ABSTRACT

SPENCER, DAN. Enhancing Socially-Shared Metacognition in Introductory Geology. (Under the direction of John Nietfeld and Margareta Thomson.)

The ability to collaborate successfully with others is a highly-valued skill in the modern workplace and has been reflected in the increase of collaborative learning methods within education. Prior research has highlighted the crucial role of regulatory strategies in students’ ability to successfully collaborate. However, this work has predominantly focused on how individuals regulate themselves in group contexts, and as such does not fully integrate the social and regulatory interaction between group members. As a result, recent research has shifted to understand how groups regulate their interactions and how this affects their learning. The current study aimed to compare the effectiveness of using individual- or group-centered problematizing prompts during group review activities to increase the frequency of social metacognitive activities and performance of undergraduate geology students.

Tentative study findings suggest that group-centered problematizing prompts were moderately successful in shifting groups towards more social forms of regulation such as co-regulation; however, were not enough to move groups towards shared metacognitive regulation. Further, qualitative analyses revealed lowered levels of group engagement in aspects of the intervention during task completion for groups in the control condition. No differences between conditions were observed in the function and focus of regulatory episodes or the influence of group dynamics on collaboration. Experimental conditions also showed a minimal impact on monitoring accuracy during review activities, with the individual condition evidencing lower bias scores compared to the control condition on the final review activity. Finally, experimental conditions were found to have no impact on
group performance during review activities. However, those in the individual condition were found to perform lower on a collaborative midterm exam compared to the control condition.
Enhancing Socially-Shared Metacognition in Introductory Geology

by
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CHAPTER ONE

Introduction

The ability to collaborate successfully with others is a highly-valued skill in the modern workplace (Barron, 2000; Casner-Lotto & Barrington, 2006) and has been reflected in the uptake of collaborative learning methods in the classroom aimed at providing opportunities for shared knowledge construction and productive collaborative interactions (Ocker & Yaverbaum, 1999). Despite the potential of collaboration to promote positive learning outcomes, simply placing individuals together in a group does not automatically result in collaboration or productive interactions (Janssen, Erkens, Kirschner, & Kanselaar, 2012; Jarvela et al., 2014). The lack of productive collaborative interactions observed in groups led to efforts to increase collaborative performance through understanding how collaborative tasks affect individuals’ ability to regulate their cognitive, behavioral, and motivational strategies, known to be crucial to effective learning (Bol, Hacker, Waleck, & Nunnery, 2012; DiDonato, 2013).

Theoretically, there has been an acknowledgment of the importance of social context for the development of regulation (e.g., Schunk & Zimmerman, 1997). However, research investigating self-regulation in collaboration has predominantly focused on individuals and their contribution to the group, with a limited amount of work investigating the impact of regulatory processes of the group as a whole (Panadero & Jarvela, 2015; Volet, Vauras & Salonen, 2009). Researchers have therefore sought to re-contextualize SRL in social/collaborative settings, expanding understandings of regulation from the individual
(SRL), to how groups jointly regulate their cognitive, behavioral and motivational strategies in collaborative work (termed socially-shared regulation) (Hadwin et al., 2011).

Over the past decade, there has been a rise in literature aimed at both understanding social regulation across age groups and domains, as well as the differences between high and low regulating groups (Panadero & Jarvela, 2015). However, despite prior research providing the field with an understanding of how social regulation occurs, little is known about what impacts or how to foster social-regulatory processes.

**Study Purpose**

The purpose of the current study was to understand how socially-shared regulation occurs in collaborative learning groups of college students within an online introductory geology course, as well as to explore how to foster this form of regulation in groups. More specifically, the current study built upon the work of Molenaar, Sleegers, and van Boxtel (2014) and examined the use of problematizing prompts to increase social metacognitive activities of undergraduate geology students. Over the course of a semester, student-participants took part in researcher-designed group activities that used either a social regulatory or individual regulatory framework. A concurrent mixed methods design was used to investigate the impact of both frameworks on the occurrence of metacognitive episodes during collaboration, as well as changes in performance and monitoring accuracy over time.

**Theoretical Framework**

The theoretical framework for the current study combined elements from different theoretical perspectives, presented as a hierarchical model: 1) *Collaborative learning* is the
most generic level of the theoretical framework, framing the context in which the study is situated. 2) Within this, and viewed through the lens of collaborative learning, is *regulation of learning* which comprises three forms of regulation spanning the social/collaborative continuum (self-regulated learning, co-regulated learning, and socially-shared regulation of learning). 3) *Metacognition*, the construct of focus in the current study, is placed in the lowest level of the theoretical framework. As a component of regulation, it is also viewed as occurring across the social continuum (individual, other, and social metacognition).

**Collaborative learning**

In the broadest sense, collaborative learning refers to any situation in which two or more people learn (or attempt to learn) something together (Dillenbourg, 1999). Although vague, such a definition is useful in highlighting the wide variety of interpretations made by researchers when conceptualizing collaboration. This variation encompasses not only those involved (two or more can include a small group, a class, or a community), but also the view of learning (learning could constitute following of a course, study of materials, or performing activities such as problem-solving), as well as how individuals interact (face-to-face or online, synchronous or asynchronous, frequent or infrequent in time, joint effort or division of labor) (Dillenbourg, 1999).

A situation can be deemed more collaborative if the individuals collaborating are at the same level (in regard to knowledge and status), perform the same action, have a common goal, and work together. Alongside this, the interactions that take place in these situations are considered more or less collaborative based on the extent to which they influence cognitive
processes, and in particular, the interactivity and synchronicity of negotiations between individuals (Dillenbourg, 1999). In the context of the current study, collaboration or collaborative learning is used to refer to any situation that entails individuals working towards a shared goal in unison. More specifically, to be considered collaboration individuals should be seen as responsible for their own learning and involved in interdependent interaction that leverages individuals’ knowledge and expertise to achieve a product that could not be achieved alone (Dillenbourg, 1999; McInnery & Roberts, 2004; Winne, Hadwin, & Perry, 2013).

**Regulation of learning.** The current study adopted four key assumptions of regulation from the work of Hadwin et al. (2011): 1) regulation is intentional and goal-directed, 2) regulation is distinct from the construction of knowledge, instead focusing on the regulation of cognition, motivation, or behavior to reach a goal, 3) metacognition is central to the theoretical structure of regulation, and 4) regulation is social, and researchers need to understand the interplay of social surroundings in order to understand regulation (Hadwin et al., 2011).

Regulation is viewed as being present along the social continuum from individual or solo environments to collaborative environments. A main assumption of the current theoretical perspective is that across these environments, regulation can be classified into three types: self-regulated learning (SRL), co- (or other) regulated learning (Co-RL), and shared regulation of learning (SSRL). SRL, Co-RL, and SSRL are viewed as qualitatively
distinct and are distinguished based on their regulatory goals (see Table 1.1 below for an overview).

Table 1.1
Definition and Goals of Self-regulated, Co-regulated, and Socially-Shared Regulation of Learning.

<table>
<thead>
<tr>
<th></th>
<th>SRL</th>
<th>CoRL</th>
<th>SSRL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>Strategically planning, monitoring, and regulating cognition, behavior, and motivation</td>
<td>Temporary guiding, prompting, or assisting that occurs between individuals to accurately monitor and control cognitive work in the production of a group product</td>
<td>Even distribution of regulatory activities amongst members as individuals negotiate shared task perceptions, goals, plans, and strategies</td>
</tr>
<tr>
<td>Goal</td>
<td>Personal adaptation or independence in regulatory activity</td>
<td>Mediation of individual adaptation and regulatory competence</td>
<td>Collective adaptation and regulation of collaborative processes</td>
</tr>
<tr>
<td>Metacognition</td>
<td>Regulating one’s own cognitive strategy use</td>
<td>Regulating the activity of another individuals’ cognitive activity/strategy use</td>
<td>One or more individuals regulate their collaborative cognitive activities/strategy use</td>
</tr>
</tbody>
</table>


**Self-regulated learning.** The term self-regulated learning (SRL) refers to strategic and metacognitive behavior, motivation, and cognition aimed toward a goal (Hadwin, Oshige, Gress, & Winne, 2010; Winne & Hadwin, 1998; Zimmerman, 1989). The current study used Zimmerman and colleagues’ (Zimmerman 1989; 2002; Zimmerman & Moylan, 2009) social-
cognitive perspective as its lens to view self-regulated learning. The social-cognitive perspective views social aspects as playing a central role in framing and influencing regulation and outlines SRL as a developing process within the individual that is assisted by task modeling and feedback provided by others. Within this, social and self are viewed as distinct. Social influences shape the development of SRL by defining conditions for tasks as well as providing standards and feedback, with the use of instructional tools such as modeling, guided practice, and instructional feedback being key for regulatory development (Hadwin et al., 2010; Zimmerman & Moylan, 2009).

Highly self-regulated individuals set specific proximal goals for themselves and exhibit effective strategy use (Zimmerman, 2002). Alongside this, they attribute causation to outcomes associated with their choice of strategy, using feedback to self-evaluate progress towards their goals and adapt future methods (Bol et al., 2012; Zimmerman, 2002). These component skills are exhibited in the three cyclical phases of SRL: forethought, performance, and self-reflection (see Figure 1.1).

The initial forethought phase consists of the decomposition of the task, setting of goals, and strategic planning. This process of planning and goal setting is influenced by self-motivation, including student’s beliefs about learning, such as having the capability to accomplish the task (self-efficacy), outcome expectations, interest and value of the task, as well as learning goal orientation (Zimmerman 1989; 2002; Zimmerman & Moylan, 2009).
The performance phase encompasses the deployment and observation of strategies selected during the forethought phase. As individuals deploy learning strategies, they can observe and track their progress via self-observation and self-monitoring, which influences the selection of strategies, management of time and environment, self-incentivizing one’s efforts, and development of self-consequences for successes or failures (Zimmerman 1989; 2002; Zimmerman & Moylan, 2009). The final self-reflection phase involves self-evaluations of performance against a standard (such as one’s prior performance or that of another person, or an absolute standard of performance), evaluated alongside the perceived cause of one’s errors or successes. Within this phase, self-reactions and modifications also occur, which involve feelings of self-satisfaction and affect regarding performance. Based on self-evaluations and reactions, modifications are made that can either increase the effectiveness of one’s method of learning or decrease it by avoiding opportunities to learn (e.g., protecting self-image). This view of self-regulation is cyclical in that self-reflections from prior efforts to learn affect subsequent forethought processes (e.g., feelings of self-dissatisfaction in the evaluation phase will lead to lower levels of self-efficacy and subsequently reduce effort and persistence during the next learning episode; Zimmerman, 2002; Zimmerman & Moylan, 2009).

**Co-regulated learning (Co-RL).** Co-RL refers to the temporary guiding, prompting, or assisting that occurs between individuals to accurately monitor and control cognitive work in the production of a group product (DiDonato, 2013; Hadwin et al., 2011; Hadwin & Oshige, 2011; Winne et al., 2013). In contrast to SRL, which emphasizes regulatory abilities developing within the individual (assisted by external modeling and instrumental feedback),
Co-RL shifts the focus to emphasize those who aid the learner’s acquisition of SRL. Co-RL occurs when interpersonal interactions with more capable others within a shared problem space lead to SRL being gradually developed by the less capable individual (Hadwin et al., 2010; Hadwin et al., 2011; Panadero et al, 2013; Panadero & Jarvela, 2015). Although Co-RL implies some level of reciprocity between individuals and occurs in collaborative tasks, the goal of group members assisting each other is to reorganize and redistribute responsibility amongst the group members, and optimize individual regulatory activity (Hadwin et al., 2011; Winne et al., 2013).

**Socially-Shared Regulation of Learning (SSRL).** SSRL occurs when regulatory activities are evenly distributed amongst members within the group, and emerges as individuals negotiate shared task perceptions, goals, plans, and strategies (Hadwin et al., 2011; Panadero & Jarvela, 2015). The construct of SSRL shifts the focus of regulation from the individual (self-regulation) or another individual (co-regulation) to how well the group is working together to accomplish its shared goal (Hadwin et al., 2011; Hadwin & Oshige, 2011; Malmberg et al., 2015; Winne et al., 2013). SSRL is truly reciprocal in that group members co-construct and synthesize strategies toward shared outcomes, with the ultimate goal of SSRL being the collective modification and regulation of collaborative processes (Hadwin et al., 2011).

Hadwin et al. (2011) conceptualized SSRL as unfolding in four loosely sequenced stages. Initially, groups are seen to negotiate and construct shared task perceptions based on representations of the current task. Based on these negotiations, groups set shared goals for
the task and make plans on how to approach the task together. During task completion, groups coordinate their collaboration strategically and monitor their progress. Depending on this monitoring activity, the groups can change their task perceptions, goals, plans, or strategies to elevate their collective activity towards the shared learning goal.

Metacognition. Metacognition is a construct within the larger theoretical framework of SRL. Defined as an individual’s acquired knowledge about his or her own cognitive processes (Flavell, 1979), metacognition encompasses two main components: knowledge (or awareness) and regulation. The present study focused on metacognitive regulation, which consists of multiple dimensions including but not limited to: planning, monitoring, and evaluation, and is defined as effortful, motivated control of one’s cognition, memory, or learning (Schraw & Moshman, 1995; Pintrich, 2000).

As a component of SRL, metacognitive regulation is cyclical, involving phases of planning, monitoring, and evaluation. However, whereas SRL encompasses monitoring and control of behavior, cognition, motivation, and the environment, metacognition is limited to the monitoring and control of cognition (Efklides, 2011).

The aspect of planning in metacognitive regulation involves the selection of appropriate cognitive strategies, sequencing of strategies, and allocation of time before beginning a task (Schraw & Moshman, 1995). Monitoring occurs during the task, encompassing one’s on-line awareness of comprehension and task performance that is used to inform cognitive control processes during task completion (Nelson & Narens, 1994; Schraw & Moshman, 1995). Evaluation occurs upon task completion, involving the appraisal
of products and regulatory processes (e.g., re-evaluating goals or conclusions) (Schraw & Moshman, 1995).

In the context of collaboration, individual metacognitive activities are typically conceptualized as occurring when individuals control, or monitor, their own cognitive activities (Molenaar et al., 2014; Volet et al. 2009). For example, when a student evaluates whether the response he/she has provided is correct.

Other metacognition. Metacognition, as it appears within co-regulation, is often termed other metacognition. Like Co-RL, regulatory activities are directed at another individual, occurring when a group member regulates the individual activity of another group member (Iiskala, Vauras, & Lehtinen, 2011, Molenaar et al., 2014; Volet, 2009).

Other metacognitive regulation is often seen as unequal, where one member has mastered an aspect of a task and another has not (Iiskala, Vauras, & Lehtinen, 2004), and within which students are engaged in asking for, or providing, help to others to enhance the mutual learning experience or achieve intended outcomes (Garrison & Aykol, 2014).

Socially-shared metacognition. Socially-shared metacognition (SSMR), occurs when group members interrupt, change, or promote the ongoing process of carrying out a group task (Hurme, Merenluoto, & Järvelä, 2009; Iiskala, Vauras, Lehtinen, & Salonen, 2011). Social metacognitive activities are directed at group members’ joint cognitive processes, often involving monitoring and exerting control in the construction of common ground, facilitating shared representations, and inhibiting inappropriate conceptualizations (Molenaar & Chiu, 2014; Molenaar et al., 2014). Four types of interactions occur in collaboration when
groups engage in socially-shared metacognitive regulation: ignored, accepted, co-
constructed, and shared social metacognitive activities. The differences between forms of
social metacognitive activities can be highlighted through a group’s reaction or response to a
metacognitive statement (see Table 1.2 below).

Table 1.2
Scenario and Example of Metacognitive Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignored</td>
<td>The remaining members of the group ignore the comment and move on.</td>
</tr>
<tr>
<td>Accepted</td>
<td>The remaining members of the group accept the comment and engage in a cognitive activity. E.g., the group reassesses the geological landmarks on the map</td>
</tr>
<tr>
<td>Co-constructed</td>
<td>The remaining members of the group use the metacognitive statement to collaboratively construct a metacognitive activity to regulate learning. E.g., another member responds that they believe the groups response to be correct, providing a rationale as to why. The group then works to evaluate the contrasting metacognitive statements and come to a consensus.</td>
</tr>
<tr>
<td>Shared</td>
<td>The remaining members of the group use the metacognitive statement to share their metacognitive ideas surrounding their response. E.g., another member comments that they also view an error as occurring when completing the map.</td>
</tr>
</tbody>
</table>
CHAPTER TWO
Literature Review

Collaborative learning

Research has built strong evidence to support the theory that collaborative learning positively impacts both student development and learning. One of the most researched outcomes of successful collaboration has been academic achievement, with a wide range of studies showing increased achievement of individuals in collaborative settings (e.g., Jarvela et al., 2014 Johnson & Johnson, 2009; Johnson, Johnson, & Maruyama, 1983; Johnson et al., 1981; Lou, Abrami & Spence, 2000; Shachar, 2003; Slavin, 1990). Furthermore, meta-analyses (e.g., Johnson & Johnson, 2009; Johnson, et al., 1983; Johnson et al., 1981) have shown that, on average, those in collaborative situations show an increase of two-thirds of a standard deviation (SD) in achievement measures compared to those in competitive and individualistic settings. These achievement gains are also matched with process gains, including greater transfer, higher quality decision making, and engagement in more complex discussions compared to competitive and individual efforts (Johnson & Johnson 2009).

Alongside this, collaboration has shown positive relationships with a large list of cognitive and behavioral outcomes including intergroup relations, self-esteem, locus of control, time on-task, positive classroom behavior, and the ability to take other’s perspective (Slavin, 1990). Meta-analyses also revealed that individuals in collaborative environments evidence higher levels of engagement, positive experiences when working on a task,
increased use of higher cognitive strategies, and more accurate perspective taking compared to competitive and individualistic settings (Johnson & Johnson, 2009).

However, even though collaborative learning methods have shown positive impacts on learning outcomes, the act of simply grouping students does not automatically result in collaboration and productive interactions (Chan, 2012; Malmberg, Jarvela, Jarvenoja, & Panadero, 2015; McInnery & Roberts, 2004; Summers & Volet, 2010). Researchers have documented a number of debilitating processes that can occur during collaborative work including off-task talk, social loafing, low quality, unequal, or negative interactions, working independently instead of together (or splitting up work instead of collaborating), and the reinforcement of beliefs that some students are not capable of contributing to the group (Chinn, 2010; Webb, 2013).

Based on these findings, researchers have investigated factors that can impact interactions in collaborative work or environments, with the main focus of research being on the personal characteristics of those involved in collaboration itself (e.g., personality, status, gender, race, and regulatory ability). Characteristics of individual group members, such as personality, are posited to impact individuals’ level of participation, with those who are extroverted, outgoing and energetic interacting and participating the most within collaborative groups (Webb, 2013). Alongside this, cooperative preferences (defined as a desire for group work and a willingness to help others) have been linked with constructs associated with beneficial outcomes in performance and resilience, such as approach temperament, general self-efficacy, and incremental ability beliefs (Gocłowska et al., 2015).
Status, defined based on academic standing, perceived attractiveness, or popularity, has also been found to influence collaboration and participation in groups (Webb, 2013). High-status students have been found to be more active and influential than low-status individuals; whereas low-status individuals tend to be less assertive, more anxious, talk less, and give fewer suggestions and less information than high-status individuals (O’Donnel & Hmelo-Silver, 2013; Webb, 2013). Alongside this, boys and white students have been found to be more active than girls and black students, especially when groups are heterogeneous and small (Webb, 2013).

The current study focused specifically on the personal characteristic of regulation. Regulatory strategy use is viewed as important to collaboration as it is through such strategies group members enhance their commitment to collaborative learning itself (Malmberg et al., 2015). Within collaborative activities, groups are required to negotiate consensus about task perceptions and goals, as well as evaluate collective progress and outcomes (Winne et al., 2013). An individuals’ ability to self-regulate is important in maintaining their involvement and engagement in collaborative tasks, as well as participating in group discussions that are dependent upon coordinated regulatory knowledge, monitoring, and control (Hadwin et al., 2011; Jarvela & Hadwin, 2013; Winne et al., 2013).

**Self-Regulated Learning and collaboration**

General research in SRL supports the assertion that regulation is important for collaboration. SRL has been shown to enhance student’s commitment to collaborative learning itself, increase feelings of togetherness, and facilitate coordinated engagement in
joint problem sharing (Chan, 2012; Malmberg et al., 2015; Winne et al., 2013). Further to this, students who can accurately evaluate their learning are better equipped to provide guidance or generate feedback when developing a new skill (Bol et al., 2012).

Collaboration itself is highly valued regarding the promotion and fostering of regulatory behaviors, as the processes of collaborative goal setting and conceptual discussions require and promote regulation of the interactions and learning processes taking place (Raes, Schellens, De Wever, & Benoit, 2016). Social interactions involved in collaborative discussions provide dynamically responsive guidance and can promote the internalization of regulatory knowledge and skills. For example, verbalizations that occur during discussions make individual’s cognitive tools available to others, as well as elicit additional regulation and assessment of one’s own and others’ knowledge (i.e., calibration) (Bol et al., 2012).

However, collaboration is complex and achieving coordination among group members who have unique goals, cognitions, and emotions can be difficult. Groups face multiple challenges that can interfere with key processes to successful collaboration, such as the creation of common ground, negotiating perspectives, and handling complex content (Jarvela & Hadwin, 2013; Malmberg et al., 2015). As a result, it is not surprising to find that individuals do not always engage in effective SRL behaviors in collaborative settings. Students have been found to monitor poorly (especially in ill-structured environments), with their judgments not matching their actual learning or performance, and ultimately hindering their regulatory control activities during collaboration (Molenaar & Chui, 2014). Based on
these findings, researchers have sought to understand how to promote and foster SRL in collaborative settings.

