GROUP WORK AND METACOGNITION: AN EXPLORATORY CASE

by

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ABSTRACT

This dissertation is about how learners bring metacognitive understandings of themselves as learners into a group learning context. It is about metacognitive knowledge, skills and behaviors and how these impact and are impacted by the learners' engagement with group problem-solving activity. For this study, group problem-solving activity is the important interface between the understandings an individual has about him or herself, including content knowledge, and the social environment of a collaborative problem-based activity system, such as is common use in science classrooms. The process of using metacognition in a group setting is how collective knowledge is built, and this study uses an activity theory framework to explore interactions within the groups that involve metacognitive knowledge, skills and behaviors during group problem-solving activity.

For this study, high school biology students who were studying invertebrate biology as part of their Grade 11 Biology course attended a field trip visit to the Vancouver Aquarium, where they reviewed the major phyla of the intertidal zone. In-class follow-up activities extended the students' opportunities to engage with the general topic of ecology as it applies to intertidal marine biology. Problem-solving activities were the focal point of the activity system as conceived through the theoretical framework for the study.

Data gathering included paper records and digital video and audio from the problem-solving activities and a video review activity where the groups watched themselves while they were solving problems. Subsequent focus group and individual interviews asked students to reflect on and elaborate the learning processes under way in their groups. The study gathered rich, descriptive data of how met cognitive knowledge, skills and behaviors are brought into the group context for learning. Results from the study indicate that open-ended problems offer opportunity for engaging metacognition, and when these are brought into the group context, rich possibilities for developing new understandings arise. In the group, others' thinking and learning processes become objects for one's own metacognition. This is a key finding of the study. Implications are discussed for teaching and learning science, including the development of problems that engage learners on multiple levels so as to engage students' metacognitive knowledge, skills and behaviors.

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CHAPTER ONE

INTRODUCTION

This study is about how learners bring metacognition into a group problem-solving context. Group contexts for learning have the potential to be powerful learning opportunities, and are commonly used in science classrooms. Research suggests that students who are highly metacognitive are more empowered as learners (Baird, 1986; Swan, 1988). Thus, this research is primarily concerned with exploring how individual metacognition is consequential in a group context for learning. Advancing understanding about metacognition in a group learning context requires investigating how students understand themselves as learners and how these understandings frame and influence how they engage in academic work in particular settings.

To that end, in the research reported here, I draw on particular definitions for metacognition (Baird, 1986; Flavell, 1979; Gunstone, 1994) to investigate students' engagement of metacognition in group problem-solving activities as contextualized within a high school biology classroom. I advance understanding by employing a design framework that considers how individual metacognition shapes interactions between what individuals bring to group problem-solving activity (e.g. background knowledge; prior experiences with academic work; epistemic beliefs about biology; etc.) and aspects of the activity system in which they are working (i.e. subject; object; mediational means; definitions of community; division of labor; rules for engagement). My goal is to enhance theoretical understanding about how metacognition is situated as individual learning behavior, but also to identify patterns within the sociality of the group that are consequential for how metacognition manifests in group problem-solving activity.

Building a Model of Metacognition

This study explores how metacognition manifests when learners bring individual understandings of themselves as learners into a group context for learning. A group context for learning provides an important interface between what the individual learner knows or holds as personal knowledge, and how new knowledge is developed through group interaction. Research in metacognition has characterized the kinds of knowledge, skills and behaviors that make for powerful learning. However, most research focuses on the individual and what the individual knows about himself or herself as a learner. This study begins with this individualized view of metacognition, and explores how this comes to the service of learning activity in a group setting.

There is no universally agreed upon definition of metacognition (Larkin, 2006). This is very likely a consequence of the breadth of knowledge, skills and behaviors that can be considered metacognitive. Thus, this study develops a model of metacognition that defines a range of constructs to describe aspects of learning behavior. In this research, I use this model as a framework to attend to particular aspects of learning behavior during group problem-solving activity.

Metacognition is thinking about or with one's own ideas or knowledge (Kuhn, Amsel & O'Loughlin, 1988). It is one's own perceptions of learning activity and conscious control over decisions and actions taken in the service of learning (Gunstone, 1994). Metacognition is what the learner uses during the process of problem-solving (Flavell, 1976). At the center of the model of metacognition from which I am working is a set of four constructs: metacognitive knowledge, control, self-efficacy and awareness. These constructs are enacted in complementary ways (Gunstone, 1994), and represent aspects of problem-solving activity that are significant for the goals of this study.

Metacognitive knowledge functions as background knowledge when the learner enters a problem-solving situation, and this knowledge shapes engagement with learning activity. Metacognitive knowledge refers to understandings and beliefs that the learner has about *the self* (and other learners), *the task* and *the strategies* (Flavell, 1979; Flavell & Wellman, 1977) relevant to a given problem-solving context. Personal understandings about the self as a learner include personal attributes, characteristics of one's own memory (and the different ways it can function) and beliefs about one's strengths and weaknesses. Beliefs about who you are as a learner, relative to others, is also metacognitive knowledge. Beliefs about the self as a learner are linked to one's own theories about the nature of intelligence (Dweck, 1991; Dweck & Bempechat, 1983). If an individual holds an entity theory of intelligence (which is a belief about the self as a learner and hence, metacognitive knowledge), the learner attaches beliefs about his or her own capability to the perceived presence or absence of intelligence. This is significant as an individual enters a problem-solving situation, especially if the activity is perceived as challenging, because such beliefs can lead to poor decision-making or withdrawing from attempting a learning task. Understandings about the self as a learner are important aspects of metacognitive knowledge because they frame engagement with learning activity. So, in this study, I was interested in how students were influenced by these understandings as they worked with others in a group learning context.

Understandings about the task are also part of metacognitive knowledge (Flavell, 1979; Flavell & Wellman, 1977). For example, understanding what the task requires is important task knowledge. Strategy knowledge includes the how-to steps for strategies that work (Flavell, 1979). For example, knowing the steps needed for a given problem-solving context is strategy knowledge. This background knowledge is significant for individual learning. But in this study, I wanted to explore how this individual knowledge matters in a group context. To this end, how individuals bring their own task and strategy knowledge into a group learning context is significant for this research.

The second aspect of metacognition to be elaborated for this study is metacognitive control. Aspects of metacognitive control parallel what others have called self-regulated learning (see for example, Butler & Cartier, 2004; Butler & Winne, 1995; Zimmerman, 2000; Zimmerman & Schunk, 2001). Self-regulation is important because this is how "learners control their thoughts, feelings and actions in order to achieve academically" (Zimmerman & Schunk, 2001, p. vii). In general, control is about managing learning activity and making decisions along the process of problem-solving, which involves an understanding of the nature of decisions being made and subsequent actions taken (Gunstone, 1994). Learners who are able to do this are more likely to be successful, but unfortunately, few learners are in fact self-regulated (Zimmerman, 2000). Aspects of self-regulation include, among others, planning, monitoring and evaluating. These are particular kinds of self-regulatory strategies and actions that may be situational (Butler & Cartier, 2005), or situationally-specific (Schunk, 2001). Planning involves assessing and interpreting task demands and establishing goals and objectives for learning activity. Monitoring is attending to the state of one's own memory and problem processing (Chi, 1987), as well as keeping track of the learning process (Anderson & Nashon, 2007). After developing a learning plan, looking forward and backward along it are monitoring behaviors (Ertmer & Newby, 1996). Evaluation involves, "judging whether understanding is sufficient...[and] searching for connections and conflicts with what is already known" (White, 1992, p. 157). Individual learners use planning, monitoring and evaluating as self-regulatory and control strategies during learning activity, and this study explores how these individual self-regulatory abilities are also part of their learning behavior in a group.

The third construct that comprises the model of metacognition for this research is self-efficacy. Self-efficacy is self-perception of capability and capacity to learn (Bandura, 1993). Personal beliefs about competence and control are significant influences on learning processes and personal agency. These beliefs are situated in particular kinds of activities and tasks and frame a learner's entry into problem-solving activity, influencing personal choices and engagement with the activity. Decisions about courses of action are shaped through these beliefs: "efficacy beliefs influence how people feel, think, motivate themselves, and behave" (Bandura, 1993, p. 118). Effects of these beliefs are visible on many levels, and the current study explores these beliefs and their effects in terms of how individual perceptions of competence and control influence and are influenced within a group context for learning.

The final part of the model for metacognition in the current study involves metacognitive awareness. Metacognitive awareness is attending to the demands of the learning situation, but also features of the task and individual engagement with the process of learning (Marton & Booth, 1997). Awareness structures perception, and hence, cognitive activity. Of course, awareness is dynamic and, like other aspects of metacognition, is situated in a context. For example, realizing that one's mind is drifting during a reading activity is an example of metacognitive awareness. This sort of awareness may or may not lead to a change in learning behavior. The current research attempts to develop a better understanding of how awareness, as part of individual metacognition, comes into play during group learning activity.

Knowledge, control, self-efficacy and awareness are the four constructs that comprise the model of metacognition used in this study to examine how metacognition is implicated in group problem-solving processes. Each of these general categories is significant for individual learning, but the research asks questions about how these individual, 'in-the-head' kinds of behaviors are consequential for group learning activity. In order to explore this question, the research uses the model of metacognition developed here and provides a context where metacognition can manifest. Concerned as I am with the group context for learning, a group problem-solving activity was developed for the study.

Building a Problem for Group Problem-Solving Activity

In secondary school contexts, problem-solving is a common curricular requirement (BC Ministry of Education, 2006; Gunstone, 1994). Particularly in the domains of science and mathematics, students are routinely required to solve problems as a means to developing content knowledge and facility with the processes of science and mathematics. For students to be successful problem-solvers in science, they must invoke their own metacognitive knowledge, skills and behaviors. Learners must recognize their own beliefs and ideas, make decisions about the need for reconstructing their beliefs or ideas, and then replace or add to them. Since I am interested in how individual beliefs and understandings about the self as a learner manifest in a group learning context, in this research, I created a series of problem-solving activities that required students to use their own metacognition as they worked with other students to collectively solve problems.

In this study, I call upon Gunstone's (1994) suggestion about how to invoke metacognition: "one aspect of content appropriate for the achievement of metacognitive purposes is that it is neither already understood nor totally unfamiliar" (p. 145). Problem-solving activities that call upon prior knowledge, require strategizing and enable individuals to work together are appropriate in this study context, not only because problem-solving is a major focus in science learning, but also because in this research, I wanted to provide a context where students could work together and develop meaning collectively. This honors a socioconstructivist perspective on learning in science (Driver & Leach, 1993; Duit & Treagust, 1998; Solomon, 1993), where what one person knows is significant for how collective understanding is built. This is also how scientific knowledge is built and so this study contributes to our understandings of how knowledge is built collectively. This study builds a problem-solving context using guidance from problem-based learning [PBL].

PBL activities introduce science students to the nature of scientific activity, and are widely used in science education. Problems should provide for active engagement, be ill-structured, work with substantial content information, fit the course, program or curriculum objectives and be suitable for the target audience (Stephien & Pyke, 1997). Rich problems engage learners on multiple levels, drawing on background knowledge, as well as metacognitive knowledge, skills and behaviors. Rich problems create a context for active engagement with learning, help students connect learning from both in and out of school contexts, and offer a place where individual metacognition is called into service. The current study draws on these notions of task design to develop a series of engaging problems for the students to work on collectively.

With collaborative tasks as a context for engaging metacognition, this study also builds on research in out-of-school contexts for learning. Anderson, Thomas and Ellenbogen (2003) had suggested that out-of-school learning experiences might be a fruitful place to help learners become more aware of their own metacognitive learning processes. Learning activities, such as those designed for the current study, that encourage students to integrate knowledge across contexts thus offer an interesting research context for studying metacognition.

As Brown (1987) stated, in order to be metacognitive, one needs something to be metacognitive about. In other words, in order to explore the processes whereby individual metacognition is brought into the service of group learning, some context must be provided whereby individuals can be metacognitive, and this is the role of the problem-solving activity and its integration across both in-school and out-of school contexts in the current study. Thus, for this study, the problem-solving activity offers a window into how the individual uses his or her metacognition in the service of group learning.

Group Processes and the Social Context for Learning

Because learning occurs individually and in groups, both cognitive and situative perspectives are relevant to this research (Anderson, Greeno, Reeder & Simon, 2000). Cole (1991) located cognitive processes both within the individual and the social group. This study also locates metacognitive processes within both the individual and the social group. Thus, metacognition can be seen to bridge the gap between the cognitive and social worlds of the individual (Jost, Kruglanski & Nelson, 1998). Further, metacognitive knowledge, skills and behaviors can be considered *tools* or *signs* in the Vygotskian sense: "means for psychologically influencing behavior—either the behavior of another or one's own behavior" (Vygotsky, 1962, p. 125). In other words, tools or signs are mediational and facilitative, and in a group learning context, metacognitive tools help the individual bridge the gap between individual and group learning processes. While tools can also be seen somewhat mechanistically, the tool's particular use is defined for the task at hand and for use in a particular way to accomplish the intended task, along the lines of Brown's (1987) notion of metacognitive-like entities in an individual learner's toolkit. What is missing in the literature is how metacognitive knowledge, skills and behaviors are used as part of a learner's toolkit during collective learning activity, which is a gap addressed in the current research.

