions of behaviors can be used to inform past and future research looking at metacognition in engineering.
There is evidence of higher engagement in regulatory activities than discussions of metacognitive knowledge.	Supported by the focus in literature on pedagogical interventions to develop metacognitive regulatory activities.	Due to the fact that metacognitive knowledge is also important in learning, can be accurate or inaccurate, and can be very resistant to change, future work should focus on developing pedagogical interventions with the purpose of building accurate metacognitive knowledge.
A Picture of Metacognition in Engineering Education		
Monitoring activities were identified as the majority activity in metacognitive regulation.	Supported by the work of Litzinger et al. (2010) that shows that students engaged in problem-solving engage in more monitoring than evaluation	

## THINKING ABOUT THINKING IN STUDY GROUPS

	activities.	
Evaluation activities focused on evaluating time to completion.	The work of Case et al. (2001) found that novice students in a chemical engineering course started the course by focusing on estimates of time to completion.	Educational practitioners should focus on helping students develop methods for self-assessment that focus on learning objectives and shift away from time to completion.
Participants engaged in evaluation strategies that look at the reasonableness of solutions at a lower rate than other evaluation strategies.	This may be because students do not have enough knowledge about the context of a problem to make a reasonableness judgement.	As educational practitioners, we must either select problem contexts that are familiar to our students or provide them with the resources needed to make reasonableness judgments.
Under the category of planning, students did not explicitly state the goals that they had for a study session or task.	Student goals may be implicit or discussed in other contexts	Due to the important role of goals in learning, it could be equally important to help students engage in the process of explicitly stating goals for learning in order to impress upon our students the critical nature that those goals have on actual learning outcomes.
<b>The Impact of Context on Metacognitive Engagement</b>		
Learning Environment: There is potential impact on metacognitive engagement due to the structure of the learning environment.	Also cited as a contextual factor in SRL literature, like Zimmerman and Schunk (2001)	These three contextual factors call for a need to focus on study skill development for undergraduate engineering students. We should

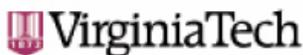
## THINKING ABOUT THINKING IN STUDY GROUPS

<p>Learning Resources: Through my research, I found that student groups that used fully worked solutions tended to engage in fewer metacognitive behaviors, specifically in the areas of monitoring and evaluation.</p>	<p>Supported by the work of Chi et al. (1989)</p>	<p>focus on developing ways to integrate instruction on learning and study skills into the engineering curriculum.</p>
<p>Study Group Schedule: Metacognitive engagement was potentially impacted by study group schedule, specifically how close in proximity to the assignment deadline was to when the work was completed.</p>	<p>Achievement goal literature suggests that a shift in goals can occur due to competing demands (Fryer and Elliot, 2008)</p>	
<p>Workload: Metacognitive engagement was potentially impacted by student workload.</p>		<p>Instructors should work with one another to ensure that the scheduling of assignments and examinations is as balanced as possible. Negotiations should occur to ensure that situations do not arise where students have exams or projects due in every course in a short amount of time, if at all possible.</p>
<p>Study Group Purpose: In the context of the current study, it is possible that, while studying for their exam, LIB had inaccurate knowledge about their own understanding and abilities and thus chose study strategies that were not suited for their actual level of knowledge.</p>	<p>Evidence that metacognitive knowledge is not always accurate, like Pintrich (2002)</p>	<p>Focusing on activities that help students build accurate metacognitive knowledge can help them more accurately determine how they should prepare for examinations.</p>

## THINKING ABOUT THINKING IN STUDY GROUPS

<p>Three contextual factors identified (learning environment, learning resources, study group schedule) have the common theme that they are intentional choices made by study group members. This theme reflects choices in study habits or study skills.</p>	<p>Supported by work of Winne and Nesbit (2009)</p>	<p>These three contextual factors call for a need to focus on study skill development for undergraduate engineering students. We should focus on developing ways to integrate instruction on learning and study skills into the engineering curriculum.</p>
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Appendix H: IRB Approval Letter



**Office of Research Compliance**  
Institutional Review Board  
North End Center, Suite 4120, Virginia Tech  
300 Turner Street NW  
Blacksburg, Virginia 24061  
540/231-4606 Fax 540/231-0959  
email [irb@vt.edu](mailto:irb@vt.edu)  
website <http://www.irb.vt.edu>

**MEMORANDUM**

**DATE:** May 6, 2014  
**TO:** Holly Matusovich, Rachel Mccord  
**FROM:** Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)  
**PROTOCOL TITLE:** Student Use of Metacognitive Practices While Studying: A Naturalistic Approach to Studying Metacognition (Full Study)  
**IRB NUMBER:** 13-645

Effective May 6, 2014, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Amendment request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

<http://www.irb.vt.edu/pages/responsibilities.htm>

(Please review responsibilities before the commencement of your research.)

**PROTOCOL INFORMATION:**

Approved As: **Expedited, under 45 CFR 46.110 category(ies) 6,7**  
Protocol Approval Date: **August 13, 2013**  
Protocol Expiration Date: **August 12, 2014**  
Continuing Review Due Date\*: **July 29, 2014**

\*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

**FEDERALLY FUNDED RESEARCH REQUIREMENTS:**

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

*Invent the Future*

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY  
*An equal opportunity, affirmative action institution*

# THINKING ABOUT THINKING IN STUDY GROUPS

IRB Number 13-645

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Virginia Tech Institutional Review Board

Date*	OSP Number	Sponsor	Grant Comparison Conducted?

\* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office ([irbadmin@vt.edu](mailto:irbadmin@vt.edu)) immediately.