**Fostering SRL in collaborative environments**

The large majority of literature in the field has examined how individual SRL can be fostered through the use of social factors, as opposed to the impact of SRL on collaborative outcomes or group processes. Research has indicated the use of support and assistance (provided by others such as peers and teachers) can facilitate self-regulatory processes such as strategy use, metacognitive monitoring and control, and information processing (Bol et al., 2012). Further, through observation learners are also seen to gain information about the model’s actions, processes, and related consequences (Hadwin et al., 2011; Schunk, 1981; Zimmerman, 2008). However, the most common approach of this line of research has been to investigate the use of scaffolding (Hadwin et al., 2011).

Scaffolding research is based upon the view that providing support to students on an as-needed basis is a key aspect of promoting SRL. This line of investigation has focused on individual’s regulatory processes and outcomes as a result of scaffolding, rather than the transition of regulatory thoughts or behavior between participants as they collaborate (e.g., Azevedo et al., 2004; Azevedo et al., 2005). For example, Molenaar, Chiu, Sleegers, and van Boxtel, (2011) examined the relationships among different scaffolds, metacognitive activities (conversational turns about monitoring and controlling cognitive activities), and individual learning achievements of grade 4-6 students as they collaborated in an e-learning environment. Students were randomly assigned to triads in three experimental conditions: no
scaffolds, structuring scaffolds, and problematizing scaffolds. Structuring scaffolds gave direct support through context-suitable examples of metacognitive activities to the group (e.g., during planning, “The expert would like to know what you want to learn. Please write all the topics about that you would like to learn more about in this mind map” p. 608), whereas problematizing scaffolds posed context-suitable questions to elicit students’ metacognitive activities (e.g., during planning, “How are you going to make the mind map?” p. 608). Findings of the study indicated that students in both the structuring and problematizing conditions showed higher levels of metacognitive knowledge compared to the control condition. Additionally, students in the problematizing condition were also found to outscore students in the control on a domain knowledge post-test. Students receiving metacognitive scaffolding also displayed proportionately more metacognitive activities than other students, with these activities mediating the relationship between different scaffolds and students’ domain and metacognitive knowledge.

Studies such as Molenaar, et al. (2011) add to the literature that has evidenced positive regulatory outcomes through the use of scaffolding. However, due to their focus on outcome measures that examine the individual in isolation, the role of metacognition and self-regulation on joint collaborative learning outcomes remains unclear. Researchers have therefore argued that research should adopt an integrative perspective of self- and social aspects of regulation when investigating regulation in collaborative environments (Jarvela, Volet & Jarvenoj, 2010; Volet & Mansfield, 2006; Volet, Vauras, & Salonen, 2009). Coined social regulation, this perspective outlines that as collaborative work fuses individuals
distributed regulatory work with the shared and coordinated work of the group, success in this work is dependent on not only individuals’ strategies and self-regulatory skills, but also the support members provide to one another that facilitate regulatory competence and the coordination of shared regulatory strategies (Volet & Mansfield, 2006; Winne et al., 2013).

**Social Regulation**

Social regulation can be split into two constructs: Co-RL and SSRL, with the current study focusing specifically on SSRL. Prior literature has supported the theoretical distinction made between Co-RL and SSRL (Ucan & Webb, 2015), as well as provided evidence that SSRL can be reliably identified during collaboration in areas such as mathematics (Rogat & Linnenbrink-Garcia, 2011; Vauras et al., 2003; Volet & Vauras, 2013), multimedia/technology (Malmberg et al., 2015), educational psychology (Jarvela et al., 2013; Jarvela & Jarvenoja, 2011), science inquiry (Saab et al., 2012; Ucan & Webb, 2015), medicine (Khosa & Volet, 2014), and history (Janssen et al., 2012). Further to this, SSRL has been linked to positive outcomes such as higher levels of collaborative engagement (Jarvela et al., 2013; Janssen et al., 2012), increased performance (Hurme et al., 2015), as well as increased cohesiveness between group members (Ucan & Webb, 2015).

**Socially-Shared Metacognition**

Specifically, the study will focus on a subcomponent of SSRL, socially-shared metacognition (SSMR). Literature surrounding SSMR is limited; however, seminal studies can be categorized based on their three major research goals: 1) observing/recording SSMR in collaborative contexts, 2) understanding learning outcomes associated with SSMR, and 3)
fostering of SSMR processes within collaboration. Initial research was dominated by the fundamental need to develop an understanding of how social regulation occurs. Research exploring whether instances of SSMR were capable of being observed in collaborative environments has found positive results in areas such as mathematics (Goos, Galbraith, & Renshaw, 2002; Hurme & Jarvela, 2001; 2005; Hurme, Merenluoto & Jarvela, 2009; Hurme, Palonen & Jarvela, 2006; Iiskala et al., 2011), science (Grau & Whitebread, 2012; Iiskala, Volet, Lehtinen, & Vauras, 2015), geography (Molenaar, Sleegers, and van Boxtel, 2014), and education (de Backer, Van Keer, Moerkerke, & Valcke, 2015).

Alongside this, studies investigating the theoretical relationships between SSMR and collaborative outcomes have found that groups who engage in social metacognitive activities show lowered feeling of difficulty (Hurme, Palonen, & Jarvela, 2006), higher levels of domain and metacognitive knowledge (Molenaar, Sleegers, & van Boxtel, 2014), and increased performance during problem solving (Goos, Galbraith, & Renshaw, 2002; Hurme, Jarvela, Merenluoto, Salonen, 2015).

Research has also evidenced positive impacts of social metacognitive activities on group interactions, with shared metacognitive processes related to increased engagement in talk about essential aspects of the task, such as references to fundamental knowledge (Grau & Whitebread, 2012). Such interactions are viewed as essential, as without them collaborative work may become derailed or less satisfying for learners, resulting in less effective, efficient, and/or enjoyable learning (Jarvela & Hadwin, 2013).
Although the above literature provides evidence that SSMR can be observed and related to positive outcomes, researchers studying collaborative groups have not always observed all phases of social metacognition. For example, when Hurme, Palonen, and Jarvela (2006) examined the occurrence of social aspects of metacognition for pairs of high-performing high school geometry students working on collaborative software, results revealed that comments concerning planning were non-existent. Further to this, students’ perceptions of, and actual, regulatory behavior are not always aligned. For example, in a study examining shared planning by Miller & Hadwin (2012, as cited in Jarvela & Hadwin, 2013), group members reported having a high consensus about shared plans, task perceptions, and goals. However, analysis of their task-planning negotiations indicated that none of the groups systematically solicited or discussed individual perceptions of task purpose or goals. In fact, the higher performing groups converged on common ideas, neglecting to share or discuss divergent ideas held by single members of the group, even when those task perceptions and goals were well aligned with the collaborative task.

Consequently, researchers have sought to understand factors that may impact social metacognitive activities/episodes, with the majority of research examining personal (e.g., regulatory knowledge) and group (e.g., quality of interactions) characteristics. Research in this area is still in its formative phases, with initial investigations of the impact of group members’ metacognitive knowledge revealing that groups consisting of highly metacognitive learners show higher levels of participation in socially-shared metacognitive processes (Molenaar et al., 2014). Alongside this, group characteristics such as positive group
interactions have also been found to contribute to the emergence SSMR in multiple studies through the creation of a favorable social climate and shared positive emotions between group members (e.g., Hurme & Jarvela, 2005).

In the latest phase of research, researchers have been advocating for the development of interventions to foster these processes in collaborative groups. Three main design suggestions having been made to support social regulatory processes such as social metacognition: 1) increase learners’ awareness (knowledge or perception) of their own and others’ learning process, 2) support externalization of students’ and others’ learning process via sharing and interaction, and 3) prompt the acquisition and activation of regulatory processes (Jarvela et al., 2014).

When increasing students’ awareness during collaboration, researchers are recommended to target not only behavioral awareness (information about group members’ activity in the collaborative environment), but also cognitive awareness (information about the knowledge level of group members), and social awareness (information about the functioning of the group as perceived by its members) (Jarvela et al., 2014).

The second aspect, supporting externalization of learning processes, can be achieved through the creation of a shared space in which members can collaborate and decide how to regulate their efforts and actions. A “shared space” refers to not only the collaborative environment, but also a shared psychological space that can encourage social interaction and shared regulation (Jarvela et al., 2014). To achieve this, researchers need to create tools that target the phases of regulated learning, such that students are able to plan together, monitor
their collective performing, evaluate the final product, and regulate/change to achieve their learning goals (Panadero et al., 2013).

The third aspect, prompting the acquisition and activation of regulatory processes, is based on research in the field of SRL. Research in this area has outlined that interventions should aim to promote planning, monitoring, and evaluation of cognitive, motivational, and emotional factors that support specific phases of regulated learning (e.g., task understanding, planning, strategic action, and motivation regulation) (Jarvela et al., 2014). In the context of socially-shared regulation, this can be achieved through encouraging groups to negotiate and align representations of task requirements and goals, as well as focus groups on learning and collaborative processes as opposed to task completion (Jarvela et al., 2014).

Although several studies have aimed to increase socially-shared regulation (e.g., Jarvela, Naykki, Laru, & Luokkanen, 2007; Panadero et al., 2015; Saab, van Joolignen, & van Hout-Wolters, 2012), only one study to date has focused specifically on fostering SSMR in collaborative contexts. Molenaar et al. (2014) investigated the effects of metacognitive scaffolds on social metacognitive interactions of triads of grade 4-6 students during a collaborative learning assignment to understand a foreign country. Students were randomly assigned to triads in three experimental conditions: no scaffolds, structuring scaffolds, and problematizing scaffolds. Similar to the work of Molenaar et al. (2011), structuring scaffolds gave context-suitable examples of metacognitive activities to the group, whereas problematizing scaffolds posed context-suitable questions that elicited students’ metacognitive activities. General findings of the study revealed that scaffolding increased
instances of high-quality intra-group social metacognitive interaction. Overall, groups receiving scaffolds engaged in significantly more co-constructed social metacognitive activities; however, showed no significant increase in shared social metacognitive activities. Further, problematizing scaffolds were found to induce fewer ignored and more co-constructed social metacognitive activities than structuring scaffolds. The positive findings of the study provided a possible framework to increase SSMR in collaborative settings. However, due to lack of performance measures in the study, it is unknown whether increases in SSMR also led increases in performance on the task.

**Gaps in the literature**

Aside from the lack of empirical research investigating SSMR, there are a number of methodological issues affecting research.

**Theoretical coherence**

There is a lack of unity regarding the coding of SSMR. Rather than converging around a few widely-accepted codes, various coding schemes have been built to highlight socially-regulated behavior for specific contexts (Summer & Volet, 2010). This has led to differences in grain size, with some studies focusing on specific conversational notes or turns when coding (e.g., Hurme & Jarvela, 2001, 2005) and others using multiple notes/turns to create larger episodes or threads (e.g., Iiskala et al., 2011; Molenaar et al., 2014). Alongside this, there are variations in the application of theoretical models, with some research utilizing holistic models of metacognition when developing their coding scheme (e.g., Hurme & Jarvela, 2001) and others focusing on specific components of larger models (e.g., Hurme &
Jarvela, 2005). This variation in use of coding schemes has allowed researchers to capture context-sensitive elements of regulation that may otherwise be missed by a more general coding scheme; however, it has come at the cost of limiting researcher’s ability to collate research on social regulation and measure variability in regulation across contexts or populations (Simon & Volet, 2012).

**Environmental/context of research**

There is also a lack of coherence regarding the justification for the choice of environment and type of task students engage in. As outlined by Panadero and Jarvela (2015), research in shared regulation frequently lacks clear argumentation as to why authors selected tasks for their studies. It is often not clear if the way in which tasks were defined created a need for students to collaborate. Moreover, some studies investigating social metacognition place individuals in non-naturalistic collaborative settings, involving one-off tasks detached from the curriculum (e.g., Iiskala et al., 2011), or ask students to collaborate face-to-face when using online learning environments (e.g., Molenaar et al., 2014).

**Temporal and sequential changes in SSMR**

Commonly, when examining social-regulatory processes, SSMR researchers have focused on individuals or groups confronting a problem or challenge (e.g., Malmberg et al., 2015). However, when doing so, descriptions of episodes are often presented in the aggregate (i.e., across tasks) to provide an overall understanding of socially-shared regulatory processes. For example, Molenaar et al. (2014) took place over eight one-hour sessions; however, analyses did not assess differences across sessions, and instead, the overall impact
of scaffolding was analyzed. As a result, there remains a gap in the literature relating to how socially-shared regulation changes from challenge episode to challenge episode, or more generally, task to task (Hadwin et al., 2011). Based on this, there is a need in the field for researchers to provide a clearer understanding of the evolving phases/sequences of social regulation both within and across time and tasks (Molenaar & Chiu, 2014).

**Investigating individual and other metacognition**

As a field, researchers have recognized that learning is not solely individual or collaborative, and aspects of SRL, Co-RL, and SSRL occur as individuals work on shared tasks (Hadwin et al., 2011). However, in research investigating social regulation in collaboration, very few papers (with the exception of Ucan and Webb, 2009) have jointly addressed co-regulation and socially-shared regulation together. Further, in research that has attempted to increase SSMR processes (Molenaar et al., 2014), other and individual metacognitive episodes were ignored/not coded. As a result, it is unclear whether (or how) different forms of metacognitive regulation occur together in collaborative learning, and in turn, whether interventions designed to increase SSMR also impact the occurrence of individual and other metacognitive episodes.

**Overview of the Present Study**

Given that research on fostering SSMR is extremely limited, the current study aimed to build upon the work of Molenaar et al. (2014) and examine the use of problematizing prompts to increase social metacognitive activities of undergraduate introductory geology students. Student-participants took part in three researcher-designed group activities over the
course of a semester that involved individual planning, group planning and monitoring, and individual evaluation tasks. Using a concurrent embedded mixed methods design (QUAN(qual)), the study compared the use of social regulatory, individual regulatory, and non-regulatory frameworks during these tasks, and their influence on students’ ability to collaborate and regulate their cognitive process within collaboration.

An introductory geology classroom was chosen as the context for the current study. General science literacy has been stated by the National Research Council as of particular importance for the security and economic vitality of the US for the coming decades (NRC, 1996). Introductory geoscience courses possess a special potential for generating and nurturing students’ attitudes and motivations towards learning science, as many non-majors select the course to fulfill a degree requirement (Gilbert et al., 2012). As part of the effort to nurture positive attitudes, studies in geoscience courses have suggested that the use of collaborative learning methods in the form of collaborative exams can increase student investment in the content material (Eaton, 2009).

In the design of intervention materials, the current study incorporated the three design principles present in the literature discussing the promotion/fostering of socially-shared regulation: 1) increase learners’ awareness, 2) support externalization of the learning process, and 3) prompt the acquisition and activation of regulatory processes (Jarvela et al., 2014; Jarvela et al., 2016; Miller & Hadwin, 2015).

To increase learner’s awareness, questions that formed the individual planning, group planning, and individual evaluation phases of the review activity were targeted at increasing
not only behavioral awareness (e.g., “what occurred during collaboration?”), but also
cognitive (e.g., “what strategies can the group use?”) and social awareness (e.g., “how can
the group overcome challenges observed?”). Alongside this, visualizations of group’s beliefs
about the task (how the other members were thinking and feeling about the current learning
situation) were provided to groups during the group planning phase to increase learner’s
awareness of their own and others’ learning process.

Visual representations of student’s perceptions and feelings towards the task also
served as a way to support the externalization of student’s learning process during group
planning. Additionally, the structure of group planning was aimed at promoting discussions
and interactions between group members so that they had the resources to plan together,
monitor how the group is performing, and evaluate the final product against their learning
goals.

Finally, prompting regulation, which was the main focus of the study design, was
embedded in the course design. Before and during collaborative tasks, social-metacognitive
prompts encouraged groups to negotiate and align representations of task requirements and
goals, as well as orient groups towards the discussion of learning and collaborative processes
as opposed to task completion (Jarvela et al., 2014).

Alongside the incorporation of design principles in social regulation literature, the
current study built upon coding schemes developed during prior research (Molenaar et al.,
2014) in order to establish whether these codes (accepted, ignored, shared, co-constructed)
were appropriate for the analysis of the use of problematizing prompts during collaborative
geology tasks in older populations. Additionally, the study aimed to provide clarification to
the understanding of the relationship between aspects of SRL (i.e., metacognition), Co-RL
(i.e., other metacognition) and SSRL (i.e., social metacognition), by comparing scaffolds that
orient students towards either individual, or group-level, regulatory goals and strategies.

The use of multiple group tasks over the course of a semester allowed the study to
investigate and understand how regulation unfolds temporally (from task to task and episode
to episode), as well as sequentially (patterns of episodes within tasks), and provided a clearer
understanding of the evolving nature of social regulation.

**Research questions and hypotheses**

The study addressed the following research questions:

1. How do *individual* and *social regulatory* scaffolding conditions impact collaboration?
   
   a. What are the differences between conditions in the occurrence of social
      metacognitive episodes during scaffolded collaborative problem-solving?
   
   b. What are the differences between conditions in reported challenges faced
during scaffolded collaborative problem-solving?

   The first research question was answered using both quantitative and qualitative
analyses. Quantitative methods were used to understand changes in frequencies of episodes,
as well as differences in challenges experienced, and qualitative analyses were used to
augment the quantitative data, adding detail and further understanding to the impact of
individual and social regulatory scaffolding.
For the quantitative component of the analysis, it was hypothesized, based on the work of Molenaar et al. (2014), that groups within the social condition would show an increase in metacognitive episodes during scaffolded review activities across the course of the semester compared to groups within the control condition. Specifically, it was expected that groups in the social condition would engage in significantly more co-constructed social metacognitive activities and fewer ignored social metacognitive activities by the end of the semester compared to both the control and the individual condition. It was also hypothesized that groups in the individual condition would show a general increase in the use of social metacognitive activities compared to groups in the control condition. Changes in types of metacognitive activity over time/task could not be predicted due to lack of empirical literature that has addressed temporal and sequential patterns when embedding problematizing prompts to increase social metacognitive activities. However, it was hypothesized that co-constructed and social activities would be less frequent, based on prior literature (Molenaar et al., 2014) evidencing these types of episodes to be less common during collaborative learning.

Prior research has also not investigated the impact of problematizing prompts on self-reported challenges that students experience or confront during collaborative problem-solving. Therefore, no hypotheses could be made for research question 1b.

2. How do individual and social regulatory conditions impact monitoring accuracy during scaffolded problem-solving?
The second research question was answered using quantitative analyses. Prior research that has investigated the fostering of social metacognitive processes has not embedded a measure of monitoring accuracy (such as group monitoring judgments) in its experimental design. However, based on prior work that has looked at the impact of scaffolding on self-regulation (e.g., Azevedo et al., 2004) it is expected that, during the scaffolded review, groups in both experimental conditions would show higher levels of monitoring accuracy compared to those in the control condition. No between experimental group differences were expected.

3. How do individual and social regulatory conditions impact group performance during both scaffolded problem solving and collaborative tests?

The third research question was answered using quantitative analyses. Based on research that has shown the positive impact of social regulation on group outcomes (e.g., Hurme et al., 2015), it was hypothesized that groups in both social and individual conditions would exhibit higher levels of performance compared to groups in the control condition during scaffolded review activities and collaborative exams. Based on the expectation that groups in the social condition would show increases in social regulation compared to those in the individual condition, and literature showing positive relationships between social regulation and performance, it was also expected that these groups would show increased performance on both forms of assessment.
CHAPTER THREE

Method

Participants

Fifty-two undergraduate students (29 male, 23 female) from an online introductory Physical Geology course, consisting predominantly of science and engineering majors (53.9%; 13.5% Social Science & Humanities; 13.4% Business & Accounting; 9.5% Other; 9.6% unspecified), and Juniors (50%; Seniors 21.2%; Sophomore 19.2%; 9.6% unspecified) participated in the study. The sample was ethnically representative of the university (67.3% White; 5.8% African American; 7.7% Hispanic/Latino; 1.9% Asian; 1.9% American Indian/Alaska Native; 5.8% Other; 9.6% unspecified). Participants were aged 18-45 ($M = 20.89$, $SD = 3.93$), and cited a range of GPA (15.2% 2.0-2.7; 53.8% 2.8-3.6; 21.2% 3.7-4.0; 9.6% unspecified).

Based on the Geoscience Content Inventory (GCI), Students were assigned to triads of mixed (low, medium, and high) geology knowledge. Groups were then randomly assigned to condition, with six groups assigned to both the social ($n = 19$; includes a group of 4) and individual ($n = 18$) conditions, and five groups ($n = 15$) to the control condition. Four students were removed from the sample as they dropped the course between the initial group task and the first experimental task ($N = 48$). Final groupings consisted of five control groups ($n = 14$; one group of 2), six social groups ($n = 17$; one group of 2) and six individual groups ($n = 17$; one group of 2).
Design

The current study employed a concurrent embedded mixed methods design (QUANT(qual)). Both quantitative and qualitative data were collected simultaneously; however, the quantitative aspect was more central to the research design (Creswell & Clark, 2011). As part of this design, the same individuals were sampled for both qualitative and quantitative data, with qualitative data being quantified to address the same concept (Metacognition).