Personal understandings develop through a social and collective process (Davis & Sumara, 2003; Mason & Santi, 1994; Shapiro, 1994). This is where metacognition and its manifestation within group learning contexts is also 'situated.' How these individuals use their own metacognitive knowledge, skills and behaviors in this group context is the focus of the research reported here. Learning spaces such as classrooms or field trip experiences often include a social component so as to allow and encourage interactions between individuals. The social context is where individual learning behaviors and metacognition are potentially influential to other learners.

Individuals bring their own varied interests, motivations and skills, including their learning toolkits to a group context for learning, and this social diversity mediates learning by virtue of individual involvement with the sociality of the group context (Karpov, 2003; Lave & Wenger, 1991; Vygotsky, 1978). Learning activities that allow individuals within the group to work in their own *zone of proximal development* (Vygotsky, 1978) provide a context where individuals can learn from the experiences or understandings of others. Herein lies the group potentiality for cognitive and metacognitive activity among the individuals in a group: new development and progression toward more sophisticated functioning becomes possible in a group learning context (Cole, 1985).

Group learning activity provides a context for the interactions that foster learning, where interactions within the group, as learners problem-solve together, can lead to the development of richer, more elaborated understandings. Individuals bring their own background knowledge, but also their understandings of themselves as learners to the group context. This means additional social and psychological demands are placed on the learner within a group context for learning. The current study attends to these demands on the individual in terms of how they manifest in interactions among the members of each group.

Group process literature offers background for considering how interactions among learners are consequential. Ideally, the peer group is a motivating context where interactive patterns support learning activity and collaboration (Palincsar & Herrenkohl, 2002). Conditions that promote *collaboration* or, "the construction of shared meanings," include distributing thinking across the group; working on the same parts of the task, so that there is shared cognitive responsibility; and, sharing thinking with other members of the group (Brown & Palincsar, 1989). The nature of the problem space enables these sorts of collaborative interactions, and for this study, a specially-designed problem set was developed in order to promote collaborative interaction within the study groups.

Groups offer different kinds of learning opportunities than individuals might have alone. For example, groups offer the opportunity to share expertise within the group (Brown & Campione, 1994). Guided discovery work and reciprocal teaching (Palincsar & Brown, 1984) are also possible within a group context, giving individual learners the chance to be involved with different aspects of group learning activity to collectively construct knowledge. Through a process of mutual appropriation,

> learners of all ages and levels of expertise and interests seed the environment with ideas and knowledge that are appropriated by different learners at different rates, according to their needs and to the current state of the ZPD in which they are engaged (Brown & Campione, 1994, p. 237).

This is an idealized view of a knowledge building community (Scardamalia & Bereiter, 1991), but suggests how certain kinds of activities promote learning at a group level. The current study tracked how individuals within their learning groups engaged in these sorts of group learning activities in order to consider how they bring individual metacognitive knowledge, skills and behaviors into collective learning activities.

Part of what enables a group to be a successful learning group is 'shared referential anchoring' (Resnick, 1991). The anchoring could be a common experience or task that provides a focal point for the group's attention. While not specifically about 'group process,' prior experiences and features of the task are significant for the current study, particularly when the activity around which they organize involves problem-solving. Here is also where particular kinds of interactional patterns can lead to successful group problem-solving (Barron, 2000). These patterns include a high degree of mutuality, where each group member has the potential to contribute or be heard in the group discussions; a joint focus of attention for the group's members; and, a shared collaborative orientation to problem-solving activity. Further, individuals within the group may be able to model or scaffold self-regulatory behaviors for their group members (Perry, Hutchinson & Thauberger, 2007). This kind of support links the learning behavior of more experienced or skilled group members to how others in the group can learn to become more skilled. The current study looked for these patterns and supportive behaviors among the study groups as a place where individuals apply their own metacognitive knowledge, skills and behaviors in a group learning context.

On a more particular level, interactions and the groups' ability to coordinate them depends on a multitude of social cues, such as posturing, facial expressions, rhythms and tempos, and the emotions of the others in the group, and can take several forms. Interactions within the group can be parallel, associative or cooperative (Forman & Cazden, 1985). Parallel interactions involve little monitoring of others' thinking or processing: comments in the group discourse center on aspects of the task. Associative interactions occur when there are attempts to share information among the members of the group, but individual roles within the group's activity are not well-coordinated. Cooperative interactions involve constant monitoring of others' work, and roles are enacted complementarily within the group. It is this level of interaction that characterizes 'co-regulation' (Butler, Schnellert & Higginson, 2007), where the relationships among individuals within a community of practice are significant for engagement with cycles of inquiry. The current study attended to interactions within the student groups in order to explore the ways in which metacognitive knowledge, skills and behaviors manifest through interactions.

Self-regulatory behaviors, and thus, interactional patterns, within a social context for learning fall across a developmental continuum. Schraw, Crippen and Hartley (2006) extend Schunk and Zimmerman's (1997) phases of development of self-regulation, where learners (potentially) progress through four stages: observational, imitative, self-controlled and self-regulated. These stages evolve progressively into more sophisticated learning behavior, involving social interactions and processes at each stage, from the observational end where learners model others' learning behaviors, to the self-regulated end of the continuum where individuals with strong self-efficacy select among their potentially vast pool of cognitive strategies to self-regulate their own learning processes within a social context. It is significant that the most sophisticated stage of Scraw et al.'s stages involves the much higher level of complexity of responding to a social environment while engaged in learning behavior. This work also suggests that better understanding of these sorts of social processes is needed. The current study responds to this call through providing a problem-solving activity where the social context and its interactional patterns become a context for exploring how metacognitive knowledge, skills and behaviors manifest during group learning activity.

Activity Theory to Model Group Interaction

"Only by interacting with the material world and with other humans can we develop a knowledge of reality" (Wertsch, 1979, p. 11). Cultural-Historical Activity Theory [CHAT], or simply, *activity theory,* is an integrative theory that I use in this study to explore interactions among individuals within a group context for learning. Through its focus on *activity,* activity theory offers a framework for considering how humans interact with one another. *Activity systems* are goal-directed, and culturally-constrained and specified systems of actions and operations, which include motivations and interactions amongst the agents in the system (Engeström, 1987; Leont'ev, 1979). Actions and operations within the system are mediated by tools or signs (Vygotsky, 1978). Vygotsky was, "concerned with how humans come to master sign systems and then use those sign systems to organize their activity" (Wertsch, 1979, p. 13). The current study positions metacognition as a sign system within the larger activity system of group learning activity.

CHAT presumes that individuals exert personal agency to control their environment through the activities in which they engage. *Activity*: 1) occurs at several possible levels of analysis (activities, actions, operations); 2) is goal-directed; 3) is mediated through instruments of labor (e.g. tools or signs) (Vygotsky, 1978); and, 4) arises from social engagement and interaction. Engeström (1987) offered a model for an activity system where connecting lines indicate multiple relations that structure the system and serve as linkages between components of the system. I have adapted Engeström's model of an activity system for the current study, as shown in Figure 1.1.

Activity systems can be viewed at several different levels, including the subject/object dialectic; rules for engagement; the instruments, tools or mediational means that are used; the division of labor within the system; and, the community or communities to which the individual

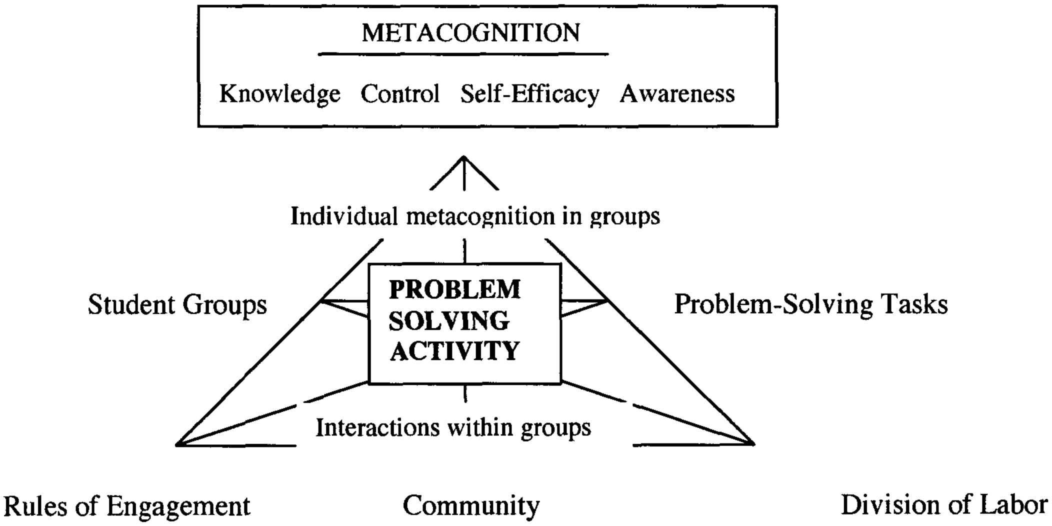

Figure 1.1 Integrated Framework for the Current Study, Adapted from Engeström (1987)

within the system belong. These components must, however, be viewed dynamically and holistically within the system, since they interweave to specify the system. Metacognition is positioned as a sign system for the current study, which enables a view into how group learning activity is mediated by metacognitive knowledge, skills and behavior. Engeström's (1987) model is adapted for use in the current study to provide a framework for exploration of the components of this activity system viewing metacognition as mediational means for group learning activity.

Within the model for the current study, as in Engeström's original model, linkages between the components of the system become focal points to explore connections among the various aspects of the system. This study considers how interactions are mediated by metacognitive knowledge, skills and behaviors and this is a key utility of activity theory as an integrative framework for understanding group problem-solving activity.

Problem-solving activity in the group context is the central activity of the system for this study, and the framework allows exploration of the complexity of group learning activity and how 'instruments' (or, metacognitive knowledge, skills and behaviors) mediate actions and operations within the system. Through a variety of data gathering methods, this study explores the various connections within the activity system and how metacognition mediates group learning activity.

Chapter Summary and Research Questions

Much research on metacognition views learning and learner behavior from an individual perspective, where metacognitive knowledge, skills and behaviors are used during learning activity, for example, during problem-solving. But, humans are social beings who continually interact with and change the world around them, and this happens through their activities. Interacting with others in a group learning situation involves both individual and social dimensions to learning; attending to the learning task AND the social context of the group. An activity system is where these interactions are negotiated. Through interaction, behavior is specified, including learning behavior. Within activity theory, an activity system provides a framework to explore how individual metacognitive knowledge, skills and behaviors are consequential within group learning activity.

Metacognitive knowledge, skills and behaviors are tools that learners use in the process of meaning-making, which from a constructivist perspective, constitute background knowledge that supports learning activity. Problems that connect to prior knowledge, engage learning on multiple levels and involve substantial content information offer opportunity for individual metacognition to be called into service. As object of an activity system, problems provide a context where metacognition manifests, framing also a research focus into the individual and group use of metacognitive knowledge, skills and behaviors as mediational means within an activity system. This study adapts Engeström's (1987) model of an activity system as a framework for considering how metacognition as mediational means manifests within the activity system of groups working together to solve problems in a science learning context.

What is missing from the research literature is work that views individual metacognition as learning behavior as it applies to a group learning context. How does what an individual knows about himself or herself in the context of problem-solving activity translate into group learning activity? Metacognitive knowledge, skills and behaviors are key to developing new understandings, but how these are called into service within the social setting of a learning group needs further exploration.

Thus, this study asks the following research question: *How does metacognition manifest within the social context of group settings as students engage in problem-solving activities?* The following sub-questions guided the inquiry:

1. What is the nature of the social context and interactions in which active group learning is manifested in this study?
2. In what ways were metacognitive knowledge, skills and behaviors deployed within the group settings studied here to empower learners' knowledge construction in problem-solving contexts?
3. How did social interactions in group-learning contexts serve to shape, engage and promote metacognition?
4. What were individual group members' perceptions of their roles and metacognitive knowledge, skills and behaviors within the learning groups?

Study Context and Methods

The context for this study included one classroom of high school biology students who attended a field trip to the Vancouver Aquarium as a regular part of their biology classroom experiences. Post-visit problem-solving activities were designed for these students in order to provide an integrative problem-solving context for the current research, which sought to explore how metacognition manifested during group problem-solving activity. The problem set called on students' prior knowledge, including biology subject matter and the field trip (and other personal) experiences, but also themselves as learners. In other words, the study context created metacognitive experiences in order to explore metacognition in a group learning context.

Multiple data collection methods were employed to capture evidence of students' use of metacognitive knowledge, skills and behaviors. Baseline measures of metacognitive knowledge, skills and behaviors were gathered through an instrument; observations and video and audio recordings were made of group interactions; paper records of problem-solving activities were collected; and, focus group and individual interviews were conducted. Analyses of these multiple data sources were informed by an activity theory framework to investigate interactions between individuals within the groups and explore how metacognition manifested in this group learning context, as developed for the research.