## **Appendix I: Participant Consent Form**

### **VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY Informed Consent (Student Observations and Interviews)**

#### **Title of Research Study**

Student Use of Metacognitive Practices While Studying:  
A Naturalistic Approach to Studying Metacognition (Full Study)

#### **Research Investigators**

Dr. Holly Matusovich (Engineering Education) – Principle Investigator  
Rachel McCord (Engineering Education) – Co-Investigator

#### **I. Purpose of the Research**

This study involves research and its overall goal is to investigate the metacognitive practices used by undergraduate engineering students when studying. All participants of this study will be undergraduate students in an engineering discipline.

#### **II. Procedures**

My participation in the above-mentioned observations will involve studying with a minimum of 2 students and 1 researcher. The time and location of this observation will be set by the study group. During this session, I will be asked to study with my group as I normally would. The observation session will video and audio recorded so that the researcher can use the video and audio for analysis. The researcher present will also be taking notes during the observation session. Finally, the researcher may ask to take pictures or make copies of different artifacts that are used during the observed session. All identifying information on these artifacts will be kept confidential.

After an observation session, I may be asked to participate in an interview. This interview will ask me questions about the experiences from the study session that just occurred and other general questions about the course that we are studying for. The interview will be audio-recorded for the purpose of transcription.

As part of this study, the researcher will also ask me to self-report my grades for the academic term. I will be asked to provide these grades at the end of the term.

#### **III. Risks**

The risks associated with participating in this research are minimal.

#### **IV. Benefits**

The risks associated with participating in this research are minimal and there are no known benefits to participants. The data collected from participants during this research will be developed into one or more papers for publication in academic journals or for presentation at professional conferences.

**V. Extent of Anonymity and Confidentiality**

My identity, and that of any individuals who I mention, will be kept confidential at all times and will be known only to members of the research team and other members of the study group. The above-mentioned study group session will be video recorded. The interviews will be audio recorded and later transcribed by a member of the research team or a professional transcriber. When transcribing the focus group recordings, pseudonyms (i.e., false names) will be used for my name and for the names of any other people who I mention. These pseudonyms will also be used in preparing all written reports of the research. Any details in the study group recordings that could identify me, or anyone who I mention, will also be altered during the transcription process. After the transcribing is complete, the study group recordings will be stored in locked offices used by the research team. Identifying information will also be removed from any notes made during the study groups and these notes will be stored in locked offices used by the research team. The video and audio recordings, transcriptions and notes will be stored indefinitely.

It is possible that the Institutional Review Board (IRB) at Virginia Tech will view this study's collected data for auditing purposes. The IRB is responsible for overseeing the protection of human subjects who are involved in research.

**VI. Compensation**

My study group will be compensated with snacks for each study group session that is observed.

**VII. Freedom to Withdraw**

My participation in this research is entirely voluntary and my refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. Similarly, I am free to withdraw from this research at any time. If I choose to withdraw from the research, any information about me and any data not already analyzed will be destroyed. I am free to choose to not answer any question, or to not complete any activity, and this choice will involve no penalty or loss of the above-mentioned benefits.

**VIII. Participant's Responsibilities**

I voluntarily agree to participate in this research. I have the following responsibilities: (1) to participate in study groups and at least one interview lasting no more than 1 hour that involves the activities described in Section II above, and (2) to keep the identity of all study group participants confidential.

**IX. Participant's Permission**

I have read and understand the *Informed Consent* and the conditions of this research. I have also had all of my questions answered. I hereby acknowledge the above and give my voluntary consent:

\_\_\_\_\_ Date \_\_\_\_\_  
Signature of Participant

\_\_\_\_\_  
Printed Name

If I have any questions about this research or how it is conducted, my rights as a participant, or whom to contact in the event of a research-related injury to me, I can contact:

## THINKING ABOUT THINKING IN STUDY GROUPS

Dr. Holly Matusovich, Principal Investigator	(540) 231-4205 matushm@vt.edu
Dr. Stephanie Adams, Department Chair	(540) 231-6555 sgadams@vt.edu
Dr. David M. Moore, Chair, Virginia Tech Institutional Review Board for the Protection of Human Subjects Office of Research Compliance	(540) 231-4991 moored@vt.edu

## Appendix J: IRB Recruiting Statement

### Attachment D: Recruiting

The study will be advertised at the school via email. Research participants will be identified through personal contacts of Rachel McCord. Personal contacts will ask potential members if they are willing to be contacted about participation in a research study about study groups. If permission is give, the personal contact will pass on contact information to Rachel McCord. Potential participants will be contacted through the following email.

Dear [possible participant]-

I am conducting a research study regarding how people learn in engineering. Specifically, I am interested in how people learn in study groups while studying engineering coursework. Your name was passed on to me as someone who works in a study group that focuses on engineering content.

The study sessions will be video recorded for the purpose of analysis by the researcher. During the study sessions, you will be asked to study as you and your group normally would. The researcher may also ask to take a picture of documents that you and your study group work on during the study session. You may also be asked to participate in a short interview to discuss your experiences in the study group. At the end of the semester, the researcher will also request that you self-report your grades for the academic term.

Participation is completely confidential. Your identity will be known only to the researcher (R. McCord). Participation will have no impact on grades, academic standing or eligibility for any activities. Participant groups will be compensated with snacks for each study group session that is observed.

Would it be possible for me to come to your study group and talk about my study to see if you are interested in participating? If you are willing to participate in this study, please respond to this email. If you do not respond, you will not be contacted again regarding this study. You must be 18 years of age or older to participate.

Thank you for your consideration.

Rachel McCord  
Graduate Student  
Department of Engineering Education  
[mrachel@vt.edu](mailto:mrachel@vt.edu)  
(804) 836-9657