Study context

The current study was conducted in a three-credit hour online introductory physical geology course at NC State during the Fall semester. The course is a requirement for many geoscience and engineering majors. However, it is also a popular science elective and commonly attracts students from several other areas (most commonly from business and humanities programs). The instructor of the course was a graduate student with two years of experience in the course, both as a TA and instructor. The course was solely conducted in an online CMS (Moodle) and had no face-to-face meetings.

The course comprised eight modules of geology content that investigated the processes operating at and below the earth's surface, how these processes influence the landscape, earth’s structures and materials, and the occurrences and utilization of earth's physical resources. Students had approximately two weeks to complete each module. All assignments for each module were due at the same time and day every two weeks, with new content opening upon completion of prior modules. Assignments for the course included
exams (3 midterm exams and a comprehensive final), short 3-6 question retrieval practice exercises called Learning Journals (25 total), collaborative activities (4 review activities, collaborative midterm and final), and end of module multiple-choice quizzes. The current study focused solely on the collaborative review activities, online collaborative case studies designed to provide students with opportunities to synthesize geology content from preceding modules.

**Collaborative review activities.** Students completed four review activities across the semester. Each followed the completion of two modules of content. Activities were designed for individuals to work within a group to solve a multifaceted problem in a geology-related case study. The goal of each activity was to allow students to develop a better understanding of course material by engaging in processes of analysis, evaluation, and application during group work.

The tasks were designed to challenge students at a difficulty level that would require students to work together. The intention of the task design was to create ‘challenge episodes’ for groups. Previous researchers, such as Hadwin et al. (2011), have suggested that these episodes can be used to contextualize and examine regulated learning processes as they not only create occasions for regulatory strategies and processes to be applied and made visible, but also frame goals and intent (see Table 3.1 below for summaries of each review activity).
<table>
<thead>
<tr>
<th>Task</th>
<th>Modules completed</th>
<th>Description/Goals</th>
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| 1    | • Geology and the Scientific Process  
      • The changing solid earth | **Scenario:** You and your group have been transported to an unknown, earth-like, planet somewhere in the universe. It is believed that the geology is similar to that of earth. While in your group’s chat space, collaborate to answer the questions and consider the evidence presented in order to analyze this area of the planet (adapted from Reynolds, 2010).  

**Goals:**  
- Use the features of an ocean and two continental margins to identify possible plate boundaries and their types.  
- Use the types of plate boundaries to predict the likelihood of earthquakes and volcanoes.  
- Determine the safest site for two cities, considering the earthquake and volcanic hazards.  
- Draw a cross section of your plate boundaries, to show the geometry of the plates at depth. |
| 2    | • Reading Rocks to Interpret Earth’s History  
      • Volcanoes vs. Earthquakes: Dealing with unstoppable natural disasters | **Scenario:** The city of San Francisco has passed a bond measure that will give $10 million each to retrofit one school out of a set of three that has the highest seismic risk. Your job is to identify which of the schools has the highest risk, and to give the city and the school board advice on where to use the $10 million (adapted from Selkin et al., 2015).  

**Goal:** Examine the overview maps of the San Francisco area schools that the class will be using in this activity. Find each of the labeled schools on the San Francisco Marina District map. |
Table 3.1 Continued

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<th>Task</th>
<th>Modules completed</th>
<th>Description/Goals</th>
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<tr>
<td>3</td>
<td>• Life's effect on Earth; Earth's effect on life</td>
<td><strong>Scenario:</strong> In the upcoming task, you will consider the reflectivity of the Greenland ice sheet through two mediums. The first is that of multiple reflectivity plots that plot the time of the year vs. the albedo for different areas of the Greenland ice sheet for the years 2000-2012. The second is a reflectivity anomaly map, which compares the overall change in reflectivity for each area in Greenland as compared to the long-term average (calculated between 2000-2012). Each plot and map will be available in the appropriate question pages included in the Task quiz (adapted from Walker, 2014).</td>
</tr>
<tr>
<td></td>
<td>• Earth's Climate Past</td>
<td><strong>Goal:</strong> Your challenge (in tandem with your group and communicated in your chat space, of course) is to identify and reflect (pun intended) on how Greenland may be changing over recent years, why this change may be occurring, and what this change may mean for the future of the Greenland ice sheet and the climate as a whole.</td>
</tr>
<tr>
<td>4</td>
<td>• Water and Society</td>
<td><strong>Scenario:</strong> In this Collaborative Case Study, you and your group mates will explore the classic case of Love Canal, New York, in which Lois Gibbs—originally described as a &quot;hysterical housewife&quot;—mobilized her community and called attention to the contamination of groundwater by buried hazardous waste and the resulting impact on the health of local residents. The activities will require you to investigate the history of events at Love Canal, use Google Earth to consider the land use and spatial distances involved in the case, and use your knowledge of groundwater processes to consider how and why Love Canal was such a bad idea all around (adapted from Schneiderman &amp; Stewart, 2015).</td>
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<td></td>
<td>• Energy Resources &amp; Earth's Climate Future</td>
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Table 3.1 Continued

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<tr>
<th>Task</th>
<th>Modules completed</th>
<th>Description/Goals</th>
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| 4    | • Water and Society  
      • Energy Resources & Earth's Climate Future | **Goals:**  
      • Discuss Love Canal from a historical and environmental justice standpoint.  
      • Articulate the events that led to the passage of the Superfund Act.  
      • Demonstrate how geology and hydrology facilitated the flow of toxic materials at Love Canal. |

**Time Frame and Conditions**

The current study used three conditions (social, individual, and control) to manipulate the structure of discussions surrounding group review activities. Group activities involved three phases that were adapted based on prior research on SSRL (Miller & Hadwin, 2015; Jarvela et al., 2016; Panadero et al., 2015): 1) individual planning task, 2) group planning and activity checkpoints, and 3) individual evaluation task. Conditions varied in the focus and types of prompts administered during each phase. In the social condition, the focus of the prompts was to emphasize social-regulatory skills through understanding the importance of the regulation of the group to the success on the task, issues that may arise, and how these can be avoided. The individual condition was structured to emphasize the individual’s own regulatory skills, prompting students to think about their ability to complete the task, potential challenges they may face individually, and how they could solve them. Finally, the control condition was structured to provide generalized and procedural instructions to guide
their collaborative interactions, involving content-specific filler tasks, as well as prompting students to discuss as a group without further instructions or information.

**Individual planning task.** Prior to participating in each group review, students completed an initial planning task individually on Moodle (see Appendix A). Students across all conditions began the planning task by completing five questions (adapted from Panadero et al., 2015) relating to their beliefs regarding the upcoming group task. Students in experimental conditions (social and individual) were then asked to respond to planning prompts that involved setting of goals, highlighting possible obstacles, and listing strategies to overcome them. The prompts differed between experimental groups in their reference point, with the social condition prompts referencing the wider group, and the individual condition referencing the individual themselves. The control condition completed a comprehension check surrounding material covered in the current module.

**Group planning.** During the group planning phase, groups across conditions were asked to plan for ten minutes prior to engaging in the group case study (see Appendix B). All groups received an overview of the case study used in the activity, including an outline of the tasks involved. Following this, groups in the social condition were prompted to engage in discussions relating to the upcoming task and used a collated response sheet from the individual planning tool (see Appendix C for example). Groups in the individual condition were asked to do the same; however, they were prompted to think about their (individual) response and were provided only their own responses to the individual planning tool. The control groups were not prompted to use their responses during their group planning.
Activity checkpoints. At targeted points during the case-study activity (25%, 50%, 75% completion), experimental groups were prompted to consider the effectiveness of their current strategy use and rate their confidence in their work (see Appendix B). Groups in the social condition were asked to consider their success in relation to achieving group goals, whereas groups in the individual condition were asked in relation to their own individual goals. The control groups were simply asked to double-check their answers for the previous sections.

Individual evaluation task. After submitting their group assignment, each group member was asked to respond to evaluation prompts (adapted from Panadero et al., 2015) and make judgments individually via a wrap-up Moodle activity. Again, prompts differed based on condition, with the social condition prompted orienting students towards evaluating the group (goal completion and challenges) and the individual condition towards evaluating themselves (see Appendix D). Those in the control group were asked to evaluate the general success of their group on the task. Evaluating their success was intended to focus students in the control group on performance as opposed to regulation of their behavior.

In the weeks following, groups were provided feedback on their performance in the activity and asked to complete post-feedback prompts during the beginning of the next individual planning task. Within this, students in all groups were prompted to consider their responses to the evaluation tool completed immediately after the task and use these responses to aid their completion of the individual planning task. The same procedure was used as the
group planning, with the social group receiving a collated response sheet and the individual group only their own responses.

**Instruments and Measures**

**Quantitative Sources.**

*Monitoring accuracy.* During the semester, participants were asked to make postdiction judgments relating to their performance (“How confident are you that you were successful in the current task?”) directly following the completion of each review activity using a 100mm line (0 = not confident to 100 = extremely confident). The accuracy of these judgments was measured using the calibration indices of absolute accuracy and bias (Schraw, 2009). The indices of bias measures the degree to which an individual is over- or under-confident and ranges from -1 (extremely underconfident) to +1 (extremely overconfident), with 0 reflecting perfect accuracy. Absolute accuracy, on the other hand, assesses the precision of a judgment (calibration) and ranges from 0 (extremely accurate) to 1 (extremely inaccurate). For example, if an individual gave a confidence judgment of 65 and scored 84 percent on the assessment (.84) their accuracy score would be .19, and their bias score would be -.19. Indices were chosen based on the aim of the study to understand the impact of regulatory prompts. Absolute accuracy is recommended when researchers are interested in investigating whether a treatment enhances the goodness of fit between a confidence judgment and corresponding performance, and bias for when researchers aim to understand if a treatment decreases or increases confidence relative to performance (Schraw, 2009).
**Learning strategies.** Self-reported cognitive, metacognitive, and resource management strategies for the course were measured using the learning strategy scales of the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1993) (see Appendix E). The learning strategy scale of the MSLQ consists of 50 statements encompassing six subscales: rehearsal (four items), elaboration (six items), organization (four items), critical thinking (five items), metacognitive self-regulation (12 items), time and study environment (eight items), effort regulation (four items), peer learning (three items), and help seeking (four items). For each item, students rate their level of agreement on a seven-point Likert scale from one (not at all true of me) to seven (very true of me).

The MSLQ has been used in a wide variety of studies at the college level and has demonstrated reliability across academic disciplines and populations. For example, Crede and Phillips (2011) meta-analyses, comprising 67 independent samples (from a total of 59 articles) representing 19,900 independent college students provided mean reliability for all subscales: rehearsal ($\alpha = .68$, $SD = .05$), elaboration ($\alpha = .76$, $SD = .05$), organization ($\alpha = .70$, $SD = .07$), critical thinking ($\alpha = .77$, $SD = .04$), metacognitive self-regulation ($\alpha = .77$, $SD = .06$), time and study environment ($\alpha = .72$, $SD = .07$), effort regulation ($\alpha = .61$, $SD = .10$), peer learning ($\alpha = .68$, $SD = .10$), and help seeking ($\alpha = .59$, $SD = .12$).

In the current study, a range of reliability was evidenced, with the scales of rehearsal ($\alpha = .79$), elaboration ($\alpha = .86$), organization ($\alpha = .77$), critical thinking ($\alpha = .79$), metacognitive self-regulation ($\alpha = .76$), and peer learning ($\alpha = .84$), showing acceptable levels of internal consistency ($\alpha > .70$) (George & Mallery, 2003). However, scales of time
and study environment ($\alpha = .50$), effort regulation ($\alpha = .50$), and help seeking ($\alpha = .51$) showed low levels of internal consistency. Based on their low reliability, these scales were removed from the analyses.

**Self-efficacy.** Self-efficacy was measured using an eight-item subscale from the motivation scale of the MSLQ (Pintrich et al., 1993) (see Appendix E). Students were asked to rate their level of agreement for statements relating to their ability to accomplish tasks and succeed in the course on a seven-point Likert scale ranging from one (not at all true of me) to seven (very true of me). The scale has shown high reliability across multiple studies, with Crede and Phillips (2011) meta-analysis revealing a mean reliability of .91 (SD = .02). Findings in the current study support prior literature, with the scale evidencing high levels of internal consistency ($\alpha = .95$).

**Social interdependence.** Students’ cooperative, competitive, and individualistic preferences were measured using the Social Interdependence Scale (SIS) (Johnson & Norem-Hebeisen, 1979) (see appendix F). Students were asked to rate their level of agreement for statements relating to how much they like and value cooperative interdependence (seven items), competitive interdependence (eight items), and individualistic interdependence (seven items) on a seven-point Likert scale from one (not at all true of me) to seven (very true of me). Due to an error in the data collection software, only cooperative and competitive interdependence scales are available for the current study. A validation study for the scale conducted on 152 Midwestern undergraduates showed high levels of reliability for each subscale: cooperative interdependence ($\alpha = .84$), competitive interdependence ($\alpha = .85$). The
current study supported prior literature, with both scales shown to be highly reliable (α = .93 for each scale respectively).

**Initial interest.** Students’ initial interest in the course was measured using seven items taken from Harackiewicz, Durik, Barron, Linnenbrink-Garcia, and Tauer (2008) adapted to specifically refer to an introductory geology course (see Appendix G). Students were asked to rate their level of agreement for seven statements relating to how much they were looking forward to the course and its content area using a seven-point Likert scale ranging from one (not at all true of me) to seven (very true of me). Initial work (Harackiewicz et al., 2008) evidenced the scale to be reliable (α = .90), and the current study also supported this, with the scale showing a high level of internal consistency (α = .91).

**Prior geoscience knowledge.** A selection of questions from the Geoscience Content Inventory (GCI; Libarkin & Anderson, 2005) was used to measure students’ prior content knowledge. The instructor of the course selected 20 items from the pool of validated multiple-choice questions available that aligned to the course's learning objectives (see Appendix H for sample items). In the current study, the GCI was shown to have moderate levels of internal consistency (α = .65).

**Performance.** Performance was measured using group scores on each of the review activities as well as collaborative exams. Collaborative exams were developed by the instructor and occurred twice over the semester (midterm and final). Each exam included 31 selected response items, covering four modules of content. The instructor of the course, who was blinded to the assignment of groups to conditions, graded both activities and exams.
Demographics. During the first online survey, students were asked to provide information regarding their age, gender, race, major, academic standing, and current GPA (see Appendix I for questions).

Qualitative Sources.

Metacognitive episodes. Metacognitive episodes that occurred during collaboration were measured for all groups via conversation analysis of student interactions when completing group activities. Coding procedures were adapted from Molenaar et al. (2014) and consisted of two phases: 1) coding individual conversational turns and 2) coding episodes (see analysis section for full coding procedure). Episode-level codes were used for analyses and group comparisons.

Challenges faced during collaboration. Student responses to the item “What was your/your group’s main challenge? What did you do/you do as a group to overcome this challenge?” on the individual evaluation tool were used to understand group challenges during collaborative activities. Responses were coded by the researcher and instructor based on a coding scheme developed in prior work by Jarvela et al. (2013) (see analysis section for coding procedure).

Procedures

The current study was embedded within an online Geology course. All intervention frameworks and surveys were part of the course structure, and all students took part in collaborative review activities under one of the treatment conditions. Participants were provided with a link to the IRB-approved consent form on the course CMS, with the
researcher contacting students regarding their participation in the study at the beginning and end of the semester. The consent form requested access their grades and student interactions during the collaborative review activities for further statistical analysis (see Appendix J for consent form).

At the beginning of the semester, students completed the Geoscience Content Inventory (GCI), self-report scales (MSLQ, initial interest, self-efficacy, and social interdependence scales). Based on the GCI results, students were placed into semester-long triads containing students of low, mid, and high geology content knowledge, with each group being assigned to one of the three conditions (individual, social, or control).

Group activities were completed online at the end of each unit (four total across the semester) via the course’s CMS (Moodle) (see Appendix K for example activity). The first activity (during the 3rd week of the semester) was used as an introductory exercise for groups to develop connections with other group members and gain familiarity with the CMS and the task structure. The remaining three activities utilized the planned experimental conditions. Prior to each review activity, students completed the individual planning tool. During the activity itself, groups were asked to spend ten-minutes on a planning exercise prior to completing the case-study activity. Immediately following the group activity, group members completed the individual evaluation tool. At both the middle and end of the semester, groups completed collaborative exams online via Moodle.
General Analysis

Table 3.2 below outlines the general analysis procedures undertaken in the current study.

Table 3.2
Overview of Analyses

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Sample</th>
<th>Type of analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Analysis</td>
<td>Self-report measures (self-efficacy, social interdependence, learning strategies)</td>
<td>Individual participants $N = 47$ (Control $n = 13$; Individual $n = 17$; Social: $n = 17$)</td>
</tr>
<tr>
<td>RQ1a</td>
<td>Group chat logs from three experimental review activities</td>
<td>11 of 17 groups (Control: $n = 3$; Individual: $n = 4$; Social: $n = 4$)</td>
</tr>
<tr>
<td>RQ1b</td>
<td>Responses to individual evaluation tool</td>
<td>All experimental groups (Individual: $n = 5$; Social: $n = 6$)</td>
</tr>
<tr>
<td>RQ2</td>
<td>Monitoring accuracy Group judgment from three experimental review activities</td>
<td>All groups ($N = 17$)</td>
</tr>
<tr>
<td>RQ3</td>
<td>Review Performance Group score from three experimental review activities</td>
<td>All groups ($N = 17$)</td>
</tr>
</tbody>
</table>
Quantitative analyses.

**Demographic differences.** To assess demographic differences between conditions, chi-square tests were performed for categorical variables of gender, race, major, and academic standing, and one-way ANOVAs run for continuous variables of age and current GPA. Data met the main assumptions of the chi-square test in that independence of data between groups were observed and cells had a frequency of no smaller than five (Field, 2009).

**Normality of distributions.** Prior to engagement in quantitative analyses, the normality of distributions for variables of motivation and learning strategies, performance, and monitoring accuracy were tested through an analysis of skewness and kurtosis. Based on common practices in statistics, critical values of greater than +/- 2 for kurtosis and skewness were used to evaluate whether a variable was verging from normality (Field, 2009).

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Sample</th>
<th>Type of analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ3 Exam Performance</td>
<td>All groups ($N = 17$)</td>
<td>Comparison of conditions at midterm using One-way ANOVA. Posthoc analyses conducted using Bonferroni.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comparison at final using Kruskal-Wallis. Posthoc analyses conducted using Mann-Whitney</td>
</tr>
</tbody>
</table>
Motivation and learning strategies. Distributions of self-report measures of motivation and learning strategies were all found to be in the acceptable range, and based on this, the assumption of normality for data was met.

Performance and monitoring accuracy. Variables of performance and monitoring accuracy for the collaborative reviews and final exam showed levels of skewness and kurtosis above the +/- 2 threshold; however, performance data for the midterm exam was found to be normally distributed (see Appendix L for values). In an attempt to correct violations of normality, data were transformed using log and square root (absolute accuracy and bias) and reverse score (performance) methods; however, transformations were unsuccessful, and variables of performance and monitoring accuracy were considered not normally distributed for the analyses.

Challenges during collaboration. Data for challenges in collaboration were assessed and skewness/kurtosis was above the accepted range for categories of challenges in collaboration, motivation, technology, external control, and no challenge (see Appendix L for exact values). Log and square root transformations were performed, however, were unsuccessful, and variables were considered not normally distributed for the analyses. For the categories of time, task, and no code, data met assumptions of normality.

Statistical tests/procedures

Motivation and learning strategies. Between-group comparisons were conducted using one-way ANOVAs for each self-report construct collected at pre-test. The independent variable in each analysis was condition (control, individual, social), with the dependent
variable being motivation/learning strategy scales. For each of the analyses, the assumption of homogeneity was met, with Levene's test being found to be statistically non-significant (all $p > .05$).

**Performance and monitoring accuracy.** Due to the violation of the assumption of normality for both variables of performance (review and collaborative final) and monitoring accuracy, non-parametric tests were utilized to understand condition differences. Kruskal-Wallis analyses were conducted separately for each review activity for both performance and monitoring accuracy. Data were ranked, and analyses compared the mean rank of groups. The data met the main assumptions for the Kruskal-Wallis procedure, with the dependent variable being measured at the ordinal interval, independent variables consisting of two or more independent groups, and independence of observations between groups being observed (Field, 2009).

Post-hoc analyses were conducted using Mann-Whitney tests. As Mann-Whitney tests are restricted to two independent groups, three separate analyses were run to assess group differences for significant main effects. Bonferroni corrections were used to control for multiple tests being run, and possible inflation of type I error (the incorrect rejection of a true null hypothesis). The critical value for significance ($p = .05$) was divided by the number of tests conducted (3) to provide the corrected significance value ($p = .0167$).

For the midterm exam, data met assumptions of normality and group differences were analyzed using a one-way ANOVA. The independent variable in the analysis was condition (control, individual, social), with the dependent variable being performance score. The
assumption of homogeneity was met for the analysis, with Levene's test being found to be statistically non-significant ($p > .05$).

**Frequency of metacognitive episodes.** Six of the 17 groups were found to complete the review activities outside of the Moodle chat platform. Therefore, data for frequencies of metacognitive episodes during online chat sessions were only available for 11 out of the 17 groups (3 control, 4 individual, and 4 social), with two of the social groups missing one review activity due to technical difficulties with the chat platform. Due to the reduction in statistical power as a result of missing data, it was felt that quantitative analyses were not appropriate to assess differences in conditions. Instead, frequencies were used to describe emerging patterns in the data. To describe differences in the occurrence of activities, the researcher created categories to describe the level of change in frequency observed ($< 5\% = \text{small}, 5-10\% = \text{moderate}, > 10\% = \text{large}$).