Thesis Overview

The thesis includes a total of five chapters. Following this introductory chapter, Chapter Two develops the theoretical framework for the study reviewing research on socioconstructivist perspectives on learning, metacognition, group processes, and problem-solving activity as pertinent to the development and implementation of the current study. Chapter Three is devoted to detailing the research methods and analysis processes used in the study. Chapter Four presents results and discussion. Chapter Five includes conclusions, implications and recommendations, and some questions for further study.

CHAPTER TWO
LITERATURE GROUNDING

As described in Chapter 1, this study explores how individual understandings of the self as learner are brought into a group context for learning. The group context is a place where individual learning behavior manifests, and is an important interface where knowledge is socially constructed, hence the value in studying groups as interesting sites for learning. Exploring this space is the focus of this study as I seek to advance understanding of how individuals use their own metacognitive knowledge, skills and behaviors in the process of working together collaboratively on group problem-solving activity. Literature from research on metacognition in science learning and problem-solving, group processes and activity theory are selectively drawn into the discussion in this chapter to build the theoretical framework for the study.

Based in perspectives on social constructivism (Cobb, 1994; Duit & Treagust, 1998; Solomon, 1993; Vygotsky, 1978) and learning in science (Driver, 1983; Posner, Strike, Hewson & Gertzog, 1982), this study explores the manifestation of metacognition in a group context for science learning. Learners bring personal knowledge into learning settings, and this is the background upon which subsequent understandings are built. In this study, metacognition involves particular kinds of knowledge, skills and behaviors that learners use to learn. It is about knowledge, control, self-efficacy and awareness over one's own learning processes (Baird, 1986; Bandura, 1994; Gunstone, 1994). These aspects of metacognition and individual learning behavior are applied in the context of learning new material but also when working with others on collective learning activity. A biology classroom is the context for learning in the current study. Literature from problem-based learning [PBL] informs the development of a biology problem-solving context in which learners within collaborative groups have something to be metacognitive about (Brown, 1987). Within a group learning context, individuals use what they know about themselves as learners and interact dynamically during collective activity.

The chapter opens by reviewing contexts for science learning and how metacognition is important for achieving science education goals. Problem-solving activity has often been used in science classrooms to focus learner activity around science concepts and for studying metacognition. This chapter reviews pertinent science education literature to link the model of metacognition developed in the previous chapter to learning in science. The subsequent section of the chapter is devoted to problem-solving within a group learning context, where the problem offers an object for learning activity and individual metacognition, but also has significance in terms of group processes and the social context for learning. Through dynamic interaction within an activity system, individuals act as agents for their own cognitive and social development, and in the final section of this chapter, cultural historical activity theory [CHAT] is explicated as a framework to explore where metacognition manifests during group learning activity.

Metacognition in Science Curricula

Building from the model of metacognition introduced in Chapter 1, this section reviews literature in science education to frame the current study in terms of how metacognition is promoted within curricular goals for science learning. Learning in science is about acquiring specialized knowledge, developing critical thinking skills, conducting scientific inquiry and learning how to discriminate among evidence sources to build warrants for arguments. These are general science learning objectives, within which the use of metacognitive knowledge, skills and behaviors is key. Along with learning particular science content, learners are expected to manage their own learning and become self-directed, which are also aspects of metacognition. Thus, metacognition is a key factor in understanding science learning, and the current study builds a science learning context within which metacognition can be explored.

The British Columbia [BC] curriculum documents provide guidance about the kinds of cognitive and metacognitive skills and behaviors to be promoted in school science. In particular, school science programs should provide experiences that:

- help students become flexible and adaptable while acquiring specialized knowledge
- develop the capacity to think critically
- offer a wide range of knowledge, methods, and approaches that enable students to analyze personal and societal issues critically
- encourage students to examine the impact of scientific knowledge on their lives, society, and the environment

• develop a positive attitude toward science

• cultivate students' appreciation of scientific endeavour and their potential to contribute to it (British Columbia Ministry of Education, 2006, p. 11)

These goals for science programs in British Columbia reflect contemporary views of the nature of science learning more widely (American Association for the Advancement of Science, 1993; DeBoer, 2000; National Academy of Sciences, 1995; Rutherford & Ahlgren, 1990) and require highly developed thinking and learning skills. Metacognition, while not explicitly stated in the BC learning objectives for science, is clearly valued in terms of learning science. Being able to put metacognitive knowledge, skills and behaviors into practice during learning activity links individual conceptual frames and cultural and historical artifacts that are the objects of science curricula and represent the kinds of knowledge we want students to develop during their years in school.

Metacognition, Knowledge Construction and Problem-Solving

Research in science education has explored classroom practices useful for promoting valued learner dispositions and behaviors alongside promoting knowledge construction. The notion of conceptual ecology (Hewson & Hewson, 1992; Posner et al., 1982) is one way to envision how the context of science frames the process of learning, and offers a perspective on possible methods for studying metacognition. Learners' prior conceptions are the most important aspects of learning anything new (Ausubel, 1969; Hodson, 1998) and these comprise the learner's conceptual ecology. Any new conception (that is to alter or replace a previously-held one) needs to have its status raised in the mind of the learner. How a new bit of information fits in structurally with what is already there in terms of the individual's epistemological commitments, beliefs about the world and other kinds of knowledge already held is key to its interpretation, integration and ultimately, its acceptability. But, since understandings are based in beliefs or commitments held previously, they can be extremely resilient. Change of status happens through conceptual change (Duit & Treagust, 2003; Hewson, Beeth & Thorley, 1998; Hewson & Hewson, 1992; Peck & Sears, 2005; Posner et al., 1982), where the learner's conceptual ecology is challenged by an inconsistency brought about through a learning experience or other encounter. These experiences or encounters are opportunities to be metacognitive, and classroom experiences that stimulate cognitive dissonance (Gunstone, 1994) motivate learners to seek to resolve the inconsistency, which necessarily invokes metacognition. In experiencing dissonance, learners will likely reflect on their own understandings, evaluate aspects of these understandings, perhaps ask more questions and seek out additional information that may help to build a model that more inclusively represents the information. Learning experiences designed to stimulate this dissonance are metacognitive experiences, "where every major step you take requires planning and evaluation afterwards; where decisions and actions are at once weighty and risky" (Flavell, 1979, p. 908). The current study designed metacognitive experiences to stimulate cognitive dissonance in order to tap into learners' conceptual ecologies and metacognitive knowledge, skills and behaviors.

Part of the dissonance involves recognizing individual stances, and as Claxton (1993) advises, it is through learning experiences and classroom encounters that learners must be helped to evaluate when a particular stance regarding a learning decision or an epistemological commitment ought to be invoked. Often, stances are pre-specified for a given situation based in the perceptual features and demand characteristics of that situation, assessments that involve metacognition. And, again, while not explicitly stated in curriculum documents, helping learners to examine their own stances and develop the skills necessary to evaluate information more broadly are significant goals within science education. Stances are possible positions where learners' understandings of both the content and themselves may be revealed, and the current study sought to provide a context for such revelation.

At issue in the current study is how metacognition as individual learning behavior is significant within the context of group problem-solving activity. To support an individual to build knowledge that is outside his or her direct experience, group learning experiences need to provide opportunities for individuals to widen their perspectives. This is a process of self-organization (von Glasersfeld, 1995) where learning involves two levels of abstraction: empirical and reflective. Metacognition is involved in both. The result of *empirical* abstraction is a description of reality representing some property of a physical object, thinking that is commonly developed via content knowledge. Mental models are constructed as a result of *reflective* abstraction, and these coexist with cognitive forms or material objects external to the individual. Reflection by the learner is an opportunity to monitor and evaluate the addition of new information to the cognitive structure, which is metacognitive. Through reflection, one's perceptual field is reorganized, and learning is, "acquisition of many specialized abilities for thinking about a variety of things" (Vygotsky, 1978, p. 53). Learner skill at organizing thinking, fitting ideas into the already-present conceptual framework and articulating conceptual understanding through the use of language, all demand metacognition. Because empirical and reflective abstraction are both aspects of modeling and problem-solving behavior, and significant for science learning, this study explores how these aspects of individual learning behavior are consequential in group problem-solving activity. So, while curriculum goals for science education value learner dispositions and behaviors, individual conceptual ecologies need to be challenged and provoked in order to learn anything new. This is where metacognition comes in—where individual stances are evaluated, content knowledge is developed and mental models built—and the context for this challenge becomes significant for both the individual and knowledge building at a collective level.

The current study explores how metacognition bridges individual learning behavior and group learning activity in the context of problem-solving activity (Cole, 1991; Jost, Kruglanski & Nelson, 1998). But problem-solving is socially situated (e.g., in a classroom; in a field trip experience) and by extension, so is metacognition. Learning activities optimally play two important functions for learning: they create a place for active individual construction of knowledge and, they serve the purpose of enculturating learners into society's practices (Cobb, 1994). Thus, learning activities can bridge the individual and social worlds. To that end, in the current study, I construct learning experiences that enable individuals to reflect on what they know and understand as well as contribute to a group problem-solving effort. Of course, learner engagement in the learning activity is prerequisite, and effort must be expended, including metacognitive effort. But, as Gunstone (1994) has suggested, it is sometimes difficult to convince learners of the value of additional effort unless the learning activity is intrinsically engaging, which may serve as the entry point for individuals to participate in learning activity. The problem-solving context is thus a window into how individual metacognitive knowledge, skills and behaviors are significant for collective problem-solving.

Much research has been conducted to explore how problem-solving activities can create opportunities to develop scientific thinking and engage in the activities of science. For example, Flavell (1976) noted that metacognition is what learners use during the process of problem-solving. In his research, he wondered why children failed to solve problems that they knew how to solve. By setting up problems where adoption of appropriate problem-solving processes was a necessary condition for solving the problems, Flavell created 'metacognitive experiences' (Flavell, 1979), and demonstrated how creating a problem-solving context provided opportunities for learners to apply metacognitive knowledge, skills and behaviors in the service of learning. Similarly, the problem-solving activity in the study by Akana and Yamauchi (2004) enabled participants to revise their own metacognitive experiences, which in turn led to the successful solving of similar problems at a later date. In other words, the problem-solving task gave students the opportunity to rethink and revise how they thought about the process of problem-solving, in effect allowing them to be metacognitive.

Learners' conceptual ecologies also include views on the nature of activity, and some kinds of problem-solving activity may require learners to adopt a different conception of the nature of learning. This may be linked situationally to the nature of beliefs about learning in science. A recent study with students enrolled in a first-year university biology course that had been revised toward an inquiry-oriented approach challenged them to learn the necessary new skills and adapt or abandon old ones (Butler, Pollock, Nomme & Nakonechky, 2008). The significant revision to the course involved open-ended laboratory experiences, and had the effect of requiring students to adjust their own learning behaviors in response to the inquiry-oriented approach. These laboratory activities were specifically designed to shift students' conceptions of the nature of biology learning, and Butler et al. found that many of these students realized the need to adjust their learning behaviors in order to process the information in a different manner as compared to what they had come to expect as science students: "students seemed to be either excited by the challenge or unnerved because there were no 'right answers' to be easily found in a reference article or text" (p. 20). Adjustments to conceptual ecologies did not come easily. The parallel for the current study lies with the inquiry-type problem-solving context that challenged learners to think differently about their own conceptions of the nature of biology learning.

Apparently, Butler et al.'s (2008) students did not perceive biology learning as involving problem-solving, reflecting a particular view of the nature of the science of biology. The students who were either 'excited' or 'unnerved' may be reflecting their own beliefs in the 'epistemic authority' of biology knowledge, which includes how it ought to be taught. Ellis and Kruglanski (1992) found that these epistemic beliefs determine how comfortable a learner is with particular kinds of instruction. For example, students who have developed comfort and confidence with biology as represented in a 'traditional' manner by the teacher, may be the ones who are unnerved when they encounter a more open-ended inquiry approach. This may provoke an experience of cognitive dissonance, where the discrepancy invites and requires different thinking by the learner. This extends to the learners' willingness to adopt or adapt their own self-regulatory behaviors for engaging in learning activity, and suggests an important linkage between self-regulatory behavior, other kinds of metacognitive knowledge, skills and behaviors and types of learning activity that engage students in thinking differently or more deeply. The study context in this thesis seeks to explore these sorts of metacognitive engagements through a problem-solving context designed along the lines of an inquiry approach, but using a naturalistic setting for biology learning.

To develop problem-based activities for the current study, I called upon literature on problem-based learning [PBL], where advice is offered on the design of learning activities to promote students' active engagement with their learning. Attending to how learners develop the necessary skills, information and dispositions for success in the information age, Gallagher (1997) argued that PBL is an innovative approach to helping students be better learners. As Dewey (1916/1966) described it, learning "should give students something to do...and the doing is of such a nature as to demand thinking or intentional connections" (p. 154). To this end, PBL approaches are designed to foster active engagement with learning activity. PBL approaches, similar to the discovery approaches out of which they arose, are often based in the structure of the discipline. PBL activities provide an important introduction for science students to the nature of scientific activity and provide opportunities to be metacognitive. In the 'doing,' then, the participants in the current study solved problems together, and revealed how they put their own metacognitive knowledge, skills and behaviors to use.