**Challenges in collaboration.** Due to the violation of the assumption of normality for categories of challenges in collaboration, motivation, technology, external control, and no challenge, non-parametric tests were utilized to understand condition differences. Mann-Whitney analyses were conducted separately for each category. Data were ranked, and analyses compared the mean rank of groups. The data met the main assumptions for the analyses, with the dependent variable being measured at the ordinal interval, independent variables consisting of two independent groups, and independence of observations between groups being observed (Field, 2009).
For the categories of time, task, and no code, data met assumptions of normality and group differences were analyzed using one-way ANOVAs. The independent variable in each analysis was condition (control, individual, social), with the dependent variable being challenge category. For each of the analyses, the assumption of homogeneity was met, with Levene's test being found to be statistically non-significant (all $ps > .05$).

**Qualitative analyses.**

**Coding of online chat logs.** As six of the 17 groups were found to complete the review activities outside of the moodle chat platform, coding and qualitative analysis of metacognitive episodes during online chat sessions were conducted solely on the remaining 11 groups (3 control, 4 individual, and 4 social). Coding steps were identical for coding of conversational turns and metacognitive episodes that occurred during online collaboration. Two coders (the researcher and instructor) conducted the analyses. Qualitative data were analyzed using a constant comparisons approach, by employing coding techniques borrowed from grounded theory (i.e., open and axial coding, see Creswell, 2013). Both, *a priori* codes (from literature review) and *emergent* codes (grounded in participants’ data) were used. The coding process undertaken in the study involved three main stages:

1. **Stage 1: Initial open coding:** The process of open coding involves coding the data for its major categories of information, with codes emerging directly from the data itself (Creswell, 2013). An initial round of open coding was conducted on chat logs from all groups for the first experimental review activity to understand some of the main
themes occurring during collaborative interactions. Following this, both coders met to
discuss the general themes observed and the appropriateness of the chosen coding
framework of Molenaar et al. (2014) to the data based on these general observations.
As a result of these discussions, the coding scheme (see Appendix M) was still
deemed appropriate for the analysis.

2. *Stage 2: A priori + open coding*: In the next stage of analysis, a priori coding, coding
based on a pre-existing theoretical framework or literature (Creswell, 2013), and open
coding were used simultaneously. Chat logs from the first experimental review
activity for three groups (one per condition, selected at random) were coded based on
the Molenaar et al. (2014) framework. Individual responses were allowed to contain
multiple codes to account for conversational turns that comprised more than one
statement or had statements that contained aspects of more than one category.
Initially, conversational turns were coded using six categories (metacognitive,
cognitive, relational, procedural, off-task, and not codable). Following this, coders
assigned a subcode for each chosen category. At this stage, discussions surrounding
the definition of codes occurred, and code descriptions were developed to align with
the context of the current study.

The process of coding metacognitive episodes was identical to the coding of
conversation turns, using the same groups and tasks. In the current study, a
metacognitive episode was defined as a sequence of connected conversational turns
that surround the same topic, or share the same focus regarding regulation of learning,
that contained at least one metacognitive activity/statement. Each episode started with a metacognitive activity/statement and ended after the last turn dealing with the same focus of regulation of learning (Molenaar et al., 2014). Episodes were first placed in one of three main categories (individual, other, social) and then social episodes were attached with a subcode (accepted, ignored, shared, and co-constructed). Within this analysis, the collaborative dynamic of the group was used to define the type of metacognitive episode observed, with analyses taking into account both the goal or purpose of a metacognitive statement (personal, other, or collective adaptation) and the response to the statement to categorize episodes (Molenaar et al., 2014).

3. **Stage 3: Axial coding:** The purpose of axial coding is to strategically reassemble data that were split during initial coding, specifying the properties of a category by relating categories to subcategories (Saldana, 2010). A first round of axial coding was utilized, with common factors merged and language describing factors unified. Axial coding was guided by the Molenaar et al. (2014) framework, and the six general categories for conversational turns (metacognitive, cognitive, relational, procedural, off-task, and not codable) and three general categories for episodes (individual, other, social). During this stage, the framework was adapted to provide a better fit for the current data. Definitions made during a priori and open coding were further refined to provide further clarity between sub codes in general categories of metacognitive, cognitive, and relational conversational turns, including the code of metacognitive
monitoring being expanded to include sub codes of ‘individual monitoring’ and ‘social monitoring.’ As within the initial open coding, open-ended responses were allowed to be coded for multiple factors, spanning across or within categories. Following this, the process was repeated on the same groups using chat logs from the final review activity. During this phase, the two raters met weekly to discuss their codes.

**Coding of collaborative challenges.** Qualitative data from responses to the item “What was your/your group’s main challenge? What did you do/you do as a group to overcome this challenge?” on the individual evaluation tool was coded using a priori coding. The coding scheme was adapted from Jarvela et al. (2013), and outlined seven types of challenges to be noted by individuals when responding to the prompt: time, external constraints, weak study strategies, challenges in collaboration, motivational challenges, technology, task, or no challenges (see Appendix N for full coding scheme).

**Validation strategies.** Validation in qualitative research is “an attempt to assess the accuracy of the findings, as best described by the researcher and the participants” (Creswell, 2013, p. 249). The current study followed the recommendation of Creswell (2013) of using multiple validation strategies.

**Memoing.** The process of memoing involves the researcher writing down ideas about the evolving theory throughout the process of open, axial, and selective coding (Creswell, 2013). Throughout the coding process, memos were used to note ideas and document the
processes that were being seen by the researcher, with aspects of these memos used in
discussions during peer review and debriefing.

**Peer review and debriefing.** The intention of peer reviewing is for a peer to
challenge the researcher regarding methods, meanings, or interpretations involved in
qualitative analysis (Creswell, 2013). Peer review and debriefing were used during both
initial coding and the later stage of axial coding when the existing framework was being
adapted to the responses collected. Peer debriefing sessions were run following each round of
coding with the instructor of the course, with the researcher keeping written accounts of these
sessions for use during later stages of analysis.

**Triangulation.** The strategy of triangulation uses multiple and different sources,
methods, investigators, and theories to provide corroborating evidence (Creswell, 2013). Two
sources of triangulation were used in the current study: 1) across sources (i.e., participants
and groups), and 2) across methods (i.e., observations from chat logs and documents taken
from group planning tool and collaborative activity).

**External audit.** At targeted points during the coding, external audits were conducted.
These involved researchers in the field who had expertise in researching self-regulated
learning, and who were not part of the study, assessing the accuracy of the process and
product of the coding being undertaken by the researcher (Creswell, 2013). Once coding was
completed, bi-weekly audits were used to assess whether the data supported the findings,
interpretations, and conclusions made by the researcher.
**Researcher bias.** Creswell (2013) outlines that it is important to understand the researchers’ past experiences, biases, prejudices, and orientations that may shape their interpretation or approach to the study they are conducting. In the current study, two areas are worth noting:

1. *View of regulation:* As a researcher, I hold the belief that regulation is a key component of collaborative interactions. As part of this, I view social metacognitive processes as observable, that can be successfully scaffolded in collaborative environments through the use of targeted interventions.

2. *Classroom experiences:* I have experience teaching online courses in a different field (Educational Psychology), and thus may view collaborative interactions based on my experience in the online classroom. Alongside this, my past experiences as a student have led to a perspective on how to behave within collaborative groups and projects. For example, engaging fully in the task and being professional when communicating with other group members.

**Reliability Perspectives.** In qualitative research, reliability often refers to the stability of responses to multiple coders of data sets (Creswell, 2013). The current study used inter-rater reliability to assess and ensure reliability in qualitative analyses.

**Inter-rater reliability.**

*Group chat logs.* During the initial coding phases, three group chat logs from one review activity were coded independently by the two raters. Following this, the raters met and examined the codes, their names, and text segments coded. The same process occurred
with the same groups for the final review activity, and through this the coding scheme confirmed.

Following this, both coders coded three additional chat logs of groups to determine the reliability of the coding scheme. During this, it was felt that it was more important to have agreement on text segments coders were assigning codes than to have the same, exact passages coded. Codes were reviewed and inter-rater agreement calculated for each group using a kappa reliability statistic. The process of independent coding and discussion was repeated twice: once for conversational turns, and once for metacognitive episodes. Coders were found to be reliable in their application of the coding scheme for both conversational turns and metacognitive episodes (Cohen's kappa > .8). Following the calculation of reliability, disagreements were discussed until consensus was reached for all conversational turns/metacognitive episodes. As reliability was met for the coding scheme, the researcher completed the analysis of the remaining data.

*Responses to evaluation tool.* Responses for all groups from the second review activity were coded independently by both coders. Codes were reviewed and inter-rater agreement calculated for each group using a kappa reliability statistic. Coders were found to be reliable in their application of the coding scheme (Cohen's kappa > .8). Following the calculation of reliability, disagreements were discussed until consensus was reached for all responses. As reliability was met, the researcher completed the analysis of the remaining data.
CHAPTER FOUR
Results

The present study examined the impact of individual and social regulatory frameworks compared to a control condition on regulatory activity in collaborative group work. The occurrence of metacognitive episodes and performance outcomes associated with the use of each framework were examined using both quantitative and qualitative data. This section contains both descriptive statistics and analyses for the study’s primary research questions.

Preliminary Analyses

Demographics. Chi-squared analyses run to test differences between groups following assignment showed no statistically significant differences between conditions in gender, race, academic standing, major \((ps > .05)\) (see Table 4.1 for frequencies).

Table 4.1
Frequencies of Demographic Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (n = 15)</th>
<th>Individual (n = 18)</th>
<th>Social (n = 19)</th>
<th>(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>6</td>
<td>9</td>
<td>8</td>
<td>23</td>
</tr>
<tr>
<td>Female</td>
<td>9</td>
<td>9</td>
<td>11</td>
<td>29</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>11</td>
<td>13</td>
<td>11</td>
<td>35</td>
</tr>
<tr>
<td>African American</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Hispanic/Latino</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
One-way ANOVAs revealed no differences in age or GPA between groups ($p < .05$) (see Table 4.2 for descriptive statistics).

Table 4.1 Continued

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control $n = 15$</th>
<th>Individual $n = 18$</th>
<th>Social $n = 19$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>American Indian/Alaska Native</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Academic Standing</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Juniors</td>
<td>8</td>
<td>13</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td>Seniors</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Sophomore</td>
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<td>2</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Unspecified</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Major</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science and Engineering</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>28</td>
</tr>
<tr>
<td>Social Science and Humanities</td>
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<td>3</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Business and Accounting</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Unspecified</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>
Table 4.2
Means and Standard Deviations for Demographic Variables

<table>
<thead>
<tr>
<th></th>
<th>Control $n = 15$</th>
<th>Individual $n = 18$</th>
<th>Social $n = 19$</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPA</td>
<td>3.14 (.56)</td>
<td>3.24 (.35)</td>
<td>3.22 (.60)</td>
</tr>
<tr>
<td>Age</td>
<td>20.08 (.862)</td>
<td>20.71 (2.29)</td>
<td>21.71 (6.13)</td>
</tr>
</tbody>
</table>

**Motivation and learning strategies.** One-way ANOVAs ran to test differences following assignment revealed no significant differences between groups for any self-report measure ($p$s > .05) (see Table 4.3 below for descriptive statistics).

Table 4.3
Descriptive Statistics for Self-Reported Motivation and Learning Strategies

<table>
<thead>
<tr>
<th></th>
<th>Control $n = 15$ ($k = 5$)</th>
<th>Individual $n = 18$ ($k = 6$)</th>
<th>Social $n = 19$ ($k = 6$)</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Interest</td>
<td>32.92 (8.22)</td>
<td>34.47 (9.37)</td>
<td>32.77 (4.66)</td>
<td>46</td>
</tr>
<tr>
<td>Liking Cooperation</td>
<td>14.82 (2.56)</td>
<td>16.41 (3.42)</td>
<td>16.00 (2.99)</td>
<td>44</td>
</tr>
<tr>
<td>Valuing Cooperation</td>
<td>18.64 (4.57)</td>
<td>20.47 (6.31)</td>
<td>19.50 (4.97)</td>
<td>44</td>
</tr>
<tr>
<td>Liking Competition</td>
<td>16.09 (5.05)</td>
<td>16.47 (5.21)</td>
<td>15.69 (6.30)</td>
<td>44</td>
</tr>
<tr>
<td>Valuing Competition</td>
<td>15.55 (6.09)</td>
<td>15.18 (6.34)</td>
<td>12.81 (4.82)</td>
<td>44</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>42.90 (5.88)</td>
<td>43.41 (9.29)</td>
<td>46.80 (5.75)</td>
<td>42</td>
</tr>
<tr>
<td>Rehearsal</td>
<td>18.80 (3.01)</td>
<td>17.88 (4.69)</td>
<td>18.60 (3.81)</td>
<td>42</td>
</tr>
<tr>
<td>Elaboration</td>
<td>27.50 (3.65)</td>
<td>28.12 (7.36)</td>
<td>30.87 (4.90)</td>
<td>42</td>
</tr>
<tr>
<td>Organization</td>
<td>18.30 (2.63)</td>
<td>18.18 (4.55)</td>
<td>19.60 (3.98)</td>
<td>42</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>21.40 (4.40)</td>
<td>20.71 (5.55)</td>
<td>22.27 (4.20)</td>
<td>42</td>
</tr>
</tbody>
</table>
Table 4.3 Continued

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control</th>
<th>Individual</th>
<th>Social</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n = 15$</td>
<td>$n = 18$</td>
<td>$n = 19$</td>
</tr>
<tr>
<td></td>
<td>$(k = 5)$</td>
<td>$(k = 6)$</td>
<td>$(k = 6)$</td>
</tr>
<tr>
<td>Metacognitive Self-Regulation</td>
<td>53.30 (4.88)</td>
<td>53.12 (9.12)</td>
<td>57.07 (8.16)</td>
</tr>
<tr>
<td>Time &amp; Study Environment</td>
<td>38.30 (4.81)</td>
<td>37.71 (5.41)</td>
<td>39.93 (6.54)</td>
</tr>
<tr>
<td>Peer Learning</td>
<td>12.10 (3.03)</td>
<td>10.88 (3.47)</td>
<td>10.73 (4.52)</td>
</tr>
</tbody>
</table>

Main Analyses

RQ1a: What are the differences between groups in the occurrence of social metacognitive episodes during scaffolded collaborative problem-solving?

**Frequency of episodes.** Due to the low frequency of metacognitive episodes, subcategories of social metacognitive episodes (accepted, ignored, co-constructed, and shared activities) were combined to provide an overall frequency count for social metacognitive episodes (see Table 4.4 below).

Table 4.4

<table>
<thead>
<tr>
<th>Review</th>
<th>Condition</th>
<th>Mean # of episodes</th>
<th>Individual</th>
<th>Other</th>
<th>Social</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Control</td>
<td>11.67</td>
<td>11.43%</td>
<td>25.71%</td>
<td>62.86%</td>
</tr>
<tr>
<td></td>
<td>Individual</td>
<td>10.50</td>
<td>11.90%</td>
<td>28.57%</td>
<td>59.52%</td>
</tr>
<tr>
<td></td>
<td>Social</td>
<td>7.00</td>
<td>21.43%</td>
<td>21.43%</td>
<td>57.14%</td>
</tr>
<tr>
<td>3</td>
<td>Control</td>
<td>7.67</td>
<td>26.09%</td>
<td>13.04%</td>
<td>60.87%</td>
</tr>
<tr>
<td></td>
<td>Individual</td>
<td>7.75</td>
<td>19.35%</td>
<td>19.35%</td>
<td>61.29%</td>
</tr>
</tbody>
</table>

Note: Individual = Individual Metacognitive Episode, Other = Other Metacognitive Episode, Social = Social Metacognitive Episode
Overall episode frequency. During the second and last review activity, groups in the social condition displayed the lowest frequency of metacognitive episodes compared to both the individual and control condition, with only a small difference seen between control and individual conditions. Frequencies for the third review activity, however, were reversed, with groups in the social condition showing higher instances of metacognitive episodes compared to control and individual conditions.

Both control and individual conditions showed a decline in the number of metacognitive episodes across review activities, with the social condition fluctuating and exhibiting an increase followed by a decrease in metacognitive episodes over time. Across all review activities, social metacognitive episodes were the most common form of episode for all conditions, with more than half of all activities coded during collaborative being social in nature (control = 63%; individual = 60%; social = 57.7%). Individual (control = 18.5%; individual = 17%; social = 20.4%) and other (control = 18.5%; individual = 23%; social = 21.9%) metacognitive episodes had a similar rate of occurrence across activities.

Table 4.4 Continued

<table>
<thead>
<tr>
<th>Review</th>
<th>Condition</th>
<th>Mean # of episodes</th>
<th>Individual</th>
<th>Other</th>
<th>Social</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Social</td>
<td>9.33</td>
<td>21.43%</td>
<td>14.29%</td>
<td>64.29%</td>
</tr>
<tr>
<td>4</td>
<td>Control</td>
<td>7.67</td>
<td>21.74%</td>
<td>13.04%</td>
<td>65.22%</td>
</tr>
<tr>
<td></td>
<td>Individual</td>
<td>6.75</td>
<td>22.22%</td>
<td>18.52%</td>
<td>59.26%</td>
</tr>
<tr>
<td></td>
<td>Social</td>
<td>5.75</td>
<td>17.39%</td>
<td>34.78%</td>
<td>47.83%</td>
</tr>
</tbody>
</table>

Note: Individual = Individual Metacognitive Episode, Other = Other Metacognitive Episode, Social = Social Metacognitive Episode
**Social metacognitive episodes.** Social metacognitive episodes are directed at group members’ joint cognitive processes, often involving monitoring and exerting control in the construction of common ground, facilitating shared representations, and inhibiting inappropriate conceptualizations (Molenaar & Chiu, 2014; Molenaar et al., 2014). Proportions of social metacognitive episodes remained relatively stable across tasks for groups in both control and individual conditions. Groups in the social condition, however, fluctuated over time, showing an increase in social episodes from review 2 to 3, and a decrease in frequency from review 3 to 4. Small differences between conditions (<5%) in proportions of social episodes were seen in review activities 2 and 3. However, in the last review, larger differences (>10%) were observed, with groups in the social condition showing a lower proportion of social metacognitive episodes compared to control and individual conditions. Groups in the individual condition also showed lower proportions of social episodes compared to control.

**Other metacognitive episodes.** Other metacognitive episodes are directed at another individual, occurring when a group member regulates the individual activity of another group member (Iiskala, Vauras, & Lehtinen, 2011, Molenaar et al., 2014; Volet, 2009). They are often unequal, with students asking for help or providing help to others to reciprocally enhance the learning experience and the realization of intended outcomes (Garrison & Aykol, 2014).

Groups in both social and individual conditions showed moderate (5-10%), and control condition large (> 10%), decreases in proportions of other metacognitive episodes
from review activity 2 to 3. Those in the control condition showed no difference, and the individual group small decreases (< 5%) in proportions from review activity 3 to the final review activity. Groups in the social condition, however, showed a large increase (> 10%) in other episodes from review 3 to 4.

During review 2 and 3, small to moderate differences between groups were observed, with the social condition showing lower proportions of other metacognitive episodes compared to individual and control conditions. However, large differences (> 10%) were seen at review 4, with groups in the social condition showing higher proportions of other metacognitive episodes than groups in both individual and control conditions. Groups in the control condition also showed lower proportions of other metacognitive episodes across all review episodes compared to those in the individual condition. However, differences between groups were small (< 5%).

**Individual metacognitive episodes.** Individual metacognitive episodes are directed internally, involving a student controlling or monitoring his/her own cognitive activities. Small to moderate (5-10%) increases in proportions of individual metacognitive episodes were observed over time for groups in the individual condition, with those in the social condition showing small (< 5%) decreases in proportions. Groups in the control condition, however, fluctuated in the proportion of individual episodes over time, showing a large (> 10%) increase from review 2 to 3, and moderate (5-10%) decrease in the proportion of individual episodes from review 3 to 4.
Differences between conditions were mixed across time. At review 2, groups in the social condition showed larger proportions of individual episodes compared to control and individual conditions. However, this was reversed at review activity 4, with those in the social condition showing moderately smaller proportions of individual episodes compared to both control and individual conditions. During review activity 3, groups in the control condition showed moderately higher (5-10%) proportions of individual episodes compared to those in both individual and social conditions.

**Qualitative analysis of episodes.** Qualitative analyses described in the current section are based on groups collaboration in online chat sessions. Due to missing data, analyses were only conducted for 11 out of the 17 groups (3 control, 4 individual, and 4 social), with two of the social condition groups missing data for one review activity.

The rich data gathered from the collaborative interactions of groups for the three tasks allowed the researcher to understand and describe how groups engaged and completed tasks. The results below describe the a) common themes identified for all participants and b) differences across case study groups (i.e., bounded case studies). Three common themes for all study participants were identified, namely: 1) adherence and interaction with framework components, 2) function and focus of observed metacognitive episodes and 3) group dynamics (see Table 4.5 below for major codes and description of themes). The themes were identified based on the theoretical framework and emergent data from the collaborative interactions during the review activities. Each condition was analyzed as a bounded case
study. The analyses are an illustration of the influence of collaborative framework(s) on groups collaboration when engaging in the review activities.