Research suggests that to develop an effective PBL unit, the problem should be ill-structured, work with substantial content information, fit the course, program or curriculum objectives and be suitable for the target audience (Stephien & Pyke, 1997). To bridge individual metacognition and group learning behavior, the problem context should create metacognitive experiences for groups of learners that allow individuals to bring in prior knowledge that is then challenged by the problem itself. Problems should actively engage all the learners and provide opportunities to explain thinking, justify stances and compare ideas with more formalized scientific knowledge. Being ill-structured means there is need to interpret the task. In a group, this becomes an occasion for dialogue and common experience making the problem-solving context a social location.

Group Processes in Problem-Solving

Researchers have critiqued school practices that most often assume an individualistic view of self-structured knowledge (see for example, Brown, Collins & Duguid, 1989), without recognizing the key role that group processes play in collective activity. Thus, in this study, I focus specific attention on how individual thinking and knowledge built socially happens through collective problem-solving activity.

The problem-solving context is an important social location for the current study, and it is significant because, "social experiences can shape the kinds of interpretive processes available to individuals" (Resnick, 1991, p. 2). In other words, according to Resnick, the social process *is* cognition and every act of cognition is a specific response within a particular set of circumstances. Common experiences among learners, then, offer a 'shared referential anchoring' so that individuals within a discourse community have a language to use in developing shared meanings. This is one way in which other people in the learning setting have a potentially great influence on meaning-making for and with their group members, and individual experiences may serve to vicariously inform others who have not shared the same experiences. Learning experiences, when constructed as opportunities for social interaction, are thus potentially significant for the learning process on individual as well as collective levels, both of which are levels of analysis in the current study.

But, it is not safe to assume that social interaction through a group context will automatically result in successful or productive learning activity. In other words, social influence does not necessarily equate to collaborative work. As in Brown and Palincsar (1989), a condition for collaboration is shared thinking, and opportunities to do so must be provided in order for learners to collaborate and learn together, or, as in the current study, for researchers to study aspects of collective learning behavior. The problem-solving context as developed for the current study created an opportunity for shared thinking. Other conditions for collaboration include distributing thinking across the group, sharing work on the same parts of a task and the sharing of cognitive responsibility (Palincsar & Herrenkohl, 2002). These conditions are enabled through the context of the social experience of collective learning activity in a problem-solving group, and in designing the problem-solving activity for the current study, attention was given to enabling these conditions for collaboration.

A successful problem-solving group also has a *joint focus of attention* (Barron, 2000). This may include a workbook or other 'center of coordination,' and even if attention is diverted occasionally, it can be easily restored in a successful group. When two or more individuals within the group are involved in co-developing solutions or are otherwise involved in a shared or collaborative approach to problem-solving, the group has a high level of *shared task alignment* and a high degree of mutuality in interaction (Barron, 2000) as individuals utilize their own self-regulatory behaviors in working together. The problems, as developed for the current study, asked the members of the group to collectively develop problem solutions, thus creating an opportunity for the groups to have a joint focus of attention. Through this focus, it was expected that individuals would then develop shared task alignment and mutuality of interaction as they negotiated their work together.

In terms of how collaborative interaction is both produced and developed through the problem-solving context, a look into learner efforts to regulate their own learning behavior is useful. Complex learning tasks and the style of classroom interaction are meaningful for promoting self-regulated learning (Perry, Phillips & Dowler, 2004). This is an important link to the purposes of the current study, since in order to study metacognition in a group, a suitable context with appropriate complexity and interactive possibility must be provided. While Perry et al. were working with mentor teachers in order to promote development of self-regulated learning among pre-service teachers, they found that where complex problems were offered, more self-regulated learning behavior resulted. The complex problems addressed multiple goals; dealt with large chunks of meaning; required involvement over a period of time; engaged a variety of cognitive and metacognitive processes; and, allowed for a wide range of products. Similarly, other research by Perry's group has demonstrated that less self-regulated learning occurs when tasks are given in isolation (such as the task of punctuating sentences); where students have few opportunities to make choices about the learning process or decision-making to control challenge or evaluate progress; or, if the tasks are not very challenging (Perry, 1998). Taken together, Perry's studies demonstrate that the nature of the learning context and tasks can stimulate or engage more sophisticated learning behaviors (e.g. metacognition) among learners, and suggests that complex problems are more likely to provide the kind of experiences where metacognitive knowledge, skills and behaviors will manifest. Alongside PBL literature in science education, Perry's work offers guidance on designing suitable problems to provoke metacognition.

In addition to the characteristics of good problems, attention to how the group interacts through the learning activity also informed the development of a problem-solving context for the current study. Brown and Campione (1994) identified underlying principles for learning activity in *The Ideal Classroom:* a community of discourse allows constructive discussion, questioning and criticism; individuals share expertise with the community, and so have both personal and community responsibilities; participant structures are ritual and familiar; tasks engage students in multiple *zones of proximal development* (Vygotsky, 1978) depending on individual rates and routes; and ideas and concepts are seeds that are taken out to the community. Classroom activity that enables learners to verbalize claims and discuss evidence can then lead to collective knowledge building (Cobern, 1993; Harding & Hare, 2000). Problems that enable individuals to work within a community of discourse and are within the learners' zone of proximal development could thus be a suitable context for considering how individual metacognition manifests during group learning activity.

Research has provided compelling examples of how establishing opportunities for collaborative problem-solving both promotes learning and offers opportunities to study metacognition. For example, Goodnough and Cashion (2006) used collaborative inquiry in their small-scale study of problem-based learning in a high school science classroom. The study was not about promoting metacognition, but through the collaborative effort of the problem context, tapped into social knowledge construction, and data for their study included student-generated work, classroom observations and student interviews as data sources. Each of these data sources provided points of reflection for the collaborative team, as they worked together to develop greater understanding of the implementation of PBL activities. The rich data sources through the intensive data gathering phases of this study offered broad perspectives on the individuals within the group as learners, as well as of collective problem-solving processes. Bray, Lee, Smith and Yorks (2000) also collaborated with the classroom teacher during the development of a PBL unit, which was specifically designed to enable social interaction for collaborative work. The current study followed guidance from these studies in particular to design a problem-solving context that was consistent with the goals for this study: build a collaborative problem-solving context to engage student metacognition in order to explore how metacognition manifests during group learning activity.

Problem-Solving In and Out of School

The particular classroom context for the current study was a 'traditional' biology classroom where the teacher included a field trip to the local Aquarium as part of the regular classroom program. This aspect of the naturalistic setting for biology learning was utilized in the study as background for the problem-solving activity that was developed for this study, since the field trip visit provided a series of common experiences for the students. Thus, literature on learning in out-of-school contexts is relevant here. Research in informal contexts for learning also offers substantive advice on how to create rich learning experiences for students.

Out-of-school contexts, or informal settings for learning, include science centers, museums and aquaria, among others, and provide rich opportunities for learners to experience science concepts and develop deeper understandings (Anderson & Lucas, 1997; Falk & Dierking, 1997). Experiences in these settings form part of students' prior knowledge that they bring to school and school science (Rennie & McClafferty, 1996). Ideally, such experiences are enriching for students' understandings of science and their everyday worlds. Giving specific attention to understandings developed through the mediated experience of exhibits and displays from out-of-school contexts provides a contextual linkage to science learning in the classroom (McManus, 1988), which for the current study, was the teachers' goal for taking his students to the Aquarium. Out-of-school learning is thus important for developing science understanding in the more formal setting of the classroom. Because the students who participated in this study attended a field trip to the Vancouver Aquarium as part of their biology classroom activities, the current study draws from the important contextual linkage between the field trip and classroom learning as a common experience shared by all the students.

Out-of-school contexts are also rich in social interaction (Falk & Dierking, 2000). Many young people visit such places as part of school field trips, which are intended to be learning experiences that may or may not be aligned with the teachers' or students' agendas (Anderson &

Lucas, 1997; Anderson, Lucas & Ginns, 2003; Anderson & Zhang, 2003). Visits to informal learning settings also happen with other groups, such as families and friends, and are valuable social experiences (Moussouri, 2003; Piscetelli & Anderson, 2001). Experiences such as class field trips foster connection to individual background knowledge while engaged in classroom learning activity, providing a joint focus of attention and offering 'something to be metacognitive about.'

The social space of the school field trip is often seen as complementary to classroom, in-school learning experiences, and indeed, this is the justification teachers often use to have their students participate in them (Anderson & Zhang, 2003). More particularly, Anderson, Thomas and Ellenbogen (2003) suggested that because field trip experiences are highly engaging for learners and are quite often rich in interactive opportunities, they represent an important context for studying metacognition. As the current study was interested in how metacognition manifested during group learning activity, using in-class, problem-solving activities to complement field trip experiences offered a possible connection between the social environment of the field-trip and related in-class collaborative problem-solving activities, and a potentially rich and engaging research context for exploring metacognition in a group learning context.

Methodological Strategies for Studying Metacognition

To this point in Chapter 2, I have developed collaborative problem-solving activity as a possible context in which to explore metacognition, but there is a methodological issue looming large on the horizon, and that is, how will metacognitive knowledge, skills and behavior be recognized in the context of the research? When learning is generally thought to happen in the mind of the individual, outwardly visible behavior may not reflect the thinking processes underlying it. This may make it difficult to recognize metacognition. Perhaps this is why Weinert (1987) questioned whether knowledge could be considered metacognitive before it was put into service. Believing that metacognition can only be seen 'in action,' researchers have used problem-solving contexts as a means to elaborate individual thinking (see for example, Paris & Winograd, 1990; Sternberg, 1998). This notion of viewing metacognition in action through problem-solving activity is adopted in the current study, and this section leads to discussion of the utility of using multiple methods for studying metacognition.

Of course, it may be less challenging methodologically to observe the 'what' of problem-solving than the 'how' of the thinking processes underlying behavior. By asking research participants to talk about their own processes of problem-solving (see for example, Baird & Northfield, 1992; Greeno & Riley, 1987; Gunstone, 1992; Mason & Santi, 1994), metacognition has been elaborated as part of the individual's repertoire for solving problems (Flavell, 1976; Gunstone & Mitchell, 1998; Vygotsky, 1978; White & Gunstone, 1992). Specifically asking individuals about the learning activity, in ways that cue descriptions of metacognitive knowledge, control, self-efficacy or awareness is one way to recognize that talk is in fact reflecting metacognition. It should be emphasized that the research cited here was concerned with the processes being used to learn rather than the content of what the learners were learning (Anderson, Lucas & Ginns, 2003). Anderson, Lucas and Ginns used naturalistic observations and video recordings to trace a variety of learning behaviors and language that could be considered metacognitive. Other research groups have also used a range of methods, including instruments, to assess particular aspects of metacognition. Using multiple methods in the current study is consistent with White's (1988) recommendation to use as many different methods as possible to study metacognition.

Manzo and McKenna (1993) suggested that better instruments were needed to properly study metacognition. Of course, instruments depend on particular definitions for metacognitive constructs and most often use self-reports to characterize aspects of metacognition. Wilson (1997) was critical of the instruments available at the time because of their dependence on self-reported measures that in turn relied on linguistic skill and not necessarily metacognitive skill. Turner and Patrick (2004) expressed mistrust of self-report measures because of the complexity of learning behaviors that vary according to many factors, which are themselves difficult to quantify. However, this does not preclude the use of self-report measures. Rather, it suggests a need to be cautious in interpretation and recommends the use of other measures in addition to self-reports.

Self-report instruments in the metacognition literature commonly probe students' metacognitive knowledge, strategies (Pintrich & Garcia, 1993; Pintrich, Smith, Garcia & McKeachie, 1991; Weinstein, Schulte & Palmer, 1987) or metacognitive processes (Biggs, 1988; Osborne, 1998). But they often do so without attention to the classroom context or in relation to specific subjects (Thomas, Anderson, & Nashon, 2007). This is significant for the current study, as the participating students were studying biology, and were asked to be metacognitive in the particular context of their biology classroom. In developing their self-report instrument, the *Self-Efficacy, Metacognition and Learning Inventory--Science* [SEMLI-S], (see Appendix A) Thomas et al. took account of the lack of particularity among existing instruments for exploring learning behavior and metacognition in science and intended that their instrument be used alongside behavioral observations to characterize what have been called metacognitive *traits* or *pointers* (Nashon, Anderson & Nielsen, 2005), *profiles* (Nielsen, Nashon & Anderson, 2006), *predictors* (Nashon, Anderson, Thomas, Yagi, Nielsen & Hisasaka, 2005) or *factors* influencing group learning behavior (Nielsen, Nashon & Anderson, 2007a, 2007b). Following Thomas et al.'s recommendation that a range of indicators be used in the assessment and evaluation of metacognition and learning processes in science, the current research used the *SEMLI-S* alongside behavioral observations and verbal self-reports to explore how metacognition manifests in a particular learning context. This section of the chapter draws links between the *SEMLI-S* and the model for metacognition as developed in Chapter One.

The *SEMLI-S* (Thomas et al., 2007) opens a window on how the individual sees himself or herself as a learner in a science learning context. While the five dimensions of metacognition and learning behavior profiled on the *SEMLI-S* do not map precisely onto the model of metacognition adopted for the current study, they represent a starting point for subsequent phases of exploration. The five dimensions of metacognition and learning behavior on the *SEMLI-S* are defined here: *self-efficacy*—organizing and executing actions in order to attain science learning goals; *learning risks awareness*—individuals' perceptions of situations that may be detrimental to learning; *control of concentration*—adjustments to concentration depending on the learning situation, the difficulty of the task or to suit different science subjects; *monitoring, evaluation and planning*—important strategies for learning generally and in science particularly; *constructivist connectivity*—a broad view of science learning where connections between new information and prior knowledge are made across different locations for science learning. The *SEMLI-S* dimensional profiles offer a self-reported perspective on aspects of metacognition highly relevant to learning in science.

While the definitions for the dimensions in the *SEMLI-S* do not encompass all of the constructs in the model of metacognition presented at the outset of this study, the *SEMLI-S* dimensional profiles offer a view into important kinds of learning behaviors that a given individual may utilize and hence, were used in this study to offer guidance on what sorts of learning behaviors to watch and listen for in the group learning context. Because the *SEMLI-S* does not encompass all of the metacognitive constructs of interest in this study, Table 1 links *SEMLI-S* dimensions to a broader range of metacognitive constructs and other methods used in this study to explore additional aspects of metacognition: knowledge, control, self-efficacy and awareness. More specifically, in the current study, a combination of self-report, interview, and observational techniques were used to explore how individual metacognitive knowledge, skills and behaviors manifested during group problem-solving activity. The quantitative *SEMLI-S* instrument was used to assess learners' dispositions or profiles on dimensions of metacognition and a problem-solving context developed for the study offered a place to observe, reflect on, and discuss learners' metacognition in action.

Table 1 Mapping Multiple Methods to the Model of Metacognition for the Study

Methods	Constructs of Metacognition			
	KN	CO	SE	AW
SEMLI-S		X	X	X
Problem-Solving	X		X	
Identify Critical Incidents	X			X
Stimulated Recall	X			X
Interviews	X	X	X	X
Observations	X	X		

KN=Knowledge; SE=Self-Efficacy; CO=Control; AW=Awareness

Through a blending of multiple methods, a rich view of metacognition becomes possible. Observations and interviews have enabled researchers to gather wide perspectives on learning behavior. Thomas and Mee (2005) were studying the development of metacognition among 8-

year-olds, and during their interviews with participating students, realized a need to offer the students a language to use to talk about themselves as learners, alongside their perceptions of classroom learning behaviors. Not surprisingly, the words and language used by the students during interviews reflected their socially and culturally-developed understandings and their abilities to describe their own learning behaviors that were developed through classroom activity. This points to the value of exploring metacognition within a particular context and suggests a need for the current study to be aware that learners may need some assistance with language in talking about themselves as learners.

Opportunities for talk can become metacognitive experiences. Recently, Larkin (2006) encouraged 5-year-old children to engage in the social construction of knowledge while she provided metacognitive experiences for groups of students. She then traced the children's interactions through coding for metacognitive knowledge, using *person*, *task* and *strategy* variables (e.g. from Flavell, 1979); metacognitive experiences; and, goals and actions. Larkin's students were accustomed to working in pairs, but not the larger groups (of up to six students) that were part of the study. Through a series of activities over the school year, Larkin's two case students demonstrated growing metacognitive knowledge. This included greater facility with language and the development of new control strategies, both of which were the result of participation in the research activities. Further, the collaborative nature of the group promoted the development of social skills, which in turn influenced individual thinking. Larkin's study suggests the fruitful potential of designing activities whereby metacognitive skills and behaviors can not only be engaged, but further develop through participation in research using a group setting for learning. Anderson, Nashon and Thomas (2008) discussed this sort of outcome in their paper on evolving methods for studying metacognition. In a way, this type of work is an ethical response to and for student learning, and is developed through the context for learning that doubles as a context for research, substantively adding to knowledge in the field of science education.

The research studies described above suggest that it is possible to learn about how learners use their metacognitive skills and behaviors, dependent of course, on the chosen definition(s) for skills or behaviors that are metacognitive and the contexts in which their learning is engaged. The current study is informed by problem-solving contexts out of PBL, where aspects of problem design provoke metacognition and engage learners in collaborative activity. Further, literature supports the suggestion that blending several research strategies to characterize and then gather information about learner metacognitive knowledge, skills and behaviors could be effective in approaching the complexity of the issue, and, it is complex: how individuals bring understandings of themselves into the group learning context happens on many levels of cognitive and social engagement. Groups are dynamic social entities that have multiply-layered interactional patterns and forms. These forms of interaction among the individuals in the group are where group learning behavior is revealed, and this study used an activity theory frame in order to explore these interactions.

Activity Systems as Theoretical Framing for Learning Activity

Cultural-Historical Activity Theory [CHAT], or simply, *activity theory,* offers a framework for considering how humans interact within a system through the focus of their activity. Problem-solving as developed in earlier sections of this chapter provides a rich activity context for provoking metacognition. Through the problems to be solved collectively, individuals within the groups interact: they negotiate positions within the group; they co-strategize and co-develop problem solutions; they engage socially with one another. This study adopts an activity theory framework as a means to explore interactions and dialogue among students working in learning groups during collective problem-solving activity, exploring both individual metacognition and group processes.

Overview of Activity

Activity as a philosophical category (Sagatovsky, 1990) describes a socially dynamic process of how humans learn, where individuals or agents in the system act reciprocally with the goals and motivations for the activity, and redefine and reconstruct themselves in the process. This is the Marxist concept of *activity* (Leont'ev, 1978/2000), which differs from the usual notional conception of activity. Activity is also culturally-mediated (Cole, 1985; Radford, 2006; Roth et al., 2004), and so in a way, reflects the relationship between the individual and the world in which he or she lives, and this includes schooling, which is an historical activity, framed by social, political, economic and cultural forces over time (Bruner, 1960, 1996; Goodlad, 1984; Repkin, 2003; Tyack, 1990). CHAT presumes that individuals exert personal agency to control their environment through the activities in which they engage. For this study, the activity context is problem-solving activity in which individuals working in groups interact as agents. Interactions among agents specify an *activity system* (Engeström, 1987; Leont'ev, 1978).

An activity system has a 'symbolic superstructure' that underpins thought (Radford, 2006), drawing an important connection to the current study where socioconstructivist perspectives on learning are the basis for interpreting interactions among individuals during group problem-solving activity. The superstructure is based in cultural and historical meanings. In turn, these establish social patterns for individual meaning-making and give rise to forms and modes of activity and to particular modes of knowing. The model of metacognition as developed in Chapter One is used to explore these forms and modes of activity and modes of knowing in the current study.

Engeström (1987) provides a model for relational configurations among the components of an *activity system*, as shown in Figure 2.1.

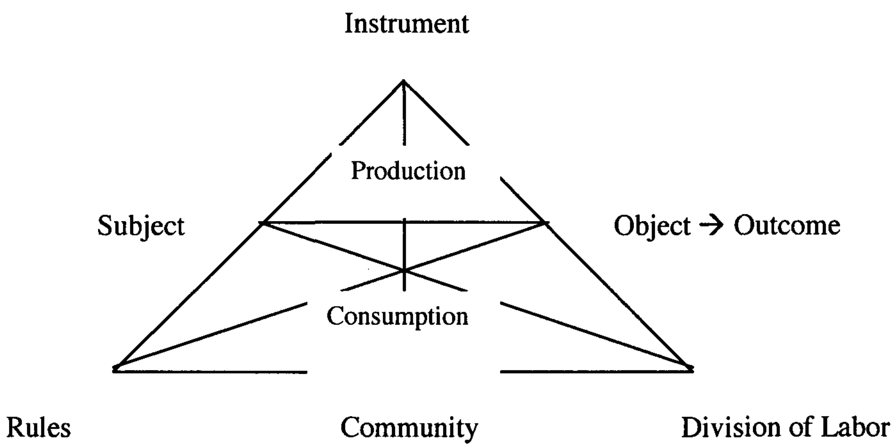

Figure 2.1. Engeström's (1987, p. 73) Model of the Activity System

Aspects of the system are facets of human activity, and arise from the Marxist origins of activity theory (Leont'ev, 1978/2000). The triangle model is divided into upper and lower halves, denoted by production and consumption, respectively. Production yields results in terms of outcomes of the system's activity, in the case of this study, results of the problem-solving tasks. Consumption, in labor terms, includes the use of object-result forms of the product, but also appropriation of the product. For the current study, this is where the open-ended problem-solving context inspired negotiations among individuals in the system that result in interaction patterns and collaborative effort. According to Zlobin (1990), 'consumption' is, "the content mastering of the human essential forces embedded in the product" (p. 62). This can be interpreted to mean that through exchange (between what is produced and consumed in the system), the essence of human activity is realized. Additionally, Engeström's activity system model encourages a holistic view with other facets of human activity.

The activity theory framework as modeled for this study provides guidance on how to focus research attention on students' interactions within their groups as mediated through metacognition (in particular, knowledge, control, self-efficacy and awareness); the rules of social engagement as negotiated within groups; the various communities to which the students belong; and, the roles adopted by individuals within the groups as a division of labor. There is a dialectical relationship between the learning group as subject within the activity system and the problems to be solved as object of their activity, and adapting Engeström's (1987) model for the current study allows exploration of the components of the system and their possible relationships to individual metacognition as it manifests during group problem-solving activity. Stake (1995) reminds us that, "issues are not simple and clean, but intricately wired to political, social, historical, and especially personal contexts" (p. 17). Here, the issue of interest is how metacognition manifests in the social context of group problem-solving activity and the case is the classroom of biology students whose activity is the focus of this exploration.

The subject-object dialectic is represented by the horizontal line through the middle of the triangle, dividing Engeström's (1987) triangle into upper and lower halves of production and consumption respectively. The subject of the activity system is, by definition, the agent or group having agency within the system. According to Stetsenko (2005), human subjectivity is sociocultural in origin, having evolved over time, and includes psychological processes such as cognition, self-regulation, emotion and the self. Subjectivity originates in social exchanges among individuals. Actions or operations by agents are individual, but when approached cooperatively, they become *activity,* as in an *activity system* (Leont'ev, 1979). Here is a significant connection between the individual and the group(s) to which the individual(s) belong: it is in the nature of collective action that an activity system emerges, which connects the system to the task of problem-solving for the current study. Figure 2.2 is a simplified version of the figure presented in Chapter One that modeled the system for this study.

The object of the activity system configured for the current study is a series of problem-solving tasks designed to be metacognitive experiences. The system of activity evolved around the problem-solving activity as the groups began their work together. Here is where other aspects of the activity system help to inform the research in this thesis. I was interested in aspects of social interaction around group problem-solving activity and how the interactions are related to the individuals' sense of themselves as learners. In other words, the activity framework allows a view into how metacognitive knowledge, skills and behaviors mediate social interaction during group problem-solving activity.

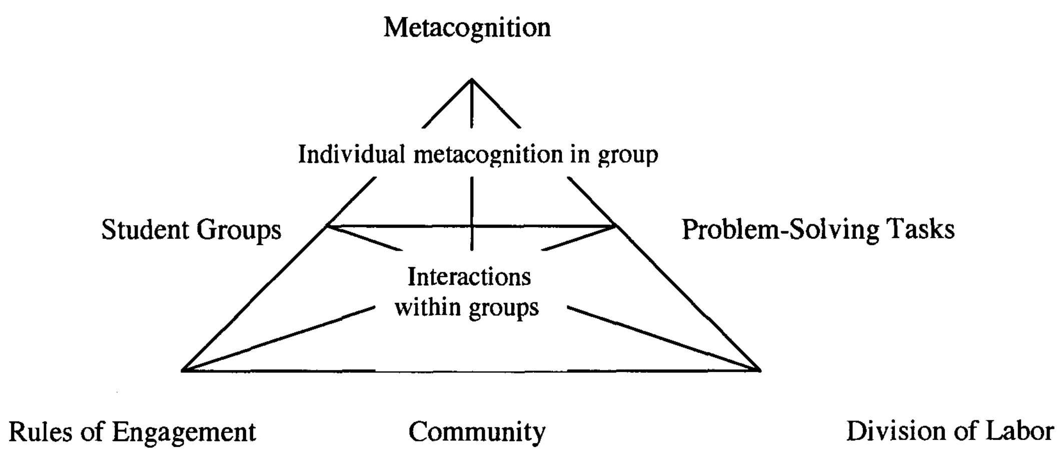

Figure 2.2. Activity System Modeled for the Study

The subject acts upon the object of the system, which in turn is transformed through activity. The relationship is dialectical because as activity proceeds, both the subject and object are transformed, which in turn may lead to redefinition or exchange of the goals which initiated the system. For the current study, student problem-solving groups were *subjects* of the activity system. As configured through the problem-solving context for the study, student groups were agents within the activity system, since the problems that they were tasked to solve were the focus of their attention (e.g. object of the system). Individuals within the groups were also viewed as agents within the system, in order to attend specifically to how metacognitive knowledge, skills and behaviors manifested within the activity system. Interactions among the group members are the linkage between the object of the system's focus and how the actions and operations are directed toward a purpose or collection of purposes. It is through interaction that new relations and meanings are built, and this is the essence of the dialectic between the subject and object for this study. The products of the system are the transformed understandings that result from collective activity (Hyysalo, 2005), and in the case of this study, these are the collected understandings developed through group problem-solving activity and revealed through interactions among individuals within the subject groups.