Table 4.5
Themes, Major Categories, and Descriptions from Qualitative Analyses

<table>
<thead>
<tr>
<th>Theme</th>
<th>Major Categories</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adherence and interaction with framework components</td>
<td>1.1 perception</td>
<td>Whether groups appeared to value and show engagement in aspects of the intervention</td>
</tr>
<tr>
<td></td>
<td>1.2 purpose</td>
<td>The outcome or influence of the intervention components on group interactions</td>
</tr>
<tr>
<td>Function and focus of observed metacognitive episodes</td>
<td>2.1 function</td>
<td>Intended purpose of episodes in regard to influencing group interactions</td>
</tr>
<tr>
<td></td>
<td>2.2 focus</td>
<td>The focal point of the regulatory episode (e.g., content orientated)</td>
</tr>
<tr>
<td></td>
<td>2.3 sequencing</td>
<td>General patterns of episodes observed across the task as a whole</td>
</tr>
<tr>
<td>Group dynamics</td>
<td>3.1 missing member</td>
<td>Group is missing one of its members</td>
</tr>
<tr>
<td></td>
<td>3.2 member enters late/leaves early</td>
<td>Group member joins the task late or leaves early</td>
</tr>
<tr>
<td></td>
<td>3.3 prior knowledge</td>
<td>Group members have not completed the pre-work fully</td>
</tr>
<tr>
<td></td>
<td>3.4 unequal participation</td>
<td>Unequal participation in task from group members</td>
</tr>
</tbody>
</table>

Theme 1. Adherence and interaction with framework components. When assessing the value placed upon and engagement shown when groups interacted with the experimental framework during collaboration, as well as the outcome or influence of the intervention
components on group interactions, two main aspects of the intervention were analyzed: 1) use of the planning tool and 2) use of the checkpoints.

*Use of planning tool.* Three patterns emerged in the use of the planning tool across the semester/review activities: 1) complete disengagement, 2) moving from engagement to disengagement, and 3) increased engagement across time. In the first sequence (complete disengagement) there was no evidence of the use of the group planning tool by the groups, with groups not engaging in any form of planning prior to engaging in the task.

In the second observed sequence (engaged \(\rightarrow\) disengaged), groups engaged with the planning tool prompts in the second review activity, using the tool to scaffold their responses. Within this, groups commonly shared the outline of the scenario, listed aspects they needed to accomplish as they moved through the task, as well as outlined important content knowledge that would help them come to their conclusions (see Table 4.6 below for example).

Table 4.6
*Example of Group Engaging in Planning Activity*

<table>
<thead>
<tr>
<th>Time</th>
<th>Participant</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:51</td>
<td>C</td>
<td>let's start the planning tool?</td>
</tr>
<tr>
<td>15:51</td>
<td>A</td>
<td>sounds good</td>
</tr>
<tr>
<td>15:51</td>
<td>B</td>
<td>Either is fine with me. And yeah I'm looking at the planning tool</td>
</tr>
<tr>
<td>15:51</td>
<td>C</td>
<td>let's start the planning tool?</td>
</tr>
<tr>
<td>15:51</td>
<td>A</td>
<td>sounds good</td>
</tr>
<tr>
<td>15:51</td>
<td>B</td>
<td>Either is fine with me. And yeah I'm looking at the planning tool</td>
</tr>
<tr>
<td>15:51</td>
<td>C</td>
<td>1. determine the sediments composition under each of the school. 2. compare the three different sediments: solid bedrock, poorly consolidated sediment and water saturated sand and mud 3. determine how badly the three schools will be affected…</td>
</tr>
</tbody>
</table>
Table 4.6 Continued

15:51 C: …by the earthquake wave 4. we predict that the school near the sea will be influenced much more than the others, because the loose sediment fill will shake much more than the rockly bedrock
15:51 C: that's my temporary answers
15:52 C: but i's not sure what else should be put onto the bullet
15:53 A: those sound good to me, we can add a few more
15:53 C: ok
15:58 A: 5. Perform an analysis of each school and rate the level of each factor relative to earthquake danger. 6. Determine how the school should use the 10$ million: should they use it reconstruct the building itself, or the soil beneath it.
16:00 B: By analysis each school you mean like send a structural engineer to each school to determine which ones are the most structurally sound?
16:00 A: yea
and by using the data he gave us
16:02 C: goodpoint
16:03 A: Yall think thats enough?
16:04 B: Yeah, other than that and possibly looking for other tall buildings that could be damaged in an earthquake and in turn damage the school
16:04 C: i think that's enough
16:04 B: I think that would be it

Note. Example taken from chat transcripts of a control group during review activity 2.

In the illustrative example, the group shows engagement and value towards responding to the planning tool through their integrated discussion. The cohesive nature of their conversation underpins their engagement in the task itself and provides a platform for regulation. Initially, group member C provides a suggestion, followed by a statement of uncertainty in the form of a metacognitive statement (15:51 – 15:52 in Table 4.6), to engage the rest of the group in a discussion surrounding their response to the planning tool. This
leads to group member A to engage in metacognitive thought and evaluate/build upon group member C’s initial outline. Following this, group member B monitors their understanding and engages member A in clarification, evaluating the group’s response before suggesting to move on. Finally, once the group develops their shared understanding through clarification of their co-constructed response, they evaluate whether they are ready to move on together.

In the later review activities, however, although groups spent an equivalent amount of time planning, the quality of group discussions were markedly different. It appeared that over time, the value that groups associated with completing the group planning tool decreased. Group members were seen to either work separately on their answers with little discussion, briefly outlining the goal for the task and then moving on, or merely suggesting to reword the task description as their response (see Table 4.7 below for example).

Table 4.7
Example of Group Disengagement in Planning Activity

<table>
<thead>
<tr>
<th>Time</th>
<th>Participant</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:32</td>
<td>C</td>
<td>on the group planning tool</td>
</tr>
<tr>
<td>12:33</td>
<td>B</td>
<td>Yeah. I'm never really sure what to put for the group planning tool.</td>
</tr>
<tr>
<td>12:35</td>
<td>B</td>
<td>In a way, I just reworded what the directions say we are supposed to do. Like how we are going to do each thing</td>
</tr>
<tr>
<td>12:38</td>
<td>C</td>
<td>what are you thinking for the second bullet</td>
</tr>
<tr>
<td>12:40</td>
<td>B</td>
<td>I think that probably has to do with the companies getting away with harming people by dumping waste and not having to deal with the consequences. The act makes them responsible for paying for the cleanup</td>
</tr>
<tr>
<td>12:47</td>
<td>A</td>
<td>you guys finish the planning tool yet?</td>
</tr>
<tr>
<td>12:47</td>
<td>B</td>
<td>Yeah I have</td>
</tr>
</tbody>
</table>

Note. Example taken from group in control condition during final review activity.
Disengagement in the task is exemplified in the example though the break down in collaboration itself. Group member A shows complete separation from the group and completing the task collaboratively, only engaging with the other group members to check if they had completed the planning. The discussion between the remaining group members is fragmented, and the group is not working together to complete their planning for the task. As a result, the group shows very little regulatory processes. Although group member B opens up the conversation with a metacognitive statement, noting that they are not sure what to do, it is ignored by group member C. In the short discussion that follows, group members remain disconnected in their work, with group member C asking B what they put down without any input. The lack of engagement in regulatory thought is further highlighted by the group failing to come to a unified consensus regarding their response to the planning tool before moving on.

In the second sequence (increased engagement), groups showed engagement from the second review activity, sharing an outline of the scenario, listing aspects they needed to accomplish as they moved through the task, and outlining content knowledge that would help them come to their conclusions. However, by the planning phase in the final review activity, groups had further developed in their cohesiveness and become more efficient in their planning, drawing on individual prework to guide their understanding of aspects of the task and their overall goal, as well as developing content-related notes on the task itself.
Table 4.8
*Example of Increased Engagement During Planning Activity*

09:12 A: I guess we can at least start the group planning tool
09:13 C: ok How can we achieve the goal, what is our main challenge
09:15 A: Im looking at the prework he emailed us and I like the second response
09:15 A: Using what we've learned about hydrology and geology, we must look into the
   events that surrounded the Love Canal and how they impacted the environment as
   well as the legislative actions that were taken because of these events
09:15 A: for our main goal
09:16 C: I like that. We will achieve our goal by looking at the data provided for us on the
   area and looking at the history of the Superfund Act.
09:18 A: Okay. And I guess for our challenge we can put communication since we all
   mentioned it
09:19 C: yep
09:21 A: Our main challenge for this task will be communication as we have had trouble
   with this in the past. To overcome this, we will establish means of communication
   ahead of time so that we can all collaborate effectively.
09:22 A: it also says we need a bulleted list of preparation notes.......  
09:22 C: i know, but it always says that and we always do well on this
09:22 A: true
09:23 C: you wanna put a list of notes on hydrology?
09:23 C: cause I can do that
09:23 A: I guess we can include a couple of bullets
09:25 C: Im typing some up
09:25 A: okay
09:26 C: Ground water flows along underground contours Losing stream- when
   groundwater contours slope away from the stream Gaining stream- when
   groundwater contours slope towards the stream
09:28 C: Aquitard- a layer of rock impenetrable by water.
09:28 C: i think were good
09:28 A: that works, I'm about to submit then

*Note.* Example taken from group in individual condition during final review activity.
In the previous example of engagement (see Table 4.6), group members showed their engagement and value towards responding to the planning tool through their integrated discussion. This is again demonstrated in the above example. However, group members do not need a statement of uncertainty to engage the group in discussion, and instead immediately share ideas surrounding planning. Alongside this, the group shows a higher level of integration of prior regulatory thought through group member A’s use of prior individual planning work when building their response. Again, the cohesive nature of their conversation underpins their engagement in the task itself and allows regulatory discussion to occur. This is exemplified in monitoring statements made by member C during initial discussion of their goal (see 09:16 and 09:18 in Table 4.8), as well as, at the end of planning, evaluating the necessary content knowledge in hydrology needed for the task (see 09:28 in Table 4.8).

There were noticeable condition differences in the patterns of engagement observed between control and experimental conditions. All groups in the control condition showed decreased engagement in group planning over time (engaged → disengaged); whereas the experimental groups in both individual and social conditions showed mixed results, with one group showing complete disengagement, one group decreased engagement, and one group increased engagement over time.

Alongside responding to planning prompts, and as part of the planning phase for the experimental (individual and social) conditions, groups were also asked to make predictions regarding their grade/performance for the upcoming task. Group differences were shown in
the occurrence of discussions surrounding predictions. In the social condition, two of the four social groups engaged in planning, with these groups failing to mention their prediction during their planning of review activity 2 (predictions were mentioned in the remaining two review activities). Whereas, in the individual condition, only one of the two groups who engaged in planning participated in a discussion about their predictions, doing so in each of the review activities.

When comparing social and individual conditions, no differences were observed in the format and content of discussions surrounding predictions held during planning. Discussions were often short and without elaboration, with one member commonly suggesting a predicted value without explaining their reasoning and other members agreeing without further input (see Table 4.9 below for example). As a result, predictions did not spur metacognitive episodes within groups, and minimal regulatory discussion occurred during these interactions.

Table 4.9
Example Discussion Surrounding Prediction of Performance

<table>
<thead>
<tr>
<th>Time</th>
<th>Participant</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:07</td>
<td>B</td>
<td>so group planning tool</td>
</tr>
<tr>
<td>14:07</td>
<td>C</td>
<td>Just opened it</td>
</tr>
<tr>
<td>14:08</td>
<td>C</td>
<td>Our goal?</td>
</tr>
<tr>
<td>14:09</td>
<td>B</td>
<td>uhh</td>
</tr>
<tr>
<td>14:09</td>
<td>B</td>
<td>to accurately discuss the issues with love canal i guess</td>
</tr>
<tr>
<td>14:09</td>
<td>C</td>
<td>can't we just say the learning goals he listed? lol</td>
</tr>
<tr>
<td>14:09</td>
<td>B</td>
<td>yeah basically lol</td>
</tr>
<tr>
<td>14:11</td>
<td>C</td>
<td>Should we say a 95%?</td>
</tr>
</tbody>
</table>
Table 4.9 Continued

14:12 C: Or should we be bold and say 100?
14:12 B: lol lets go with a 95

*Note.* Example taken from group in the social condition during the final review activity.

*Use of checkpoints.* At targeted points during the case-study activity, experimental groups were prompted to consider the effectiveness of their current strategy use and rate their confidence in their work, and control groups were asked to double-check their answers for the previous sections. The use of the checkpoints to aid conversation was limited. In the individual condition, one of the three groups evidenced a discussion surrounding the checkpoints, with this discussion only occurring during first review activity 2. In the control condition, two of the three groups evidenced that they utilized the given checkpoints to aid their discussion on the task, however, like the individual condition, these conversations only occurred during review activity 2. In the social condition, no evidence was shown in the interactions that any of the three groups considered (or used) the checkpoints during any of the review activities.

When groups did engage in conversations surrounding the checkpoints, discussions were brief, with groups using them to quickly assess their current understanding and progress toward their overall goal (see Table 4.10 below for example). However, although conversations were brief, the checkpoints did spur metacognitive regulation in groups. For example, in the excerpt below, group member C initiates the discussion surrounding the checkpoint by monitoring group progress concerning their goal of deciding upon the most
hazardous city. This statement surrounding the checkpoint prompts member A to go back and engage in evaluation of their own understanding, as well as leading group member B to engage in metacognitive planning and suggest the next step for the group to achieve their goal.

Table 4.10

*Example Discussion Surrounding Checkpoint*

<table>
<thead>
<tr>
<th>Time</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:43</td>
<td>C: SO far, I think Francisco is the most hazardous based on our numbers</td>
</tr>
<tr>
<td>15:43</td>
<td>A: I’m re looking at them</td>
</tr>
<tr>
<td>15:43</td>
<td>C: ^that was in relevance to the checkpoint</td>
</tr>
<tr>
<td>15:43</td>
<td>B: Yeah I agree, its not looking good for Francisco lol now we get to examine the building structures themselves to finalize that.</td>
</tr>
<tr>
<td>15:44</td>
<td>A: Yep</td>
</tr>
</tbody>
</table>

*Note.* Example taken from group in the individual condition during review activity 2.

**Theme 2. Function and focus of episodes.** The second theme, related to the focal point of regulatory episodes (e.g., content related), as well as an episode’s influence (or intended purpose) on group interactions. The inclusion of the theme in qualitative analyses was guided by prior literature in social regulatory processes that have used both function and focus of episodes to distinguish between types of regulation and their impact on collaborative interactions (e.g., Ucan & Webb, 2015).

The function and focus of the different types of episodes were found to remain relatively stable across conditions and review activities. Individual regulatory episodes, in which a student regulates his or her own cognitive activities, held two main functions during
collaboration. The first was to serve the individual, with the function of the episode being the alleviation of confusion. The focus of the episode was predominantly task or content related, with individual either searching for the correct answer or seeking clarification regarding task demands (see Table 4.11 below for example).

Table 4.11
*Example of Individual Metacognitive Episode (Individual)*

<table>
<thead>
<tr>
<th>Time</th>
<th>Username</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:40</td>
<td>B</td>
<td>I'm honestly not sure about C</td>
</tr>
<tr>
<td>16:42</td>
<td>A</td>
<td>A has just entered this chat</td>
</tr>
<tr>
<td>16:45</td>
<td>C</td>
<td>c) This map only includes data from Jone because this data on this map is almost all lower than the average, and on June, the albedo reach its lowest point. No, I don't think that looking only at June changes how I interpret the information depicted on the ma. Although we cannot conclude by looking at just one example, I think the answer will not change so much by picking another month in this year. Because the anomalies will not change so much, because the albedo in each year is going to be slightly lower and the anomalies is going to be slightly positive</td>
</tr>
<tr>
<td>16:48</td>
<td>A</td>
<td>A has left this chat</td>
</tr>
<tr>
<td>16:50</td>
<td>B</td>
<td>I think that sounds pretty good.</td>
</tr>
</tbody>
</table>

*Note.* Example taken from group in control condition during review activity 3.

In the example, group member B initiates the episode with an individual metacognitive statement regarding their confusion in the current task. Once group member C has provided their response, B evaluates it; however, B does not use their evaluation to come to a shared understanding with the other group members. As a result, the episode serves solely to alleviate group member B’s confusion, and there is no benefit to the group in regards to other members being involved in the regulatory discussion.
The second type of individual metacognitive episode observed served both the individual and the group, with the function of the episode being an individual monitoring their own understanding for the benefit of the group. Such episodes were often triggered when there was a pause or slowing down of collaborative interactions. The function of these episodes was to spur discussion and focused on clarification of their understanding through the responses of other group members. Although this form of individual activity commonly appeared to benefit the group as a whole, the individual initiating the episode was seen to gain more than the other participants as a result of the episode (see Table 4.12 below for example).

Table 4.12
Example of Individual Metacognitive Episode (Individual + Group)

14:08 C: I am getting very different answers but am also confused, can you explain how you got that
14:09 B: I got a value that was 10X that number, conversion issue?
14:10 B: This is what I have written down: 150 meters to centimeters is 15000 cm. Now, divide 15000cm by 10^-5 cm/s to get the number of seconds it took for the toxic waste to reach the homes which is about 1.5*10^9 seconds. Then convert to days by dividing by (3600 seconds *24 hours/day) and get 17,361 days and converted to years gives you about 47 years.
14:10 C: im getting the same values but its 0.1736 days
14:10 A: Yeah I realized I used .0864 instead of .00864 so Bs should be right?
14:12 C: Yeah I got what B got, I realized my mistake
14:13 A: Did you not use the 864m/day in your calculation?
14:13 C: thats not the rate
14:13 B: okay cool, it makes sense as well since 1920 was when the first dumping of waste into the canal began. So assuming that is right then the residents have been living with that for a little over a decade until they were ordered to evacuate
In the example, the episode starts, similar to the prior example, with a metacognitive statement of confusion from group member C. However, rather than searching for an answer for the individual, group member B uses their confusion to spur a conversation regarding the topic. This leads to the other group members engaging in regulatory thought, highlighted in member A’s monitoring and evaluation of their own knowledge regarding the calculation that the group has to perform. The episode not only benefits group member C by breaking down the task and allowing them to evaluate their error but also helps the group evaluate their own strategy use. This enables the group to come to a shared understanding that two solution paths were available for the problem before moving on to the next aspect of the task.

Other regulatory episodes occurred when a group member regulated the individual activity of another group member. These episodes commonly involved one member of the group monitoring others completion of task components or adherence to task demands, with the function of the episodes being to prompt other group members to regulate or reassess their current perspective, and the focus on content creation or providing a response. Although the interaction was not balanced, as the individual being regulated was required to engage

Table 4.12 Continued

<table>
<thead>
<tr>
<th>Time</th>
<th>Participant</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:15</td>
<td>A</td>
<td>I got the same answer just calculated differently but I guess its fine as long as it works out.</td>
</tr>
<tr>
<td>14:17</td>
<td>B</td>
<td>yeah, as long as we reached the same answer, there were two ways to solve the problem</td>
</tr>
</tbody>
</table>

Note. Example taken from group in control condition during final review activity.
more deeply than others, the outcome appeared to benefit the group as a whole (see Table 4.13 for example).

Table 4.13
Example of Other Metacognitive Episode

<table>
<thead>
<tr>
<th>Time</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:53</td>
<td>A: Looks like we each need to do one time period each</td>
</tr>
<tr>
<td>12:53</td>
<td>C: oh i see now haha</td>
</tr>
<tr>
<td>12:53</td>
<td>A: we can just copy and paste them</td>
</tr>
<tr>
<td>12:53</td>
<td>C: ill do 3rd</td>
</tr>
<tr>
<td>12:53</td>
<td>A: - It was originally planned to be a canal connecting the Niagara River to Lake Ontario, but was abandoned mid build due to a widespread financial panic in 1983. - It gradually filled with natural water over the next few decades and it was primarily used by the 1920's as a dumpsite for the City of Niagara Falls to put their garbage collection. -Hooker Chemical Company came into the Love Canal region in in the 1940's looking for a region to dumb the waste from their chemical plant. These included alkalines, fatty acids, and chlorinated hydrocarbons that were used to make perfumes and dyes and were extremely harmful. - In 1953, Hooker gave the site to the Niagara Falls School Board, and Hooker effectively used documents to remove liability from any future lawsuits that may arise in the area.</td>
</tr>
<tr>
<td>12:54</td>
<td>A: That's the first</td>
</tr>
<tr>
<td>12:55</td>
<td>A: we can just copy and paste them all in here when we finish</td>
</tr>
<tr>
<td>12:57</td>
<td>B: -In 1954, the Niagara Falls School Board built the 99th street elementary school on the land -In 1955, the school was completed and the 93rd street school was opened six blocks away -1955-1970s, houses were built on the land surrounding the area -In 1957, sewer lines were built for the surrounding houses -In 1976, reporters started to investigate the site and found barrels of toxic waste that have been seeping out and toxic residue was in the air -Love Canal Homeowners association started taking surveys and found many residents were being affected by disease -In 1978, it was recommended that the schools be closed and pregnant women and children evacuate Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act or the Superfund Act -In 1980…</td>
</tr>
</tbody>
</table>
Table 4.13 Continued

12:57 B: … Jimmy Carter ordered an evacuation of Love Canal
12:58 A: that was supposed to be 1893 in mine, not 1983
13:01 A: C do you have yours?
13:03 C: - In 1980 the Comprehensive Environmental Response, Compensation and Liability Act of 1980. - The Environmental Protection Agency cleans up contaminated sites and companies responsible have to pay. - Many of the houses near Love Canal have been destroyed since and the west side is completely abandoned. - The Superfund cleanup did not end until 2004.
13:03 C: Thats all i have right now. I can find as much as you guys did
13:03 C: cant
13:04 B: Thats good. I doubt as much happened after it was all over

Note. Example taken from group in control condition during final review activity.