The connecting lines in the model represent the various and multiple relations that structure the system, linking the components. According to Engeström (1987), *instruments* are essentially Vygotky's (1962) mediational linkages in a stimulus-response action. In other words, they are *tools* (symbolic, psychological or otherwise) (Luria, 1982; Vygotsky, 1978) or *artifacts* (Cole, 1996; Latour, 1994; Wertsch, 1998), constructed by human action, that "serve as the conductor of human influence on the object of activity" (Vygotsky, 1978, p. 55) thus mediating between the individual and the object of his/her action. *Activity* produces tools and objects (Davydov, 1999). As the activity system develops, artifacts in turn mediate activity. Engeström goes on to describe psychological tools as "instruments for co-operative, communicative and self-conscious shaping and controlling of the procedures for using and making technical tools" (p. 57). Brown's (1987) description of metacognition as a 'toolkit' is consistent with both Vygotsky's and Engeström's conception of instrument. Further, Brown, Collins and Duguid (1989) described conceptual knowledge as a set of tools. Tools share features with metacognition as developed for this study: only through use can they be understood, and through use, the user's view of the world and possibility for action change. Further, through use, it becomes possible to gain an appreciation for the tool's significance in the particular social and cultural context of the activity system. The key here is the importance of instruments or tools as mediational means within the activity system.

This study adopts a view of metacognition as mediational means within the activity system. Metacognitive knowledge, skills and behaviors are brought into the problem-solving context by individuals, and are background out of which learning activity is engaged. Thus, how individuals engage metacognition mediates their actions and interactions within the group context. Activity theory is a particularly relevant framework for considering group interactions in the context of problem-solving activity for this study. As modeled by Engeström (1987), in addition to definitions of community, the rules for engagement and division of labor are also mediational influences on the subject/object dialectic. Interaction between the individuals in the groups as subjects, and the subject and object (the problems to be solved) form other dialectical pairings within the activity system of the current study.

In a way, social interaction also structures the system, since social interaction dictates activity (Wertsch, 1979). In turn, social interaction dictates the means to mediate activity. Therefore, within an activity system, goals that are established, means to achieve them and intended outcomes are always negotiable and negotiated as the components of the activity system take shape. Activity can be oriented toward a material object (object-oriented) or social interaction (subject-oriented) and these transform each other through activity (Bedny & Harris, 2005), representing a dialectic pairing. Roth and Lee (2007) draw attention to several dialectics that the activity system is uniquely suited to addressing: individual/collective; body/mind; subject/object; agency/structure; material/ideal. Modeling the dialectics through the activity system as configured for the current study offers a window into how aspects of individual metacognition and learning behavior become consequential to the group during problem-solving.

The base of the triangle demonstrates aspects of human activity in rules of engagement (including collective traditions, rituals and rules for social engagement), communities (of individuals, linked in mutual activity) and division of labor (among the individuals in the system). Each component suggests a space where learning and collective behavior manifests during group activity, as mediated within the system. Social engagement or interactions presuppose purposeful collective activity, which are guided by rules within the system. Communities are places where individuals belong, sometimes out of shared interest, but perhaps also out of the need for sociality (Massumi, 2002; Nancy, 1991). According to Radford (2006), the community of the classroom is where students learn to 'be-with-others,' which includes learning to live in the classroom community, interacting with others and being open to both others' voices and consciousness.

A classroom community or group within the classroom, such as the biology classroom for the current study, may develop in the direction of a community of practice (Lave & Wenger, 1991) where mutual engagement, joint enterprise and a shared repertoire of action encourage cohesion. The shared repertoire also includes discourses and tools in the mediational sense

(Vygotsky, 1978) along with a common language (Wenger, 1998) and this is offered in the current study through problem-solving tasks. And, within the community, individuals construct their own identities through a continuously renewed set of relations in a socialization process. The community is situationally dynamic (Lave & Wenger, 1991), where individuals participate in community activities, engaging with one another to learn collaboratively. Members of the community also take some responsibility for supporting the learning of other members (Clarke, Erickson, Collins & Phelan, 2005). Thus, the community is a key mediating influence for learning activity.

The notion of learning community comes predominantly from Vygotsky's social theory (1978), where learning is about incorporating the self into the body politic. A description-oriented theory of 'situated learning' (Lave & Wenger, 1991) is concerned with how learners engage, apply and extend already-established knowledge (Davis, 2004) both individually and collectively. Thus, learning can be viewed as apprenticing into common knowledge alongside others who are more experienced and expert. Learners become legitimate participants in the community of practice through their participation in it. In a way, this reflects dialectic engagement within an activity system, where learning involves interaction with more-experienced others and the situated knowledge of the collective is shared. Interaction is dynamic and participation is scaffolded so that learning involves developing new knowledge, but this is also how a social identity within the community develops (Wenger, 2000). Knowledge also includes self-knowledge of the community and the work it does, and reflects back onto itself the values held by the community. Ideally, a student learning group is a community in this sense. Through the activity system modeled in this study, it is possible to consider how individual metacognition mediates interaction in the community during group problem-solving activity.

Classroom organization is also a mediational influence on group learning activity. Classroom learning and schools in general have mostly been organized according to an acquisition metaphor of learning, where the mind-as-container collects knowledge. But, within a school setting, the goals and motivations of individuals may or may not coincide (e.g. students and teachers experience the activity of schooling quite differently) (Repkin, 2003). Thus, individual motivation is a mediational influence in participation in a classroom community.

Cultural values may play an important role in the community of the school and what it is intending to do, mediating what is possible in terms of student interactions. And, individuals acting or working in collaborative activity can have multiple motives in relation to the object of activity (Nardi, 2005), more along the lines of a participation metaphor where knowledge is developed through participation in cultural practices and shared learning activities (Paavola, Lipponen & Hakkareinen, 2004; Sfard, 1998). Providing such a context for participation in cultural practices and shared learning activities, thus, is part of the project of this research, in order to explore aspects of the activity system as they pertain to metacognition as mediational means during group problem-solving activity.

Other aspects of the learning environment are also mediational means for group learning activity. Martin (2004) identified several factors of the learning environment as non-cognitive. Such things as home language, discourse patterns, nature of participation structures, students' relationships to the dominant culture and motivational states are clearly influential on group learning processes. To facilitate collaboration and organizing for collaborative work, Dumont and Moss (1996) identified 'reciprocal friendship' as a significant factor. This suggests that group constitution is important for social interactions that enable learning. Costa (1995) identified several different kinds of students, such as 'potential scientists,' 'other smart kids,' 'I-don't-know students' and 'the outsiders,' any of whom could be present in a given student group or classroom. These several sorts of mediational influences matter within the activity system.

Within an activity system, human need becomes the motive to find the object (Leont'ev, 1979), which Miettenen (2005) has extended to 'artifact-mediated desire for recognition.' Miettenen uses this concept to analyze and explain co-formation of individual capabilities, motives and object construction. This is an extension of Hegel's (1977) concept of 'desire for recognition' as a primary source for personal identity. Further, Mead (1934) suggests that division of labor is the source of individuality. This comes through recognition within the system of the uniqueness of the individual and the contributions that he or she can make to the community. Because there are different kinds of students in a classroom or within a learning group, as well as different kinds of responsibilities and tasks, labor is divided. The activity system model includes 'Division of Labor' as one of the system components. In the current study, this aspect of the system represents a place to explore how individual metacognition has bearing on roles that are adopted within a learning group as subject of the activity system. Objects of the activity system act as sense-makers for subjects (Kaptilinen, 2005).

Research Focus

Applying an activity theory frame for exploring how metacognitive knowledge, skills and behaviors are brought into a group problem-solving context is a new research direction. Experiences during the research sought to provoke students' metacognition. And then, through engaging students in group problem-solving activity, individuals were prompted to reveal how they use their own metacognitive knowledge, skills and behaviors. The research was not concerned with studying how individuals develop content knowledge of marine biology, even though biology learning activity provided a context for the research. Sub-questions for the study were: (1) What was the nature of the social context and interactions in which active group learning was manifest? (2) In what ways were metacognitive knowledge, skills and behaviors deployed within group settings to empower learners' knowledge construction in problem-solving contexts? (3) How did social interactions in group-learning contexts serve to shape, engage and promote metacognition? (4) What were individual group members' perceptions of their roles and metacognitive knowledge, skills and behaviors within the learning group?

By studying interactions between individuals in a group setting, there is opportunity to observe learning activity, and thus, interactions offer a place to direct research focus on learning processes. This can be seen in the nature of the discussions, where individuals engage with the ideas of others, thus providing a key observational opportunity within the context or environment of a research study. Interactions between the individual and those around him or her, through such things as modeled behavior or social supports, enhance development of self-regulated learning (Zimmerman, 2002). It is the aim of this study to use the activity theory framework to view the interactions within the groups that are the subject of the activity system.

What is missing in the literature is how metacognitive knowledge, skills and behaviors are used as part of a learner's toolkit during collective learning activity as conceptualized as an activity system. Viewing metacognitive knowledge, skills and behaviors as a toolkit supposes a context in which the tools operate. In this study, the context is problem-solving activity where student groups work collaboratively to solve problems. The group is viewed through an activity theoretical framework that draws attention to particular aspects of the system. The aspects exist in dialectical relationship and are always nested within social and cultural contexts (Cole, 1985, 1996). For the current study, focusing on the social context of the student groups enables a view into the learning activities in classroom and out-of-school environments, settings which themselves are nested within other no less relevant social and cultural contexts, offering opportunity to explore how individual metacognitive knowledge, skills and behaviors manifest within the system. Data collection methods and procedures are detailed in the next chapter.

CHAPTER THREE
METHODS

This research is concerned with how individuals bring metacognitive knowledge, skills and behaviors into group problem-solving activity. The primary research question addressed in this study is, *How does metacognition manifest within the social context of group settings as students engage in problem-solving activities?* Methodological perspectives in phenomenology, socioconstructivism and interpretivism frame the research design. Out of these perspectives, an instrumental case was constructed and case study methods selected in order to provoke and characterize the phenomenon of metacognition under investigation here, develop a context in which to explore the phenomenon and outline interpretive possibilities for how to make sense of the data corpus. The chapter begins with the research design and is followed by a description of the study context. Data collection methods are detailed next and the chapter concludes with the analytic framework developed for the study.

Research Design

The methodological framework for this study was based in an instrumental case study (Stake, 1995), where phenomenological, socioconstructivist and interpretivist principles framed exploration of how metacognition manifests within the social context of group problem-solving activity. Overlapping elements of the theoretical and methodological frameworks intersected to focus the inquiry in this study. Case study (Merriam, 1998; Stake, 1995; Yin, 2003) offers a range of methods for exploring the phenomenon, and these were used to track and capture how individual metacognitive knowledge, skills and behaviors were engaged through problem-solving activity, which was viewed from socioconstructivist perspectives on learning in science. Further, analytic and interpretivist (Schwandt, 2003) methods complemented the study design and data gathering methods in order to explore the phenomenon and subsequently, to make sense of the data gathered.

The case for this study was a classroom of biology students studying intertidal marine biology as part of their regular curricular activity in Biology 11. The case was defined so as to delimit aspects of the activity system within it and enable exploration of the phenomenon of interest. Within the case for this study, a problem-solving context was developed and provided as a place where individual metacognition and learning behaviors were called into action. The instrumental case thus encompassed the activity system for the study, and offered a research location and context to study metacognition during group problem-solving activity. The context also enabled interactions among the individuals, and here is where the case offered an ideal site for investigation of the phenomenon of interest for the current study. The case was thus instrumental because it served the purposes of the study.

In this study, I used phenomenological approaches (van Manen, 2002; Smith, 1991) to characterize and explore how the phenomenon of metacognition manifested within the case of this classroom as students were engaged in group problem-solving activity. The model of metacognition developed for this study in Chapter One included knowledge, control, self-efficacy and awareness. This theoretical perspective was drawn on to specify the scope of my primary research question, and to guide exploration of how metacognition was deployed within group settings and how social interactions shaped metacognitive knowledge, skills and behaviors. This model helped to delimit the phenomenon, as well as suggest where to direct the 'phenomenological gaze' (vanManen, 2002). Through the model, metacognitive knowledge, skills and behaviors became key points for the focus of research, drawing attention to specific kinds of learner behaviors and dispositions.

In order to explore the phenomenon of metacognition, I was also guided by socioconstructivist perspectives in science learning. While setting up the problem-solving context for the study, I considered that metacognition reflects a student's personal approach to learning. For the study, I wanted students to access their prior knowledge about biology concepts and science more generally, but also their own understandings of themselves as learners within a science learning context. So, through the problem set developed for this study, I deliberately linked students' participation in the research to their background understandings of biology and themselves as learners, as developed prior to and during regular classroom activity. The problem set provided opportunities to connect individual understandings and experiences, and it operated in a group context, and hence, provided a place for individuals to engage metacognitive knowledge, skills and behaviors.