Social metacognitive episodes, in which one or more group members regulate(s) their collaborative cognitive activities, were the most common form of episode observed. The primary function of these episodes was to have the group as a whole regulate or reassess their current shared perspective. The focus of the episodes was commonly on the sequencing of activities or orientation toward task demands. Episodes required input for more than one member, and rather than in other metacognitive episodes that ended in a targeted individual responding to the group, episodes ended when agreement occurred between multiple group members. Episodes did vary regarding the level of input from participating members, with some led predominantly by one member, and others dispersing agency between two (or more) individuals. Alongside this, the episodes were also relatively concise, with not a great
level of detail required in responses between group members. Based on this, the overall impact on wider group regulatory process appeared to be diminished, with episodes not having a lasting effect on collaboration past the several conversational turns proceeding it (see Table 4.14 below for example).

Table 4.14
*Example of Social Metacognitive Episode*

15:06 B: So looks like the first thing we need to do is create a bullet list of preparation notes for the group planning tool
15:06 C: Lets first take down important notes from the video.
15:07 C: Two variables affect earthquake damage: Intensity of shaking (felt motion not magnitude) and Engineering of Buildings
15:10 B: Sediment type is a key factor as well with respect to the intensity of shaking felt with S-waves
15:10 A: The type of soil
15:12 C: Change in rock type (solid, poorly consolidated, water saturated, etc.) also have large impacts on building damage, with more solid bedrock resulting in less damage. Earthquake has 3 phases in order of occurrence: P wave (quick, compressive bumps that rarely causes much damage), S Wave (side to side shearing motion which can throw loose objects and cause cracks), and Surface Waves (rolling wave that causes most damage, increase in size and damage in more saturated sediment)
15:12 C: Slower the wave, the more destructive and powerful.
15:13 C: let's take notes from the article now
15:14 B: True, so lets put all of that into bullet information for the video portion on the first assignment.
15:17 A: Sorry the fire alarm in my building just went off.
15:17 B: You're fine, we are still just working on the bullet points from the video and article
15:20 A: Okay, looking at the article, it's just about the San Francisco earthquake and …
Table 4.14 Continued

<table>
<thead>
<tr>
<th>Time</th>
<th>Participant(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:20</td>
<td>A: … what happened. I'm not seeing anything specific to take notes on.</td>
</tr>
<tr>
<td>15:20</td>
<td>B: yeah, I am not either. I just finished reading it, so most the bullet points should come from the video and C summed those up pretty well earlier.</td>
</tr>
<tr>
<td>15:21</td>
<td>C: Same, it references relations to geologic conditions and shaking, but does not go on to explain them.</td>
</tr>
<tr>
<td>15:21</td>
<td>C: Here are my Articles bullet points though..</td>
</tr>
<tr>
<td>15:21</td>
<td>C: Significant earthquake because of the scientific knowledge derived from its size.</td>
</tr>
<tr>
<td>15:21</td>
<td>C: Ruptured 296 miles (477 km) of San Andreas Fault, from northwest of San Juan Bautista to the triple junction at Cape Mendocino</td>
</tr>
<tr>
<td>15:22</td>
<td>C: Helped formulate the elastic rebound theory of the earthquake source</td>
</tr>
<tr>
<td>15:22</td>
<td>C: There was a clear correlation of shaking intensity with underlying geologic conditions.</td>
</tr>
<tr>
<td>15:22</td>
<td>C: Strongest shaking occurred in areas where ground reclaimed from San Francisco Bay failed in the earthquake.</td>
</tr>
<tr>
<td>15:22</td>
<td>C: Sediment filled valleys shook more than nearby bedrock sites.</td>
</tr>
<tr>
<td>15:24</td>
<td>A: Okay. So with that and the notes from the video, are we ready to move to the next thing?</td>
</tr>
<tr>
<td>15:24</td>
<td>C: I think so</td>
</tr>
<tr>
<td>15:25</td>
<td>A: I'm opening the next assignment now</td>
</tr>
<tr>
<td>15:25</td>
<td>B: I believe so</td>
</tr>
</tbody>
</table>

*Note.* Example taken from group in control condition during review activity 2

In the example, the group members assess and negotiate task demands together, building a mutual understanding of their goals for the upcoming task in the process. During their interaction, each member shares ideas, which prompts each other to justify and clarify their understanding. Although group member C provide more content to the group, all members were equally involved in regulation, and because of this were able to build a consensus on a mutual understanding. For example, when the group discusses the lack of
relevant information in the article that they can use regarding the task, or, at the end of the episode when each member evaluates whether they are ready to move on.

Regarding the sequencing of episodes across the tasks, two patterns emerged in the occurrence of regulatory episodes of groups. The first pattern, occurring in 37% of review activities, was that social regulatory episodes bookended the task (Social → Individual/Other → Social). Commonly, groups would begin the planning phase with social regulatory episodes concerning procedures to be undertaken. As they moved into the task, the form of episodes became individual or other metacognitive as group members would share responses with each other and subdivide components of the task. Towards the end of the activity, social episodes would be observed again as groups tied up their work and noted their conclusions as a group.

The second pattern, occurring in 40% of review activities across groups, was that social episodes only occurred at the beginning of the task (Social → Individual/Other). Like, the previous pattern, groups would begin the planning phase with social regulatory episodes concerning procedures to be undertaken. As they moved into the task, individual or other episodes would occur naturally as group members would share responses with each other and subdivide components of the task. However, towards the end of the activity, groups remained separated, monitoring their own individual understanding or conclusions compared to others. This form of sequence was often seen in groups where there was an abrupt end to the task and groups left the online space without addressing their conclusions or evaluating the groups’ progress.
In the remaining 23% of review activities, no discernable patterns occurred, with groups showing a mixture of social, individual, and other metacognitive episodes throughout the review activity. No differences were observed between conditions in patterns displayed by groups.

**Theme 3. Group dynamics.** The third theme emerged from the data and centered around aspects of the group that impacted regulation and were not captured in the analysis of groups interaction with the experimental frameworks. These aspects surrounded the dynamic or composition of the group itself that altered the context in which groups collaborated, including missing a group member, members entering late or leaving a review activity early, exhibiting a lack of prior knowledge, and unequal participation.

In approximately 20% of review activities, groups were missing a member. When this occurred, it created some indecisiveness in groups regarding how they should carry out the task. In particular, missing a member impacted regulatory episodes seen at the beginning of the task as it interfered with, and broke up, the initial planning episodes. Having a missing member somewhat hindered groups ability to fully engage in the planning episode, and groups often seemed less engaged or took a shorter period to decide on their goal or plan their activities (see Table 4.15 for example). In the example below, one group member has failed to contact or respond to the other group members and is missing from the chat. This leaves the remaining group members uncertain about how to begin the planning for the task itself. When the group does begin to plan, collaboration is disjointed. Group members engage in minimal regulatory thought/discussion, instead, working individually on their responses.
Table 4.15

*Example Initiation of Planning Episode with Missing Group Member*

<table>
<thead>
<tr>
<th>Time</th>
<th>Conversation</th>
</tr>
</thead>
<tbody>
<tr>
<td>19:51</td>
<td>B: hopefully this doesn't take long</td>
</tr>
<tr>
<td>19:52</td>
<td>C: Seriously though I wonder if we should email A again?</td>
</tr>
<tr>
<td>19:52</td>
<td>C: But anyway the planning tool isn't too bad</td>
</tr>
<tr>
<td>19:53</td>
<td>B: i emailed him a few minutes ago</td>
</tr>
<tr>
<td>19:53</td>
<td>B: not really sure what we should do with him</td>
</tr>
<tr>
<td>19:53</td>
<td>B: you look at the emails he may not have gotten the later ones</td>
</tr>
<tr>
<td>19:53</td>
<td>C: We can just start now and then catch him up later, what is our goal for the task?</td>
</tr>
<tr>
<td>19:54</td>
<td>C: I emailed him too, we'll see.</td>
</tr>
<tr>
<td>19:54</td>
<td>B: alright give me a sec to read the task</td>
</tr>
<tr>
<td>19:59</td>
<td>C: So basically the goal is just the task itself right?</td>
</tr>
<tr>
<td>20:00</td>
<td>B: yeah seems like it</td>
</tr>
<tr>
<td>20:03</td>
<td>C: what are the challenges</td>
</tr>
<tr>
<td>20:03</td>
<td>C: and preparation notes, this is the worst</td>
</tr>
<tr>
<td>20:05</td>
<td>B: challenges is a difficult one</td>
</tr>
<tr>
<td>20:05</td>
<td>B: im just saying that it will be hard to determine clearly which is the best unless it's explicitly obvious</td>
</tr>
<tr>
<td>20:06</td>
<td>C: okay thats kinda what i said too</td>
</tr>
<tr>
<td>20:07</td>
<td>C: this is what i said for tasks 1)evaluate all documents and data provided 2)assess damages from previous earthquakes 3)consider the earthquakes that could possibly occur in the coming years</td>
</tr>
</tbody>
</table>

*Note.* Example taken from group in social condition during review activity 2

One group member entered the task late or left early in 15% of cases. When group members entered late, the rest of the group had to adjust their tasking priorities, and as a result, momentum built during the task to that point dissipated. When the member entered, the focus shifted from social/individual regulation to other regulation wherein the groups’ goal is to get the member up to speed (see Table 4.16 for example). In the example below, prior to group member C entering, members are exhibiting planning (division of labor) and
monitoring prior to engagement in the next question. However, when group member C enters, regulation shifts perspective from how the group is completing the task to the regulation of the incoming group members cognitive activities. Following this, group work breaks down, and the group does not come back together to discuss their responses, instead, continuing to complete task separately/out of sync. Group member B does show some monitoring of the others progress when asking members to tell him/her when they have come to Q7, however, this doesn’t seem to be in service of working as a group as they note they have already begun the task.

Table 4.16

*Example of Interaction when Individual Enters Task Late*

<table>
<thead>
<tr>
<th>Time</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:52</td>
<td>B: ok you want A and ill take B</td>
</tr>
<tr>
<td>09:52</td>
<td>A: ok do we have to do the other two?</td>
</tr>
<tr>
<td>09:53</td>
<td>B: i pretty sure we individually are responsible for 1</td>
</tr>
<tr>
<td>09:53</td>
<td>B: cause i think there are some groups of</td>
</tr>
<tr>
<td>09:54</td>
<td>C has just entered this chat</td>
</tr>
<tr>
<td>09:54</td>
<td>C: just now getting up, you guys still on here?</td>
</tr>
<tr>
<td>09:55</td>
<td>B: yea</td>
</tr>
<tr>
<td>09:55</td>
<td>B: we are halfway in</td>
</tr>
<tr>
<td>09:55</td>
<td>B: actually just starting 5</td>
</tr>
<tr>
<td>09:55</td>
<td>B: honestly the first 4 are pretty self explanatory let us know if you have questions ill tell you what i put</td>
</tr>
<tr>
<td>09:56</td>
<td>C: Thank you!</td>
</tr>
<tr>
<td>10:00</td>
<td>B: and for number 5 we each have to pick one graph to do, A did A i did B so you…</td>
</tr>
<tr>
<td>10:00</td>
<td>B: … can do either c or d</td>
</tr>
<tr>
<td>10:00</td>
<td>B: this part is individual work</td>
</tr>
<tr>
<td>10:01</td>
<td>C: ok I’ll take c</td>
</tr>
<tr>
<td>10:01</td>
<td>A: Ok I’m done whenever you guys are ready</td>
</tr>
<tr>
<td>10:01</td>
<td>C: i'll take c</td>
</tr>
<tr>
<td>10:05</td>
<td>B: ok i finished my questions for 6 im on 7 now</td>
</tr>
<tr>
<td>10:09</td>
<td>B: let me know when yall are one 7</td>
</tr>
</tbody>
</table>

*Note.* Example taken from group in individual condition during review activity 3
On the other hand, when group members left early, collaboration was seen to end abruptly and without the group discussing the final questions in the task. This often resulted in a lack of social metacognitive episodes during the final phases of the group activity (see Table 4.17 for example).

Table 4.17

<table>
<thead>
<tr>
<th>Time</th>
<th>A:</th>
<th>B:</th>
</tr>
</thead>
<tbody>
<tr>
<td>17:02</td>
<td>just finished 10</td>
<td></td>
</tr>
<tr>
<td>17:03</td>
<td>Alright. Let me know when you get to part D of 11. IT says the earth's climate and idk what to put besides the sea level would rise</td>
<td></td>
</tr>
<tr>
<td>17:07</td>
<td>Now that I look at it that might be good</td>
<td></td>
</tr>
<tr>
<td>17:11</td>
<td>Hey I'm going to have to go. Question 11 seems pretty simple but if you have any questions just email me and ill check them on my phone.</td>
<td></td>
</tr>
<tr>
<td>17:12</td>
<td>yea I just wrapped it up</td>
<td></td>
</tr>
</tbody>
</table>

Note. Example taken from group in control condition during review activity 3

In the example, collaboration has broken down between the two group members. This is possibly exacerbated by group member B needing to leave the group chat. While there is evidence of metacognitive thought, it is in relation to the individual, rather than the group. For example, group member B monitors their own understanding when he/she notes that they are uncertain of the response they are producing. However, the other group member does not engage, and instead, B evaluates their own response, concluding that it is sufficient.

Lack of prior knowledge, in the form of the absence of pre-work, was noted by group members in 10% of cases. A group’s lack of knowledge surrounding the content area was evident during planning phases, with groups often spending little time on planning, or alternatively, not developing content notes as part of their planning. During the task itself,
this lack of knowledge appears to stifle progress as group members lack the vocabulary to discuss with each other, with members needing to clarify their own knowledge and spend time away from the group task researching content from the course.

Groups exhibited unequal participation in 20% of cases. Unequal participation was defined as when either a group member was predominantly responsible for work produced, or other members were contributing to the work, but not as actively or effectively (Hamalainen & Arvaja, 2009). These cases appeared to be driven by an individual group member having a separate agenda to the rest of the group. Two main aspects seem to influence the occurrence of this: 1) in some cases time or external constraints for an individual member resulted in them having to move quickly through the activity, 2) in some instances group members had already begun working on the activity prior to meeting or engaging with the group. Both had a similar impact on collaboration, with the individual’s own agenda dictating the group interactions. Groups were often left out of sync because of this, and when engaging in metacognitive episodes, groups appeared to be rushed to reach consensus or find a solution so that they could move on (see Table 4.18 for example).

Table 4.18

<table>
<thead>
<tr>
<th>Time</th>
<th>Participant</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:07</td>
<td>A</td>
<td>ready to start?</td>
</tr>
<tr>
<td>15:07</td>
<td>B</td>
<td>A little late than I thought I would be, buses are never cooperative lol so lets start with the group planning tool</td>
</tr>
<tr>
<td>15:07</td>
<td>C</td>
<td>I already did the group planning tool, if yal just wanna use what I have</td>
</tr>
<tr>
<td>15:08</td>
<td>C</td>
<td>Focus is on whether the Greenland ice sheet appears to be making any noticeable changes</td>
</tr>
<tr>
<td>15:08</td>
<td>C</td>
<td>For Greenland's ice sheet reflectivity we will have the following two tools to use...</td>
</tr>
</tbody>
</table>
Table 4.1 Continued
15:08 C: Multiple reflectivity plots that plot the time of the year vs. the albedo for different areas of the Greenland ice sheet for the years 2000-2012.
15:08 C: Reflectivity anomaly map, which compares the overall change in reflectivity for each area in Greenland as compared to the long-term average (calculated between 2000-2012).
15:08 C: Goal is to identify how Greenland has been changing over the recent years, why this change is occurring, and what it means for the ice sheet and Greenland as a whole.
15:08 C: Albedo: amount of energy that is reflected by a surface is determined by the reflectivity of that surface.
15:08 C: Low albedo: surface reflects a small amount of the incoming radiation and absorbs the rest.
15:08 C: High albedo: surface reflects the majority of the radiation that hits it and absorbs the rest.
15:08 C: Ex.) Fresh snow reflects up to 95% of the incoming radiation which means fresh snow has a very high albedo of .95.
15:08 B: dang C lol you're on a roll
15:09 C: 30% of Sun's energy is reflected by entire earth, so the earth has an average albedo of .30.
15:09 C: Generally dark surfaces have a low albedo, light surfaces have a high albedo.
15:10 C: Melt extent in Greenland was above average in 2016, ranking tenth highest (tied with 2004) in the 38-year satellite record. Melt area in 2016 was slightly greater than in 2015, which ranked twelfth. However, near-average to below-average coastal snowfall levels that exposed bare ice earlier in the melting season, combined with warm and sunny conditions at lower elevations, led to high overall ice loss from runoff. Overview of conditions
15:12 A: Okay do you want us to read this over and put it in our own words later so we can just go ahead and start the actual task now?
15:12 C: you can copy and paste it I don't care
15:13 C: but yeah let's get rolling on the actual task
15:13 A: yeah but I think it has to be in our own words to get credit
15:14 B: alright, I got all of that down. I am good to go on the actual task whenever

Note. Example taken from group in control condition during final review activity
In the example, group member C has begun the task without the other two members. When the other group members suggest beginning the task, C provides their full response. Due to this, there is a lack of opportunity for the group to monitor their shared understanding or plan together during the initial phases of the task. The group appears rushed to move on, exemplified when group member A suggests they move on and rewrite responses given by group member C in their own words individually later on. The power dynamic of the group shifts, with the other members looking to C as a source of knowledge as opposed to a group member. As a result, the group members do not engage in evaluation of the response provided.

When cross-case comparisons were made between groups in individual, social, and control conditions, no conditions differences were observed in how the aspects of group dynamics (missing member, member entering late/early, prior knowledge, and unequal) impacted collaboration or the type of interactions observed.

**RQ1b: What are the differences between groups in the reported challenges faced during scaffolded collaborative problem-solving?**

Each student in the experimental conditions reported the main challenge in each task. Six types of challenges were coded from the student statements: time (e.g., having time to meet and complete the task), task (e.g., interpreting the given data and graphs), technology (e.g., experiencing issue with group chat space), challenges in collaboration (e.g., coming to unified, conclusive decision as a group), external constraints (e.g., having other academic...
commitments), motivational challenge (e.g., having the motivation to complete the assignment), and no challenge.

Overall, time (21.59 %), task (37.50 %), and challenges in collaboration (18.18 %) were the most frequently identified challenges for individuals during collaborative work (see Table 4.19 for frequencies by condition). Mann-Whitney run for categories of challenges in collaboration, motivation, technology, external control, and no challenge to assess differences between individual and social condition, only one category showed differences between groups, with those in the social condition (Mdn = 5.56) reporting higher frequencies of challenges in collaboration compared to individual groups (Mdn = 23.61) (U = 1.00, z = -2.76, p = .006, r = -.79. One-way ANOVAs run for categories of time, task, and no code revealed no significant differences between groups (ps > .05).

<table>
<thead>
<tr>
<th>Table 4.19</th>
<th>Frequencies (%) of Challenges Experienced by Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Individual K = 5</td>
</tr>
<tr>
<td>Task</td>
<td>50.00%</td>
</tr>
<tr>
<td>Time</td>
<td>19.05%</td>
</tr>
<tr>
<td>Challenges in Collaboration</td>
<td>7.14%</td>
</tr>
<tr>
<td>Motivational</td>
<td>4.76%</td>
</tr>
<tr>
<td>Technology</td>
<td>0.00%</td>
</tr>
<tr>
<td>External constraints</td>
<td>2.38%</td>
</tr>
<tr>
<td>No challenge</td>
<td>11.90%</td>
</tr>
<tr>
<td>No code</td>
<td>4.76%</td>
</tr>
</tbody>
</table>
RQ2: How do individual and social regulatory conditions impact monitoring accuracy of groups during scaffolded problem-solving?

**Bias.** Descriptive statistics for bias on review activities for groups are provided in appendix O. Analyses revealed no significant differences between conditions in bias for review 2 or 3 ($p > .05$). However, results showed that there was a statistically significant difference in bias score between the different treatment conditions at review 4, $\chi^2(2) = 10.45$, $p = .005$, with a mean rank score of 29.57 for Control, 15.63 for Individual, and 27.29 for Social.

Post-hoc analysis using Mann-Whitney tests revealed groups in the individual condition ($Mdn = 11.25$) to show significantly lower bias scores compared to those in the control condition ($Mdn = 20.36$), $U = 44.00$, $z = -2.83$, $p = .005$, $r = -.52$. Groups in the social condition were not found to be significantly different from groups in the control or individual conditions.

**Calibration.** Analyses revealed no significant differences between conditions in calibration ($p > .05$).

RQ3: How do individual and social regulatory conditions impact performance of groups during review activities and collaborative exams?

**Review Performance.** Descriptive statistics for performance on both review activities and collaborative exams are provided in appendix O.

**Calibration.** Analyses revealed no significant differences between conditions in review performance ($p > .05$).
**Midterm.** Analyses revealed a significant effect of condition on performance ($F(2, 45) = 7.56, p = .001, \eta = .25$). Post-hoc analyses revealed those in the individual condition to perform significantly lower than those in the control condition ($p = .001$). No other significant differences were observed.

**Final.** Analyses revealed no significant differences between conditions in review performance ($p > .05$).
CHAPTER FIVE
Discussion

Overview of study

Based on the lack of research in the field of SSMR, the current study had two main aims. The first was to understand how socially-shared metacognition occurs in collaborative groups of college students within an online introductory geology course, and the second, to explore how this form of regulation could be fostered in groups. To achieve this, the current study built on the work of Molenaar et al. (2014) and examined the use of problematizing prompts in three researcher-designed group review activities designed to increase social metacognitive activities of undergraduate geology students. The study provided tentative findings regarding the effectiveness of social and individual regulatory frameworks in collaboration. Frequencies of individual, other, and social metacognitive episodes were found to vary between conditions and across the semester. Those in the individual condition were shown to perform lower than those in the control condition on the collaborative midterm; however, experimental conditions were found to have no impact on group performance and monitoring accuracy during collaborative reviews. Furthermore, qualitative analyses revealed slight differences between conditions in their engagement in aspects of the intervention framework. Although, no differences were seen in the function and focus of regulatory episodes, or the impact of group dynamics on collaboration.
Findings

Frequency of episodes.

Social metacognitive episodes. The current study supports prior literature that has found social metacognitive episodes to occur during collaboration (de Backer et al., 2015; Goos et al., 2002; Grau & Whitebread, 2012; Hurme & Jarvela, 2001; 2005; Hurme et al., 2009; Hurme et al., 2006; Iiskala et al., 2011; Iiskala et al., 2015). However, the general frequency at which social metacognitive episodes occurred (approximately 60%), was much lower than prior work by Molenaar et al. (2014), who found above 90% of metacognitive episodes to be social metacognitive. Further, findings of the current study failed to support prior literature that has shown problematizing prompts to lead to an increase in social metacognitive behavior (Molenaar et al., 2014). Both experimental groups showed lower proportions of social metacognitive episodes compared the control in two of the three experimental review activities, with the largest gap in frequencies being observed in the final review.

One possible explanation for the lack of intervention effects is the type of task and environment students engaged in. In the Molenaar et al. (2014) study, students not only collaborated with their group face-to-face but also with an expert in the e-learning environment during the task, as well as being monitored by a teacher. In comparison, in the current study, students interacted solely online, and tasks did not include collaboration with an expert or instructor observations. Therefore, it may be that when implementing problematizing scaffolds, the combined effects of the e-learning environment and
observations from an instructor are also needed to foster social metacognitive processes in groups.

**Individual and other metacognitive episodes.** The current research also adds to the literature by understanding the impact of regulatory frameworks on individual and other metacognitive episodes. Over time, frequencies of individual metacognitive episodes decreased for groups in the social condition. This was paired with an increase in other metacognitive episodes. Alongside this, by the final review activity, the social condition showed lower proportions of individual and higher proportions of other metacognitive episodes compared to both control and individual conditions. Based on these differences and changes over time, it could be argued that the social regulatory framework was moderately successful in shifting groups towards more social forms of regulation, however, was not enough to move groups from co-regulatory behavior to shared metacognitive regulation.

In comparison, both individual and control conditions showed an increase over time in individual metacognitive episodes and a decrease in other metacognitive episodes. This, paired with the relative lack of change in occurrence of social metacognitive episodes, suggests that focusing individuals on either their own regulatory behavior or general collaboration, may not be beneficial for increasing aspects of social regulation (other and socially-shared metacognition) in collaborative groups.

**Adherence to the experimental framework.** Findings from qualitative analyses indicated differing patterns of engagement with aspects of the experimental framework for conditions. Over time, groups in the control condition appeared to decrease in their value
towards group planning, whereas the experimental groups showed mixed levels of engagement, with one group showing no engagement, one decreasing, and one increasing engagement over time. The decrease in engagement observed for the control groups supports prior research in collaboration evidencing that merely placing individuals into groups and asking them to collaborate does not always lead to successful engagement in collaborative processes (Janssen, Erkens, Kirschner, & Kanselaar, 2012; Jarvela et al., 2014).

In comparison to the control condition, experimental conditions showed mixed findings, with one group for each condition evidencing increased, and one decreased, engagement over time, with the third group not engaging in planning at all. The mixed findings may have resulted from a lack of modeling or follow-up regarding the use of the group planning tool. In the study, groups were prompted on how to respond to the tool but were not given information on how to use the tool effectively or as a way to increase their regulatory episodes. Alongside this, no feedback was given to groups about how they engaged in group planning during the task. It could be that groups who did not show engagement did so as they felt that they had developed adequate planning strategies in the initial review activities, and therefore, there was no need to discuss them further or develop in their planning for later tasks that followed the same procedure. To remediate these differences, it is recommended that future research embed feedback and modeling for aspects of the intervention into the intervention framework.

**Function and focus of episodes.** Findings for function and focus of episodes showed qualitative differences between individual, other, and social metacognitive episodes,
supporting prior literature outlining empirical distinctions between the constructs (Ucan & Webb, 2015). Findings for other and social metacognitive episodes were in line with prior literature, with other metacognitive episodes having the function of prompting students to reflect upon and clarify their thinking, and social metacognitive episodes helping students to build a shared understanding of the task and clarifying and justifying their shared perspective (Ucan & Webb, 2015). However, findings relating to individual metacognitive episodes provided mixed support to the conceptualization of individual regulation in the field. Episodes were found to have two purposes in the current study: one serving solely the individual, and the other serving both the individual and the group. The first matches the theoretical conceptualization in the field that views metacognition as a process centered around the personal adaptation of own’s own regulation (Hadwin et al., 2011; Iiskala et al., 2011; Molenaar et al., 2014). However, the second form of episode observed, although still targeting personal adaptation, is also aimed at impacting group discussion. Thus, this form of episode appears to bridge the current conceptualizations of individual and co-regulatory processes in the field, monitoring not only an individual’s regulation but other group members’ simultaneously. It is unknown whether these episodes are an artifact of collaboration in the current context, or if they are an artifact of the coding scheme itself. It would therefore be beneficial for future research to use the same coding scheme and explore the occurrence of this type of episode in other fields and environments using similar populations.
The current study also provided some preliminary findings in relation to how episodes were sequenced. The two patterns of regulation suggest that, although the groups engaged in social episodes consistently at the beginning and end of the review activity, neither the experimental nor control frameworks were successful in maintaining these social regulatory processes across the course of the task. This finding suggests that more regulatory support would need to be given to groups during the task itself to promote social regulatory processes. In the current study, individuals were prompted to consider their understanding and current progress toward their goals using checkpoints, however, they were not required to submit a response or provide evidence that they had completed the checkpoint. It is therefore recommended that in future research using similar frameworks, groups be required to submit short responses to monitoring prompts as part of the task design.

**Challenges faced in collaboration.** The study adds to the understanding of how prompts may affect challenges experienced and reported by individuals following collaboration. Findings supports the use of the coding scheme from Jarvela et al. (2013), with six out of the seven challenges (challenges in collaboration, motivation, technology, external control, no challenge, time, task, and no code,) outlined in their study of graduate students during online collaboration present in the current context.

Minimal condition effects on the type of reported challenges were observed in the current study. Only one category showed significant differences between groups, with those in the social condition reporting higher frequencies of challenges in collaboration compared to individual groups. It could be suggested that the differences observed suggest that
individuals in the social condition are becoming more orientated towards the group in their perspective towards collaboration, and therefore are more likely to report challenges that relate to members of the group. However, due to the lack of reported analysis of how individuals overcame their challenges, it is unclear whether differences between perceived challenges by groups provided positive or negative outcomes regarding the resolution of collaborative conflict during collaboration itself. It is therefore recommended that future research analyze this data to understand the wider impact of the evaluation tool on collaboration.

**Performance.** The study added to SSMR literature by investigating the impact of metacognitive prompts on collaborative performance both when scaffolding was and wasn’t present. No performance gains were observed during scaffolded review sessions, matching prior findings in the more general area of SSRL (Panadero et al., 2015). A possible explanation for the lack of performance findings in the current study could be that the tasks themselves were not difficult enough to show differences between groups. Review activities showed a ceiling effect, with group averages being above 85% across the tasks. As a result, variance in performance was reduced, making differences between groups more difficult to observe. It is recommended that future research carrying out similar tasks in science fields increase the level of difficulty for students to provide more variance between groups.

For collaborative exams, where scaffolding was not present, those in the individual condition were found to perform significantly lower than those in the control condition on the midterm, however, these effects were not maintained at the final exam. It is unclear why
these differences occurred. A possible explanation could be that the design of the control condition to include a comprehension check surrounding material covered in the current module during the reviews aided the development of content knowledge. Based on the format of the collaborative exams being selected answers (a recognition based assessment), it could be argued that the type of practice given in the comprehension checks involving selected response allowed individuals to develop some of the necessary knowledge to succeed on the exam.

**Monitoring accuracy.** Overall, the study did not find meaningful differences regarding monitoring accuracy during scaffolded review sessions, failing to support general literature on metacognition that has shown increases in accuracy through the use of targeted regulatory scaffolding (e.g., Azevedo et al., 2004). Similar to the variable of performance, the absence of differences between conditions could be explained by a lack of difficulty in tasks. Across the three tasks, groups were extremely accurate in their judgment of performance, with this leading to a ceiling effect and reduction in variance for monitoring accuracy. Again, it is recommended that research carrying out similar tasks in science field increase the level of difficulty for students.

**Limitations of the Present Study**

Findings of the present study should be considered in the context of several limitations. The first relates to the scope of the findings. The current study only employed one type of collaborative learning task (case study), in one domain (geology). Therefore, generalizations to other collaborative learning tasks must be made carefully. Alongside this,
the study focused specifically on the social metacognitive activities of undergraduate students. Although prior work has shown younger populations to have the capacity to engage in SSMR (e.g., Grau & Whitebread, 2012; Molenaar et al., 2014), it should not be assumed that the results found in the study would generalize to these populations.

The second set of limitations relates to the learning environment used within the study. The CMS in the current study was limited in comparison to prior work with research exploring scaffolding of social regulatory process (e.g., Panadero et al., 2015) as well as SSMR (Molenaar et al., 2014), which used systems that were more complex and immersive. This allowed for co-creation of documents and sharing of links or images in prior research that were not available in the current CMS. In the context of the current study, the group chat logs were basic in their structure, and individuals couldn’t share images or produce collaborative notes. Although the platforms used in research such as Panadero et al. (2015) and Molenaar et al. (2015) are not commercially available, it is recommended for future work that an alternate chat platform is used. For example, a widely available alternative is Google Hangouts, which enables students to share links, images, as well as keeps track of any voice or video calls the students may use to supplement their discussions.

The third set of limitations relates to the data upon which the study is based. Due to the relatively small sample size, and the absence of group chat logs for 6 of the 17 groups, quantitative analyses could not be run to address differences in frequencies. Alongside this, the study was also limited by low frequencies of metacognitive episodes, meaning that the current study also could not assess differences between conditions in subcategories of social
metacognitive episodes. As a result, findings from the study are extremely limited, and are only able to provide tentative evidence of trends that occur when using differing forms of problematizing scaffolds.

The final set of limitations relates to the timing of the intervention. The low frequency and relatively short length of review activities (3 x 60 minutes) may have weakened the potential effects of the intervention framework on collaboration. However, in the current study, extra instructional time or increase in the frequency of review sessions was not plausible due to other course-related activities (e.g., individual exams, learning journals, and asynchronous discussions). It is therefore recommended that future studies work with instructors to streamline other aspects of the courses and allow for larger portions of instructional time to be allocated to collaborative tasks.

**Future directions**

In addition to addressing the limitations of the present study, future research should continue to investigate the temporal and sequential characteristics of regulation during collaboration. The current study provided some tentative insight into temporal aspects of regulation by looking broadly at differences or changes across tasks. However, further work is needed to provide a clearer understanding of the evolving phases/sequences of social regulation within tasks. In particular, it is important for intervention studies using software that is not dynamic in its administration of prompts/scaffolds (such as the current study) to understand how socially-shared regulation changes within a task so that they can better embed materials into instruction.
Another aspect of the study that should be further investigated is the impact of group dynamics. The results provide an initial understanding of how changing group dynamics impact collaboration and regulation. Although informative, it would be beneficial for further research to explore how group assignment impacts regulation during collaboration. Some initial work has considered how differences in individual SRL in groups might affect collaboration (e.g. Panadero et al., 2015). However, to date, research has yet to use regulation as the grouping variable when allocating experimental groups. It is therefore recommended that research explore the impact of grouping high, average, and low self-regulators on groups’ regulation and performance during collaboration.

Finally, due to the high demand for individuals to develop the necessary skills to collaborate successfully, research should also look to understand further what impact interventions have on collaboration when scaffolding is removed, and whether social metacognitive skills can be transferred to new settings.

**General Implications**

The purpose of the study was to not only expand upon the social metacognitive and collaborative learning literature but also to develop the relatively untouched synthesis of these areas. The findings of the study serve to report on the use of SSMR interventions as a means of potentially impacting group regulation and performance on collaborative learning tasks as well as understanding how group regulation unfolds over time. Although the study could only provide tentative findings, it serves to add to the field both theoretically and methodologically. First, little research has examined and compared the effectiveness of the
use of different forms of regulatory prompts on instances of socially-shared regulation in collaborative groups. Second, although the area is growing, there remains a distinct lack of socially-shared regulation research in the broader field of understanding student regulation within naturally-occurring academic contexts.

However, caution should be taken when assessing the general implications due to the several limitations listed above. The overall study outlines some tentative findings regarding the effectiveness of social and individual regulatory frameworks in collaboration. These findings provide researchers with an insight into the way in which these frameworks influence students’ behavior and collaborative processes over the course of a semester, and in turn, valuable information regarding the design and implementation of interventions in the classroom.
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doi:10.1080/07294360600947301


APPENDICES
Appendix A
Individual Planning Tool
(Adapted from Miller & Hadwin, 2015; Panadero et al., 2015)

**Individual Planning Tool (Control)**

**Task Questions**
1. Please use the below scale to answer the following questions:
   - if you think the statement is very true of you, select "5";
   - if a statement is not at all true of you, select "1"
   - if the statement is more or less true of you, find the number between 1 and 5 that best describes you.

I understand the task
I feel capable of doing the task
I know how to do the task
The task is interesting
My group is capable of doing this task

**Comprehension Check (sampled from review activity 1)**

Read the paragraph below and select the most correct missing word from the drop-down menu.

The Earth is a dynamic place, a place of constant activity and change. Much of this activity originates in geophysical processes deep within the Earth, and these internal processes are the focus of later material in this course. In the 1960s, the science of [Choose... † underwent a scientific revolution—a fundamental change in the way we view the functioning of the solid earth. Choose... †. That revolution led to widespread acceptance of the theory of [Choose... †. This theory suggests that the outermost part of the Earth has broken into huge, rigid [Choose... † that shift around and interact with one another, causing [Choose... †, [Choose... †, and [Choose... † and other geophysical activity. Though we still do not know everything, the theory of [Choose... † has provided a model that unifies much observational evidence about the Earth system. In the context of [Choose... †, much of what we know about the inside of the Earth is from studies of [Choose... † and [Choose... † now makes sense.
Performance estimate

Please provide an estimate of the grade your group will receive for your work: ___ %

Individual Planning Tool (Experimental Conditions)

Task Questions

Please use the below scale to answer the following questions:

- if you think the statement is very true of you, select "5"
- if a statement is not at all true of you, select "1"
- if the statement is more or less true of you, find the number between 1 and 5 that best describes you.

I understand the task
I feel capable of doing the task
I know how to do the this task
The task is interesting
My group is capable of doing this task

Planning prompts

<table>
<thead>
<tr>
<th>Individual Condition</th>
<th>Social Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is your personal goal for this task?</td>
<td>What is the group’s goal for this task?</td>
</tr>
<tr>
<td>Describe what you personally need to do to achieve that goal</td>
<td>Describe what your group needs to do to achieve that goal</td>
</tr>
<tr>
<td>What is your main challenge? What are you going to do to overcome this challenge?</td>
<td>What is your main challenge as a group? What are you as a group going to do to overcome this challenge?</td>
</tr>
</tbody>
</table>

Additional prompt given at the beginning of tool for review activity 3 and 4
Prior to beginning the next collaborative task, look back to evaluation sheet from the previous task.

Consider the responses - based on the comments made, what is the most important thing for you (as an individual) to consider in the upcoming task? Cite examples from the evaluation sheet in your answer

Prior to beginning the next collaborative task, look back to your group's evaluation sheet from the previous task.

Consider the responses - based on the comments made, what is the most important thing for your group to consider in the upcoming task? Cite examples from the evaluation sheet in your answer

Performance estimate

Please provide an estimate of the grade your group will receive for your work: ___ %
Appendix B
Group Planning and Activity Checkpoint Prompts

**Group Planning**

**Control**
Using the above goals, please take the next 10 minutes to prepare for the activity in your group. Submit a bulleted list of preparation notes as a summary of your chat discussion in the box below.

Please provide an estimate of the grade your group will receive for your work: ___ %

**Individual**
Please take the next 10 minutes to prepare for the activity in your group. Use your response sheet from your individual pre-work to aid your discussion. Based on your discussion update your responses to the pre-work: what is your goal for the task?, how will you achieve ?, what are your main challenges for the task and how can you overcome them?. Submit a bulleted list of preparation notes as a summary of your chat discussion in the box below.

Please provide an estimate of the grade your group will receive for your work: ___ %

**Social**
Please take the next 10 minutes to prepare for the activity in your group. Use the collated response sheet from your individual pre-work to aid your discussion. As a group come to a consensus on your goal, how you can achieve this goal, your main challenges for the task, and how you can overcome them. Submit a bulleted list of preparation notes as a summary of your chat discussion in the box below.

Please provide an estimate of the grade your group will receive for your work: ___ %

**Activity Checkpoints**

**Control (sampled from review activity 4)**
CHECKPOINT: Take a moment to reconsider the maps and your assessments of each element of the ice sheet as they will be important to your ultimate consideration of what is occurring in Greenland.

*Discuss in your chat space before progressing to the next question!*
**Individual**

**CHECKPOINT:** How are you doing? Check back to your personal goals from the Planning Tool - are you working well toward achieving your goals?

*Discuss your goals with your group in your chat space before progressing to the next question!*

**Social**

**CHECKPOINT:** How are you doing as a group? Check back to your group goals from the Group Planning Tool - are you working well toward achieving your goals?

*Discuss in your chat space before progressing to the next question!*
Appendix C
Collated Response Sheet

Names:

Group #:

What is the groups’ goal for this task?
1. Analyze data to determine which of three schools in different locations should receive a grant to improve their earthquake defenses.
2. Our goal is to work together to analyze the data to select the most appropriate school to receive the grant in order to protect the maximum amount of people.
3. To determine which school is the most deserving of the grant in order to earthquake-proof their buildings, based on their need and data we interpret.

Describe what your group needs to do to achieve that goal
1. Look at data collectively, brainstorm, explore and develop ideas on how to determine which school to choose.
2. We will achieve this through brainstorming and communicating together to determine the weaknesses of each site.
3. We must examine the data and area in which the schools are in. We must work together to come up with the best school in order to help them combat earthquake situations.

What is your main challenge as a group? What are you as a group going to do to overcome this challenge?

1. Collectively understanding and agreeing on the data and answers. Continually communicate and ask any questions to stay on track.
2. The main challenge will be determining just one school to receive the grant and knowing that we can't help each one. Through our understanding of the data and our group communication, we can overcome our challenges and ultimately pick the most deserving school collectively.
3. As a group, we work well together. I think the hardest part is that we are not face-to-face so sometimes things aren't conveyed the same way or as quickly as they would be.
Appendix D
Individual Evaluation Tool

Experimental conditions

<table>
<thead>
<tr>
<th>Individual Condition</th>
<th>Social Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did you achieve your personal goal as a part of your group? If so, how? If not, why?</td>
<td>Did you achieve your goal as a group? If so, how? If not, why?</td>
</tr>
<tr>
<td>How did you work within your group to achieve that goal?</td>
<td>How did your group work to achieve that goal?</td>
</tr>
<tr>
<td>How did your personal plan (set during pre-work) work in action?</td>
<td>How did your group’s plan (set during group planning) work in action?</td>
</tr>
<tr>
<td>What was your main personal challenge? What did you do to overcome this challenge?</td>
<td>What was your group’s main challenge? What did you do as a group to overcome this challenge?</td>
</tr>
</tbody>
</table>

Please provide an estimate of the grade your group will receive for your work: ___ %

Control Condition

How successful did you think you were in the task? Why? Cite examples in your response

Please provide an estimate of the grade your group will receive for your work: ___ %
Appendix E
Learning Strategies and Motivation
MSLQ (Pintrich et al., 1993)

Scales used
1. Self-efficacy
2. Rehearsal
3. Elaboration
4. Organization
5. Critical Thinking
6. Metacognitive Self-Regulation
7. Time and Study Environment
8. Effort Regulation
9. Peer Learning
10. Help Seeking

The following questions ask about your motivation for and attitudes about this class. Remember there are no right or wrong answers, just answer as accurately as possible. Use the scale below to answer the questions. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

I believe I will receive an excellent grade in this class.
I'm certain I can understand the most difficult material presented in the readings for this course.
I'm confident I can understand the basic concepts taught in this course.
I'm confident I can understand the most complex material presented by the instructor in this course.
I'm confident I can do an excellent job on the assignments and tests in this course.
I expect to do well in this class.
I'm certain I can master the skills being taught in this class.
Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.
When I study the readings for this course, I outline the material to help me organize my thoughts.

During class time I often miss important points because I'm thinking of other things. (reverse coded)

When studying for this course, I often try to explain the material to a classmate or friend.

I usually study in a place where I can concentrate on my course work.

When reading for this course, I make up questions to help focus my reading.

I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do. (reverse coded)

I often find myself questioning things I hear or read in this course to decide if I find them convincing.

When I study for this class, I practice saying the material to myself over and over.

Even if I have trouble learning the material in this class, I try to do the work on my own, without help from anyone. (reverse coded)

When I become confused about something I'm reading for this class, I go back and try to figure it out.

When I study for this course, I go through the readings and my class notes and try to find the most important ideas.