The goal of any study is to develop an understanding of the "meaning-perspectives" of the participating students, since these are intrinsic to their own learning processes. This, again, is interpretive. As Smith (1991) observes, "good interpretation shows the connection between experience and expression" (p. 191). For this research, the observer was the interpreter, so the lenses brought to the research by the observer are critical. This means that my own epistemological stances on metacognition and learning are relevant to the entire process. My job as an interpretive analyst, while I bring my own subjectivities, was to look for layers of universality and particularity (Erickson, 1986) in the patterns of behavior that describe, elaborate and direct problem-solving activity in this research context, in particular, metacognitive knowledge, skills and behaviors as mediational means within the activity system of the problem-solving system of student groups working together. As gathered and interpreted through the study, the students' perspectives were elaborated through the interpretivist framework.

Study Context

The study context for this research developed out of the notion that regular classroom activity is a place to explore the phenomenon of metacognition. Thus, there were three facets to the context for this study: the classroom where the research was conducted; the tasks that afforded opportunities for metacognitive experiences for the students; and, the participants themselves.

Classroom Context

The case for this study, with sub-cases of student groups, was one classroom of students taking Biology 11, taught by 'Mr. Brennan,' an experienced high school biology teacher, in a private K-12, co-educational school in the Vancouver area of British Columbia during the 2005-2006 school year. This classroom was chosen as a site for the research for four reasons: Firstly, this classroom provided an ideal context in which to engage student groups in problem-solving activity in which the phenomenon of metacognition could be explored. Secondly, Mr. Brennan used a field trip experience as a regular part of classroom activity. In this case, it was sequenced at the end of the unit on intertidal marine biology as a unit review activity. This is important because the integrated context of the field trip and classroom activity was of interest in this research as a place to study metacognition, as suggested by Anderson, Thomas and Ellenbogen

(2003). Thirdly, the school has had a research relationship with members of my Department, and was thus accessible for the purposes of conducting the research. Building from that relationship, Mr. Brennan offered his class as a study context, and was keenly interested in the outcomes of the study. Finally, the general school culture placed a strong value on academic excellence. I saw this as background to promoting student engagement with the process of learning more broadly, and thus, student willingness and openness to participate in the study.

Parallel to outcomes from Anderson, Nashon and Thomas (2008), I hoped that the students would benefit from their participation in the study by becoming more metacognitive, and I expected that students in a college-preparatory school would be interested in such a benefit. While the goal of this study was not specifically to help students become more metacognitive, or assess that they were in fact becoming more metacognitive through their participation in the study, this outcome was anticipated. As an experienced biology teacher, Mr. Brennan was peripherally aware of research literature on metacognition, although gave no specific attention to the development of metacognitive knowledge, skills or behaviors among his students. However, he was interested in the potential of exploring this possibility and shared my belief that being more metacognitive makes for powerful learning. Thus, he was willing to use class time to have his students participate in the study. Mr. Brennan expressed the expectation to his students that they would apply themselves to the research activities, and encouraged the students to do so when introducing the research team[1] to the class.

The classroom itself was long and narrow with fixed benches oriented longitudinally in rows toward the 'front' of the room that includes a stationary demonstration table, chalkboards and projection screen behind the table, plus two classroom doors. There were cupboards and specimen display cabinets on either side of the front of the room, plus a storage area at the east end of the classroom. The students sat on stools oriented in pairs along the fixed benches. Behind the students was a wall of windows that faces north. Students normally sat and worked together

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[1] The research team was comprised of five members of the *Metacognition and Reflective Inquiry* [MRI] project, which included two faculty members and three research assistants, me among them. The current study was a subset of the larger, 3-year, cross-cultural, international inquiry into how metacognition manifests across different science learning contexts.

in pairs at their desks occasionally doubled as laboratory stations. Some of the students had met each other from previously having taken other courses together, and other students met in this classroom by virtue of sitting next to each other.

Mr. Brennan taught one section of Grade 11 Biology each school year. The school timetable operated on a rotating block schedule for the year, so the biology class met three times in a 7-day rotation, with one of these blocks being a 'double block' every other rotation. The double-block lasted approximately 2.5 hours, while the single blocks lasted just under one hour. Students generally took a course load of seven courses, most of which are college preparatory courses at Royal Collegiate Academy.

The strong academic focus at Royal Collegiate Academy was an important part of the community in which the study was conducted. The school advertised itself as a college-preparatory school, with strong academic standards, a behavioral ethics code and strict dress code, including school uniforms. The Headmaster's Message on the school's website stated:

> Our programmes emphasize the essential skills that students need to succeed in university and later in life—solid study habits, effective communication, mastery of technology, and personal organization. In combination with our rigorous curriculum, these essential skills build a foundation of self-confidence and achievement. (Royal Collegiate Academy, n.d.a)

At this point it is important to note that student participation in the activities of the research were not graded like other assignments in this classroom. This was a potentially significant aspect of the study context. Mr. Brennan, felt that student participation would be better encouraged through a 'participation mark' rather than an assigned percentage or letter grade during the research activities. It was important that the students not perceive a risk to their course mark for their participation in the study. However, the possibility did exist that students would not participate in the study activities or be willing to extend 'metacognitive effort' (Gunstone, 1994) because the external motivator of a mark was missing. It was also possible that they would resent the extension of additional metacognitive effort if it did not in fact serve to improve their biology marks. The issue of marks as described here represented a potential limitation to the study design because some students engaged with learning activity or assignments because they generated marks, consistent with a performance orientation to learning activity (Turner & Patrick, 2004). My feeling was that there is no ideal way to handle this, and my ethical responsibility was to honor Mr. Brennan's (and his students') participation and efforts in support of the research.

Tasks

For the purposes of this study, tasks designed to engage learning activity fell into three categories: learning activity in the classroom, learning activity during the field trip, and problem-solving activity as follow-up to the field trip as established for the purposes of the research.

Learning activity in Mr. Brennan's classroom was structured around textbook readings and lectures in a fairly traditional didactic approach (Boyer, 1983; Goodlad, 1983; Lortie, 1975). Learner activity in this classroom generally involved reading the assigned text, recording notes during lectures and using these notes to study for subsequent tests. Tests occurred at the end of major units in the course. Laboratory activities were infrequent. Mr. Brennan's presentation style involved humor, story-telling and abundant information. He was well-liked and respected by his students for his breadth of knowledge and ability to communicate. During classroom learning activities, students may have used their metacognitive knowledge, skills and behaviors as they read the text, took notes during lectures, or while they reviewed for exams or studied together. Occasions for studying together were often presented at the end of class periods and before unit exams.

The intertidal marine biology unit that was the context for the research was the last unit in the biology curriculum for the school year, as chosen by Mr. Brennan. By the time of the research period, all lectures and lab activities had been completed. Throughout the unit, Mr. Brennan actively prepared his students for the summative activity for this unit, a field trip visit to the Vancouver Aquarium. The field trip has been a regular part of his biology course for many years, and it usually takes place in early May. Mr. Brennan encouraged the students to consider the field trip as an excellent chance to review material from the curricular unit on intertidal marine biology. The students eagerly anticipated the hands-on experiences during the visit as well as the chance to review and consolidate their marine biology understandings while at the Aquarium.

During their field trip to the Vancouver Aquarium's (2007a) *Intertidal Marine Biology WetLab Program*, the students engaged in a series of hands-on experiences linked quite closely to their classroom learning about marine biology. The Vancouver Aquarium is a non-profit organization dedicated, "to conservation of aquatic life through display, interpretation, education, research, and direct action" (Vancouver Aquarium, 2007b). The Aquarium offers hands-on workshops specifically aligned with the invertebrate biology sections of the British Columbia Provincial Biology 11 curriculum (see Appendix B for these learning objectives), and this curricular connection is often the justification teachers use to take students on field trips (Anderson & Zhang, 2003). The WetLab has a series of saltwater aquaria, lab stations and colorful posters and models around the room that students explored together as part of the field trip experience. Education staff guided student groups through five demonstration stations that included: echinoderms, mollusks, arthropods, cnidarians and intertidal ecology. Since all of the marine biology and ecology curriculum objectives are given attention during the WetLab, it is thus assumed that field trips to this location offer students opportunities for rich learning experiences.

The Aquarium, like many other out-of-school settings, provided a rich context for learning and opportunity to explore and experience 'real-life' applications of curricular concepts. It is in such contexts that students are highly engaged, motivated and interested in the experience (Csikszentmihalyi & Hermanson, 1995), and these factors are prerequisite to students engaging their own thinking and problem-solving behaviors (Greeno & Riley, 1987). Building direct connections between regular classroom learning experiences and subsequent follow-up activities created a potentially rich learning environment where students' prior knowledge, and earlier biology experiences can be linked with the hands-on experiences from the field trip. In other words, this field trip potentially offered 'metacognitive experiences' (Flavell, 1979) with rich opportunities to connect learning from both classroom and out-of-school domains. These types of connections were consistent with the socioconstructivist learning framework for this study and its intention that the study context offer opportunities for students to be metacognitive. The field trip and its collection of experiences could also provide a 'shared referential anchoring' (Resnick, 1991) where metacognition can be engaged within the potentially rich social setting of the field trip. And, because Mr. Brennan took his students to the Aquarium as a unit wrap-up activity, the field trip offered the potential to explore how students use metacognition in a social context.

In this study, students spent about two hours in the WetLab at the Vancouver Aquarium during their field trip visit, in groups of four to six students, with one volunteer docent leading each group. The groups spent about 20 minutes at each station and then moved to other WetLab demonstration stations. At each station, the docent described various sample organisms, told stories about them, asked the students questions, and presented a general overview of the intertidal zone from which the organisms derive. The 'hands-on' experience enabled students to ask questions, handle the live organisms and follow along through the various stations with an information-gathering worksheet developed by the Aquarium. Students also had free-choice time at the Aquarium at the conclusion of the WetLab program, and were cued to attend to other intertidal zone exhibits, since these also comprised background to the problem-solving activities that were used in the next phase of the study.

As described above, some features of the Aquarium WetLab established an exploratory environment for the students with potential to foster rich learning experiences, motivating my study of metacognition in this context. However, as the study unfolded, other features of the WetLab appeared to actually interfere with students' active learning, and with data collection. For example, the WetLab program was highly structured and not amenable to adjustments or different kinds of explorations, other than those scripted by the education staff at the Aquarium. Unfortunately, most of these seemed to reflect the lowest levels of Bloom's taxonomy, those of knowledge and comprehension (Bloom, 1976). Thus, it appeared that the kinds of experiences at the WetLab were not particularly engaging for study participants as metacognitive experiences. Further, the WetLab was small, crowded and noisy, which made it difficult to film student interactions or make audio-recordings of conversations. This led me to consider what other kinds of experiences could be created that could more sufficiently engage metacognitive knowledge, skills and behaviors during group problem-solving in a context that would afford better opportunities for data collection.

Building from socioconstructivist perspectives on science learning and guidance from literature on the nature of problems to foster active learning in science, the problem-solving activities for this study drew specifically on students' experiences from the field trip to the Aquarium, prior knowledge of biology and other personal knowledge. The intention of the problem set was to engage groups of learners in meaningful learning activity that provoked metacognitive knowledge, skills and behaviors as they worked to integrate their thinking about their biology learning experiences. The problems gave the students further opportunity to think about their experiences at the field trip and their prior knowledge and understandings pertaining to marine biology, extending the time and involvement with this information, which was suggested by Perry et al. (2004) as valuable in stimulating self-regulated learning. Thus, the activities became a focal point for group problem-solving activity, wherein the research questions could be explored.

The problem set as designed for this study included four questions, as shown in Appendix C. The questions focused on the biology and ecology of an imaginary shoreline ecosystem (see Appendix D), and invited students to use their own (and each others') personal knowledge to come to collective agreement on their answers to the questions. Additionally, the groups were asked to provide justifications for their answers. The first two questions involved a card-sorting task, where student groups were given a set of ten 'organism cards' that were color photographs of actual intertidal organisms from the BC coast that the students may have seen at the Aquarium. The first task was to sort these organisms into one of four (also imaginary) ecological zones, based on where they thought the organism would predominantly exist. The second task was to consider abiotic factors and make an argument for which organism would be most successful in each zone. The zones were described on the problem set prior to the questions. And, the organisms may or may not have been actual residents of any of the zones. These dimensions of uncertainty meant the problems had no obvious correct answers, and thus, provided opportunity for the group members to share personal knowledge, justify their own opinions and even argue, as they worked to a common response. The open-ended nature of the problems and the process of negotiating agreement were intended to provoke metacognitive engagement during the problem-solving activities.

The remaining two questions on the problem set involved a sudden change to the beach ecosystem: an overgrowth of kelp just offshore. The third question proposed a consequence of this overgrowth: an increase in the number of otters. The students were asked to consider the impact of the increased otter population on the ecosystem. The fourth question was posed as an ecosystem management challenge for Environment Canada. The groups were asked to offer a rationale for choosing to remove (or not remove) the kelp overgrowth. Questions three and four were also open-ended problems, with no obvious correct answers, that called on students' prior knowledge and experiences. The problems were intended to provoke metacognitive engagement among the group's members, and offered a context wherein conversations and interactions among the students in their groups could be observed and recorded.

The student groups worked on the problem set during one class period several days after returning from the field trip visit to the Aquarium. They had the entire period to work on the problem set. When tasked with the problem set questions, the students were asked to particularly consider their own thinking processes while engaging with the problems and their group members, and how these thinking processes contributed to group functioning. The thinking process, as well as the content of the problems, were aspects of the object of the activity system, which allowed further exploration of the object's relationship to the manifestation of metacognition within the wider context of group learning activity.