I make good use of my study time for this course.

If course readings are difficult to understand, I change the way I read the material.

I try to work with other students from this class to complete the course assignments.

When studying for this course, I read my class notes and the course readings over and over again.

When a theory, interpretation, or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence.

I work hard to do well in this class even if I don't like what we are doing.

I make simple charts, diagrams, or tables to help me organize course material.
When studying for this course, I often set aside time to discuss course material with a group of students from the class.
I treat the course material as a starting point and try to develop my own ideas about it.
I find it hard to stick to a study schedule. (reverse coded)
When I study for this class, I pull together information from different sources, such as lectures, readings, and discussions.
Before I study new course material thoroughly, I often skim it to see how it is organized.
I ask myself questions to make sure I understand the material I have been studying in this class.
I try to change the way I study in order to fit the course requirements and the instructor's teaching style.
I often find that I have been reading for this class but don't know what it was all about. (reverse coded)
I ask the instructor to clarify concepts I don't understand well.
I memorize key words to remind me of important concepts in this class.
When course work is difficult, I either give up or only study the easy parts. (reverse coded)
I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for this course.
I try to relate ideas in this subject to those in other courses whenever possible.
When I study for this course, I go over my class notes and make an outline of important concepts.
When reading for this class, I try to relate the material to what I already know.
I have a regular place set aside for studying.
I try to play around with ideas of my own related to what I am learning in this course.
When I study for this course, I write brief summaries of the main ideas from the readings and my class notes.
When I can't understand the material in this course, I ask another student in this class for help.
I try to understand the material in this class by making connections between the readings and the concepts from the lectures.

I make sure that I keep up with the weekly readings and assignments for this course.

Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.

I make lists of important items for this course and memorize the lists.

I attend this class regularly.

Even when course materials are dull and uninteresting, I manage to keep working until I finish.

I try to identify students in this class whom I can ask for help if necessary.

When studying for this course I try to determine which concepts I don't understand well.

I often find that I don't spend very much time on this course because of other activities.

(reverse coded)

When I study for this class, I set goals for myself in order to direct my activities in each study period.

If I get confused taking notes in class, I make sure I sort it out afterwards.

I rarely find time to review my notes or readings before an exam. (reverse coded)

I try to apply ideas from course readings in other class activities such as lecture and discussion.
Appendix F
Social Interdependence Scale
(Johnson & Norem-Hebeisen, 1979)

Cooperative Interdependence.
(1). Liking to cooperate.
I like to help other students learn.
I like to share my ideas and materials with other students.
I like to cooperate with other students.
(2). Valuing cooperative learning.
I can learn important things from other students.
I try to share my ideas and materials with other students when
I think Students learn lots of important things from each other.
It is a good idea for students to help each other learn. it will help them.

Competitive Interdependence.
(1). Liking to compete.
I like to do better work than other students.
I work to get better grades than other students do.
I like to be the best student in the class. I don’t like to be second.
(2). Valuing competitive learning.
I like to compete with other students to see who can do the best work.
I am happiest when I am competing with other students.
I like the challenge of seeing who is best.
Competing with other students is a good way to work.

Individualistic Independence.
(1). Liking to study alone.
I don’t like working with other students in school.
I like to work with other students. (reverse)
It bothers me when I have to work with other students.
(2). Valuing individualistic learning.
I do better work when I work alone.
I like work better when I do it all myself.
I would rather work on school work alone than with other students.
Working in small groups is better than working alone. (reverse)
Appendix G
Initial Interest

All items are rated on a 7-point scale (1 - not at all true of me, 7 - very true of me)

I’ve always been fascinated by physical geology.
I chose to take MEA 101 because I’m really interested in the topic.
I’m really excited about taking this class.
I’m really looking forward to learning more about physical geology.
I think the field of geology is an important discipline.
I think what we will study in MEA 101 will be important for me to know.
I think what we will study in MEA 101 will be worthwhile to know.
Appendix H
Geoscience Concept Inventory
(Libarkin & Anderson, 2005)

Sample items:

Some scientists claim that they can determine when the Earth first formed as a planet. Which technique(s) do scientists use today to determine when the Earth first formed? Choices: True, False

A. Comparison of fossils found in rocks
B. Comparison of layers found in rocks
C. Analysis of uranium found in rocks
D. Analysis of carbon found in rocks
E. Scientists cannot calculate the age of the Earth

Some people believe there was once a single continent on Earth. If this single continent did exist, how long did it take for the single continent to break apart and form the arrangement of continents we see today?

A. Hundreds of years
B. Thousands of years
C. Millions of years
D. Billions of years
E. It is impossible to tell how long the break up would have taken

During a recent trip to Canada a traveler visited two mountains made up of the same type of rock. The sketches below represent the outlines of these two mountains. Which of the following reasons best explains the differences in the two drawings?

A. Mountain I is older than Mountain II+
B. Mountain II is older than Mountain I
C. Mountain I is on a continent that is moving faster than the continent Mountain II is on
D. Mountain I is on a continent that is moving slower than the continent Mountain II is on
E. Mountain I has experienced more erosion than Mountain II
Appendix I
Demographic Questions

Enter your full name

Please select your gender
- Male
- Female
- Other

Please enter your age, in years

Please select your race
- American Indian/Alaska Native
- Asian American/Asian/Pacific Islander
- Black/African American
- Hispanic/Latino
- White
- Other

Please select your major from the list below
- Education (i.e., Elementary, Middle Grades, Secondary)
- Technology, Engineering, and Design Education
- Business and Marketing Education
- Art/Design
- Business/Management
- Science (i.e., Chemistry, Physics, Geology, Environmental, Zoology)
- Mathematics and Statistics
- Engineering
- Agricultural and Life Sciences
- Humanities and Social Sciences
- Undeclared
- Other

What is your present academic level?
- College Freshman
- College Sophomore
- College Junior
- College Senior
- Masters
- Doctoral
- Other

Please estimate your current college GPA
Appendix J
Informed Consent Form

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Enhancing Group Outcomes In The Introductory Geology Classroom
Principal Investigator: John Nietfeld, Dan Spencer & Jason P. Jones

What are some general things you should know about research studies?
You are being asked to take part in a research study. You must be 18 years or older to
participate. Your participation in this study is voluntary. You have the right to be a part of
this study, to choose not to participate or to stop participating at any time without penalty.
The purpose of research studies is to gain a better understanding of a certain topic or issue.
You are not guaranteed any personal benefits from being in a study. Research studies also
may pose risks to those that participate. In this consent form you will find specific details
about the research in which you are being asked to participate. If you do not understand
something in this form it is your right to ask the researcher for clarification or more
information. A copy of this consent form can be requested through your lecturer. If at any
time you have questions about your participation, do not hesitate to contact the researcher(s)
named above.

What is the purpose of this study?
The purpose of this project is to investigate the impact of interventions on student motivation
and their performance in the MEA 101-601 section at college class at NCSU. Findings will be
used to target instructional methods and technologies to enhance motivation and performance
in geology problem solving in higher education.

What will happen if you take part in the study?
As part of this class you will take part in group activities/exams during selected weeks and
complete surveys throughout the semester. We request your consent to use the information
from these surveys as well as group interactions (in the form of chat logs) as data for research
purposes. These surveys will be compared to your assignment grades and course grade for
MEA 101-601: Physical Geology.

Risks
There are minimal risks associated with participation in this research.

Benefits
The potential benefits of the intervention may lead to deepening your understanding of
activities embedded within college level geology classroom courses. In addition the goal for
the study is to investigate how students interact in group activities and subsequently make recommendations for improving instruction to facilitate students’ engagement and performance in such activities.

**Confidentiality**
The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely in computer files that are password protected. No reference will be made in oral or written reports that could link you to the study.

**Compensation**
You will not receive any compensation for participating.

**What if you are a NCSU student?**
Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at NC State.

**What if you have questions about this study?**
If you have questions at any time about the study or the procedures, you may contact the researcher, Dan Spencer, at 646A Poe Hall, NCSU Campus, or (919) 793-4915.

**What if you have questions about your rights as a research participant?**
If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

**Consent To Participate**
“*I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled.*”

Subject's signature __________________________ Date ______________
Investigator's signature ______________________ Date ____________
Appendix K
Example Review Activity

“Unknown World”
You and your group have been transported to an unknown, earth-like, planet somewhere in the universe. It is believed that the geology is similar to that of earth. While in your group's chat space, collaborate to answer the questions and consider the evidence presented in order to analyze this area of the planet. What data is important? What other factors do you need to consider? Work with your group and come up with a solution to report

Question 1

This perspective view shows two continents, labeled A and B, separated by an ocean. First...
- Use the topography to identify possible plate boundaries and how many tectonic plates are present in the image

Discuss your answer with your group in your chat space and come up with a group consensus on how many plates and boundaries are present and drag a 'plate' label onto each plate present in the image and a 'boundary' onto each boundary. (NOTE: You may or may not use all the 'plate' and 'boundary' labels!!)
Question 2

Now, use the PoodiLL plugin to mark the location and type of each plate boundary on the figure. Use the following colors:

- divergent = black;
- convergent = red;
- transform = green or blue. For transform boundaries, mark only transform faults (where motion is still occurring), not fracture zones (where it is not).

Discuss your answers in your chat space and come up with a consensus on the locations!
Question 3

Use your plate boundaries to mark where on the map earthquakes and volcanoes are most likely. On the figure above, do the following:

- Draw yellow circles [○] at any place, on the land or on the ocean floor, where you think earthquakes are likely.
- Draw orange triangles [▲] in any place, on land or in the ocean, where you think volcanic eruptions are likely.

Remember that not all volcanoes form directly on the plate boundary; some form off to one side. Also, a line of islands and seamounts (mountains that are beneath the sea) could mark the track of a hot spot and may not be on a plate boundary.
Question 4

Discuss with your group to determine a relatively safe place to build one city on each continent. Show each location with a blue plus sign (+) on the map.
Question 5

In the space below, explain your group's reasons for choosing these as the safest sites. Your answer should contain two bulleted lists of three reasons each:

Reasons for location of city on Continent A
- Reason 1
- Reason 2
- Reason 3

Reasons for location of city on Continent B
- Reason 1
- Reason 2
- Reason 3
Question 6

On the figure below, draw a simple cross section of your plates in the subsurface. Use other figures in your textbook as a guide to the thicknesses of the crust and lithosphere and to the geometries typical for each type of plate boundary. Some features are not located along the front edge of the figure and so cannot be shown on the cross section.

- Draw the geometries of the plates at depth for any spreading center or subduction zone.
- Show the variations in thickness of the crust and variations in thickness of the lithosphere.
- Draw yellow arrows to indicate which way the plates are moving relative to each other.
- Show where melting is occurring at depth to form volcanoes on the surface (use red circles).
## Appendix L
Kurtosis and Skewness Values

*Kurtosis and Skewness values for performance and monitoring accuracy*

<table>
<thead>
<tr>
<th></th>
<th>Skewness Statistic</th>
<th>Skewness Std. Error</th>
<th>Kurtosis Statistic</th>
<th>Kurtosis Std. Error</th>
</tr>
</thead>
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<tr>
<td><strong>Performance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midterm Exam</td>
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<td>0.34</td>
<td>0.04</td>
<td>0.67</td>
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<tr>
<td>Final Exam</td>
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<td>0.35</td>
<td>3.16</td>
<td>0.68</td>
</tr>
<tr>
<td>Review 2</td>
<td>-4.47</td>
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<td>22.51</td>
<td>0.69</td>
</tr>
<tr>
<td>Review 3</td>
<td>-2.75</td>
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<td>6.82</td>
<td>0.69</td>
</tr>
<tr>
<td>Review 4</td>
<td>-1.97</td>
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<td>5.66</td>
<td>0.67</td>
</tr>
<tr>
<td><strong>Bias</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review 2</td>
<td>3.72</td>
<td>0.37</td>
<td>19.71</td>
<td>0.73</td>
</tr>
<tr>
<td>Review 3</td>
<td>2.58</td>
<td>0.36</td>
<td>8.51</td>
<td>0.70</td>
</tr>
<tr>
<td>Review 4</td>
<td>1.29</td>
<td>0.35</td>
<td>3.09</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>Absolute Accuracy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review 2</td>
<td>4.04</td>
<td>0.37</td>
<td>20.69</td>
<td>0.73</td>
</tr>
<tr>
<td>Review 3</td>
<td>3.19</td>
<td>0.36</td>
<td>11.78</td>
<td>0.70</td>
</tr>
<tr>
<td>Review 4</td>
<td>2.09</td>
<td>0.35</td>
<td>5.98</td>
<td>0.68</td>
</tr>
</tbody>
</table>
Kurtosis and skewness values for categories of challenges experienced

<table>
<thead>
<tr>
<th>Category</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistic</td>
<td>Std. Error</td>
</tr>
<tr>
<td>Task</td>
<td>0.78</td>
<td>0.64</td>
</tr>
<tr>
<td>Time</td>
<td>0.82</td>
<td>0.64</td>
</tr>
<tr>
<td>Challenges</td>
<td>1.77</td>
<td>0.64</td>
</tr>
<tr>
<td>Motivation</td>
<td>2.44</td>
<td>0.64</td>
</tr>
<tr>
<td>Technology</td>
<td>3.11</td>
<td>0.64</td>
</tr>
<tr>
<td>External</td>
<td>2.06</td>
<td>0.64</td>
</tr>
<tr>
<td>No Challenge</td>
<td>2.13</td>
<td>0.64</td>
</tr>
<tr>
<td>No Code</td>
<td>1.43</td>
<td>0.64</td>
</tr>
</tbody>
</table>
Appendix M
Coding Scheme for Metacognitive Episodes
(Adapted from Molenaar et al., 2014)

Conversational Turns
- Conversational turns can contain multiple statements that can be split and coded separately
- Conversational turns can be combined if they are two halves of the same statement (i.e. split due to chat software)

<table>
<thead>
<tr>
<th>Main category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacognitive activity</td>
<td>Turns about monitoring and controlling the cognitive activities during learning</td>
</tr>
<tr>
<td>Cognitive activity</td>
<td>Turns about the content of the task and the elaboration of this content</td>
</tr>
<tr>
<td>Relational activity</td>
<td>Turns in response to metacognitive, cognitive, or relational activities regarding the social interaction between the students in the triad.</td>
</tr>
<tr>
<td>Procedural activity</td>
<td>Turns regarding the procedures to use the learning environment (includes entering sections of the task/parts of the environment), including:</td>
</tr>
<tr>
<td></td>
<td>- Chat</td>
</tr>
<tr>
<td></td>
<td>- Materials (e.g. spreadsheet)</td>
</tr>
<tr>
<td></td>
<td>- Moodle activity</td>
</tr>
<tr>
<td>Off task</td>
<td>Turns not relevant to the task.</td>
</tr>
<tr>
<td>Not codable</td>
<td>Turns too short or unclear to interpret</td>
</tr>
</tbody>
</table>
Subcategory: Metacognitive episodes

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>Orientation on prior knowledge, task demands and feelings about the task.</td>
</tr>
</tbody>
</table>
| Planning    | Planning of the learning process, for instance, sequencing of activities or choice of strategies. 

Note: during the task (at the beginning of a sub-task) this can be in the form of a suggested action “I could just work on question 7 and 8 while yal do this? Or I can try to see if I can help without google earth” |
| Monitoring  | Monitoring of the learning process: checking progress and comprehension of the task. 

**Individual:** sharing monitoring of your own comprehension for the purpose of aiding the groups progress (sharing thoughts) 

**Social:** monitoring others comprehension 

Note: Individual monitoring statements in response to a question are considered orientation; however, if statements start conversational turns they are considered individual monitoring |
| Evaluation  | Evaluation of the learning process; checking of the content of the learning activities. Judgment on quality e.g. Good look man. I completely missed that. I need to pay closer attention next time |
| Reflection  | Reflection on the learning process and strategies through elaboration on the learning process. |
### Subcategory: Cognitive Activities

<table>
<thead>
<tr>
<th><strong>Subcategory</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
</table>
| Questioning     | Asking a question that is related to the content of the task  
*Note:* anytime cognitive questioning statement followed by brief idk etc it should not be considered metacognitive |
| Elaboration     | Elaboration of task content: relating to other concepts, giving examples or connecting to own experiences. |
| Summarizing     | Summarizing what has been said before  
*Note:* needs to be summary of things said prior in the chat |

### Subcategories: Relational Activities

<table>
<thead>
<tr>
<th><strong>Subcategory</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Engaging</td>
<td>Asking group members to engage in the task</td>
</tr>
</tbody>
</table>
| Task division   | Division of tasks between the group members  
*Note:* can be in the form of a question |
| Support         | Repetition or support of a previous speaker  
*Note:* includes acknowledgement of previous speaker |
| Reject          | Rejection of previous speaker  
*Note:* specifically rejecting the request, statement, or suggestion of the previous speaker |
### Metacognitive activities/episodes

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
</table>
| Individual | occur when a student is regulating his or her own cognitive activities  
  *for example: “Stop! I need to think about this”* |
| Other | occur when a group member regulates the individual activity of another group member  
  *for example: “What are you doing?” “I am trying to understand this question”* |
| Social | occur when one or more group members regulates their collaborative cognitive activities,  
  *for example: “What are we writing?”; “The goal statement”; “What is the goal statement?”* |

### Social Metacognitive Activities

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
</table>
| Accepted | Occurs when group members show their agreement with a metacognitive remark by implementing it in a cognitive activity.  
  *E.g., a student evaluates the answer the group produced, commenting that the answer is wrong. Another group member starts to reassess the answer.* |
<p>| Ignored | Occurs when a group member attempts to control or monitor the group’s learning activities, but the other group members ignore this effort. |</p>
<table>
<thead>
<tr>
<th><strong>Category</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ignored</strong></td>
<td><em>E.g., a student evaluates the answer the group produced, commenting that the answer is wrong. The other group members do not respond to his comment.</em></td>
</tr>
</tbody>
</table>
| **Shared** | Occurs when students share their metacognitive ideas: they respond to each other’s contributions, but they do not build on each other’s ideas towards a new idea.  
*E.g., a student evaluates the answer the group produced, commenting that the answer is wrong. Another group member comments that he believes the answer might be wrong too.* |
| **Co-constructed** | Occurs when group members build on each other’s ideas, collaboratively constructing a metacognitive activity to regulate their collaborative learning.  
*E.g., a student evaluates the answer the group produced commenting that the answer is wrong. Another group member comments that he believes the answer might be right and justifies this comment. The third student continues to evaluate the comments of the other two.* |
## Appendix N
Coding Scheme for Collaborative Challenges

<table>
<thead>
<tr>
<th>Code</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>difficulty finding a joint work time</td>
</tr>
<tr>
<td>External constraint</td>
<td>flu; stressful situation at work</td>
</tr>
<tr>
<td>Weak study strategies</td>
<td>too much to study and did not know how to start</td>
</tr>
<tr>
<td>Challenges in collaboration</td>
<td>unequal participation in group work</td>
</tr>
<tr>
<td>Motivational</td>
<td>no interest in topic</td>
</tr>
<tr>
<td>Technology</td>
<td>technology did not work well</td>
</tr>
<tr>
<td>Task</td>
<td>content, theoretical understanding, or coming to the correct conclusion in the task</td>
</tr>
<tr>
<td>No challenges</td>
<td>no challenges experienced</td>
</tr>
</tbody>
</table>
### Appendix O
Descriptive Statistics for Performance and Monitoring Accuracy

#### Mean and Standard Deviation for Performance on Review Activities

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Individual</th>
<th>Social</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review 2</td>
<td>92.48 (18.54)</td>
<td>98.60 (2.50)</td>
<td>96.73 (8.79)</td>
</tr>
<tr>
<td>Review 3</td>
<td>92.25 (7.46)</td>
<td>86.53 (22.87)</td>
<td>93.88 (14.81)</td>
</tr>
<tr>
<td>Review 4</td>
<td>84.42 (6.17)</td>
<td>87.97 (15.16)</td>
<td>83.69 (12.66)</td>
</tr>
</tbody>
</table>

#### Mean and Standard Deviation for Bias on Review Activities

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Individual</th>
<th>Social</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review 2</td>
<td>.02 (.19)</td>
<td>-.05 (.07)</td>
<td>-.04 (.05)</td>
</tr>
<tr>
<td>Review 3</td>
<td>.03 (.09)</td>
<td>.05 (.20)</td>
<td>&lt;.01 (.10)</td>
</tr>
<tr>
<td>Review 4</td>
<td>.11 (.08)</td>
<td>.03 (.14)</td>
<td>.11 (.13)</td>
</tr>
</tbody>
</table>

#### Mean and Standard Deviation for Calibration on Review Activities
<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Individual</th>
<th>Social</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review 2</td>
<td>.10 (.16)</td>
<td>.07 (.05)</td>
<td>.04 (.05)</td>
</tr>
<tr>
<td>Review 3</td>
<td>.07 (.06)</td>
<td>.11 (.17)</td>
<td>.05 (.08)</td>
</tr>
<tr>
<td>Review 4</td>
<td>.12 (.07)</td>
<td>.08 (.12)</td>
<td>.13 (.12)</td>
</tr>
</tbody>
</table>

*Mean and Standard Deviation for Performance on Collaborative Exams*

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Individual</th>
<th>Social</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midterm</td>
<td>89.07 (7.08)</td>
<td>75.82 (11.29)</td>
<td>82.10 (10.71)</td>
</tr>
<tr>
<td>Final</td>
<td>87.29 (9.90)</td>
<td>83.06 (22.87)</td>
<td>86.00 (6.40)</td>
</tr>
</tbody>
</table>