Participants

Mr. Brennan's class included 15 girls and 7 boys (aged 15-17 years) who took this Grade 11 elective science course to meet their high school graduation requirement. As described earlier, the classroom within which these students were learning represented a bounded instrumental case (Merriam, 1998; Stake, 1995; Yin, 2003). Within this case, the activity system (Engeström, 1987) was specified by individuals, operating as agents within the context of their social groupings on problem-solving activity as the object of their attention. Students' participation in the study, and thus inclusion in the case, was defined by their enrolment in this particular course, and these students were selected for participation in this study because their biology classroom was an excellent context in which to pursue the research questions for this study.

In constituting groups for the problem-solving activities, seat-pairs joined other seat-pairs to make groups of four students. I felt it was important that these groupings be voluntary, so that students would feel comfortable with their group members during the study. Mr. Brennan agreed with this approach. The five groupings were labeled A, B, C, D and E. Table 2 shows the group configurations, which were consistent for the remainder of the study.

Table 2	Focus Groups and Students				
	Group A	Group B	Group C	Group D	Group E(#)
	Paula	Mark	Ann	Shelley	Matt
	Sue	Evan(*)	Amber(*)	Caz	Jayde
	Chris (*)	Adie	Nevin	Glynnis	Adam
	Mary	Mel(*)	Earl	Abby(*)	Kurt

(*) denotes students who participated in an individual interview later in the study

(#) members of this group were not available for either focus group or individual interviews

Data Collection Methods

The research questions for this study explored aspects of metacognition and learning behavior and how they are significant within a group problem-solving context. A reminder of the sub-questions for this exploration is appropriate here. In collecting data for a study of the case examined here, I sought to consider: 1) What was the nature of the social context and interactions in which active group learning was manifested? 2) In what ways were metacognitive skills deployed within the group to empower learners' knowledge construction in problem-solving contexts? 3) How did social interactions in the group-learning contexts serve to shape, engage and promote metacognitive thinking? 4) What were individual group members' perceptions of their roles and metacognitive skills within the learning group?

Through the use of multiple methods, I sought to explore various facets of the manifestation of metacognition through converging evidence from various data sources. Data gathering methods and procedures for the study sought to capture metacognitive knowledge, skills and behaviors in action, as well as interactions among the students during their activity. Data gathering for this study took place over a two-month period during April and May 2006. Each of the methods was chosen for its suitability to gather data that was pertinent to one or more of the research questions for the study, as shown in Table 3.

Table 3 Research Questions and Data Collection Methods

	Main Res Q	Sub-Q 1	Sub-Q 2	Sub-Q 3	Sub-Q 4
Observations	X	X	X	X	
SEMLI-S	X				X
ID Critical Incidents	X	X	X	X	
Focus Group Interviews	X	X	X	X	X
Individual Interviews	X	X	X	X	X

The following section describes each of the data collection methods adopted in this study, along with the procedures used and justification for their selection. Each of the five data collection methods is addressed in turn: observations, *SEMLI-S*, critical incident identification, focus group interviews and individual interviews.

Observations

Observations of student interactions and the general classroom context were conducted throughout the study in order to gain greater understanding of the case (Stake, 1995). Observations are important for gaining perspective on human activity within a naturalistic setting (Lincoln & Guba, 1985), and I used them to gain perspective of the social context and to inform my understanding of how individuals deployed their metacognitive knowledge, skills and behaviors during group problem-solving activity. Using naturalistic observation as a study method required attention to both individual and group levels of analysis. Observations were recorded as field notes, research recollections and memos. All problem-solving activities conducted in the classroom were also video-recorded.

Preliminary observations began during the research team's first visit to the classroom. Observations were also made while the students were completing the *SEMLI-S* questionnaire; during the field trip; during the problem-solving activities, and follow-up video review activity; and, during focus group interviews and individual interviews. There was an additional classroom visit about two weeks after all of the research phases were complete. This visit included a short summary of the research activities and some preliminary results reporting to the students and Mr.

Brennan. During the brief presentation, the researcher who made the visit thanked the students and Mr. Brennan for their participation in the research activities and encouraged the students to continue to think about themselves as learners as they moved through their high school programs and on to university and other learning experiences. This active consideration of the self as learner was encouraged as the means to continue the process of personal development that would make them powerful learners who are in control of their own learning processes.

Data collected during observations of individuals and groups influenced how the study unfolded. For example, questions were developed for interviews to explore interactions that were observed during the study. Further, observations and associated field notes gathered during each encounter with the students were key to subsequent analysis (Gay & Airasian, 2003; Miles & Huberman, 1994; Palys, 1997). These records and memos served as backdrop for interpretations, review and triangulation, as an audit trail of claims and warrants was developed through the phases of the study. These are important aspects of dependability in qualitative research (Marshall & Rossman, 1998). As the different phases of the study proceeded, I tried to be "unusually thorough and reflective in noticing and describing everyday events in the field setting" (Erickson, 1986, p. 121) and recorded these as memos in a research journal. The memos were used further in a search for universality and particularity (Erickson, 1986) within the bounded case of the activity system for this study.

SEMLI-S

During this study, observations of student activity and interactions with other students were guided by an understanding of the metacognitive skills and behaviors individuals brought to group problem-solving activity, as revealed by their responses to the *SEMLI-S* (Thomas, et al., 2007). The *SEMLI-S* was administered during the research team's second visit to Mr. Brennan's classroom. Completing the questionnaire took about 20 minutes, after which dimensional profiles for five aspects of metacognition and learning behavior were generated for each student. For this study, *SEMLI-S* profiles provided an entry point for understanding the types of metacognitive skills and behaviors individuals usually used during learning activity in science, and thus offered a guide for what to watch for as students engaged in learning activity. I used the profiles as background information as I watched for particular kinds of learner behavior during the series of activities that provided the context for this research.

The *SEMLI-S* (Thomas, et al., 2007) was chosen for use in this setting because of its ability to simply 'signpost' (Anderson & Nashon, 2007) four key aspects of science learning behavior, including metacognitive awareness, control and other behaviors, self-efficacy and constructivist connectivity. Recall that Engeström's (1987) model of the activity system as adapted for use in this study included 'Metacognition' positioned at the apex of the triangle. Individual metacognition and learning behaviors were signposted by the *SEMLI-S*, and thus, directed attention during observations to the kinds of behaviors that were of interest to the purposes of this research.

Data from the *SEMLI-S* included a numeric score for each dimension for each student. The profiles were calculated as an aggregate average score (range: 1 to 5, low to high) on the cluster of questionnaire items corresponding to each of the dimensions. As a self-reported instrument, the score on each of the dimensions represented an individualized perspective on how the learner approached a learning situation.

Interpreting this numerical score offered a background from which to observe students in their learning groups. By scanning the range of scores among the individuals in the group, the particular scores for individuals, and looking for any trends overall, the *SEMLI-S* data became 'signposts' for observing individual learning behavior much as Anderson and Nashon (2007) found when they used their *Metacognition Baseline Questionnaire*. Part of the current study also used the dimensions as signposts for learning and group behavior. Because the scores represented self-reported perspectives on learning behavior, the aggregate scores offered a place where and how the individual engaged this aspect of learning behavior or metacognition.

Identification of Critical Incidents

Video data for each group was recorded during the problem-solving phase of the study. During the class period immediately following the problem-solving activities, each group was asked to watch the video of their group and collectively identify three occasions, or critical incidents, where they felt they were working together as a highly effective learning group. The students were cued to watch for instances where they were: learning new things; prompted to rethink individual beliefs or understandings; intensely wrestling with ideas or concepts; or, doing things that helped the learning process. Each group identified timer references to the incidents they chose and recorded reasons for selecting these incidents on an accompanying worksheet. The groups were video and audio-recorded as they conducted the video review activity.

This video review activity was constructed for this study for two complementary reasons. First, it provided a further metacognitive experience (Flavell, 1979, 1987), and was explicitly intended to focus individuals' attention on the group as a learning unit, while also drawing attention to individual learning behaviors. Second, it offered a further window into the deployment of individual metacognition and how it was shaped, engaged or promoted through social interactions. This added another layer to the study's data gathering procedures since these episodes were also used to stimulate subsequent discussion during focus group interviews, and offer further opportunity to reflect on learning behaviors within the group.

Focus Group Interviews

Focus group interviews (Erickson, 1986; Fontana & Frey, 2000) were conducted in this study to engage participating students from the four case groups in discussions about their experiences at the Aquarium, the problem-solving activities, and the video review activity as these pertained to their group problem-solving activity. These discussions were used to elicit perspectives from study participants as to their own metacognitive knowledge, skills and behaviors, and further, provided opportunity for the researchers and participants to engage in discussion about events and interpretations from the earlier observation and problem-solving phases of the study (Anderson, 1990). Interviews were used in this case study as a "road to multiple realities" (Stake, 1995, p. 64).

Focus group interviews allowed the researcher to seek clarification, probe more deeply into issues that had been raised, or share interpretations so that the participants could corroborate, elaborate or correct the researcher's interpretations. A key portion of the focus group interviews for this study was a discussion of the video of critical incidents that each group had identified as significant in terms of their working together as a learning group. Discussions around the episodes (both during their identification and subsequently, during the focus group) were also viewed as metacognitive experiences and opportunities for deeper reflection by the students about their own thinking and learning processes within the group context. During the focus group discussions, the social context, the nature of interactions and how these were metacognitive experiences were explored further.

Focus group interviews were conducted with the four case groups of students over the course of two biology class periods. Each group of students met in a private room down the hall from the classroom, where video and audio equipment was arranged to record the conversations. There were two research team members present during each focus group interview, and two teams of researchers conducted interviews simultaneously (in different rooms). Interview questions for the focus groups followed a semi-structured format (see Appendix E) in order to "produce rich data that are cumulative and elaborative" (Fontana & Frey, 2000, p. 652). Appendix E also specifically links research sub-questions to focus group interview questions. Each focus group lasted for approximately 45 minutes.

Focus groups were used to interrogate group engagement with a shared experience (Fontana & Frey, 2000), in this case, a field trip away from the classroom and follow-up collective group activity. Because the focus group interviews happened late in the study, questions probed thinking and reasoning as evidenced from observations, group problem-solving records (including problem worksheets) and video records from the problem set and video review activity. The focus group also provided further opportunity to observe group interactions, in this case, relations among group members as agents within the activity system, as well as metacognition and learning behaviors as mediational means within the activity system. So, through watching the videos of their groups 'in action,' collectively identifying episodes, then being interviewed with these episodes as focal points, these several layers deepened and broadened the possibility for students to share how they deployed their metacognitive knowledge, skills and behaviors, and provided rich data for the current study and its research focus on metacognition and group problem-solving activity.

Individual Interviews

Individual interviews were conducted as the final data collection activity in this study, and after focus group interviews were complete. These interviews complemented the focus group interviews because they provided opportunities to probe more deeply into the individual's understanding of his or her metacognitive knowledge, skills and behaviors and how these informed his or her activity in a group context. Individual interviews were conducted with selected students who had indicated willingness to be interviewed individually. Follow-up individual interviews were sought with students who, in the view of the researcher, had something to offer in terms of personal or interesting contributions to understanding the role of individual metacognition during group problem-solving. Those students who seemed to make significant contributions to the group discourse (during problem-solving, in focus groups) in terms of their metacognitive knowledge, skills and behaviors were specifically sought out for individual interviews.

Five students made themselves available to be interviewed individually and met with me for about one hour, several days after the focus group interviews. Interviews were conducted before school, at lunchtime or after school, depending on the student's schedule and availability. Various places throughout the school were used for these individual interviews. Protocols for the individual interviews were developed as follow-up to the focus group interviews (Gallagher & Tobin, 1991) and followed a semi-structured format (see Appendix F for the individual interview protocols and linkages to the research questions).

The semi-structured format enabled open conversation that followed emergent lines as interesting issues arose. This also offered an additional interpretive cycle for the research, since issues, themes or ideas raised in the focus group were further interrogated during individual interviews. As a follow-up to focus group interviews, individual interviews provided opportunities for additional insights to be revealed and discussed. Individual ideas or thoughts may be elaborated once the individual is no longer under direct group influence, and thus, may have more to say about the self or others. For some students, the individual interviews provided opportunity to share what could not be said in a group context. Barton and Levstik (1998) suggest that minority students ought to be interviewed individually (and not in groups) so as to minimize the possibility of being overshadowed by students from the dominant culture. These researchers had noted that students of color (particularly Native American students) would drop out of conversations when a European-American student argued a point. While the study reported in this thesis is not about ethnic difference and did not sort students by racial background, Barton and Levstik call us to attend to what is not being (or cannot be) said in a group context or during a focus group interview, and offers an important justification for the addition of individual interviews to the research methods for the current study. Both focus group and individual interviews were transcribed verbatim.

This Data Collection Methods section has provided details and procedures for the data gathering portions of the study This study established a sequence of activities that afforded opportunities to study metacognition. The activities, which included classroom learning, a field trip visit to the Vancouver Aquarium, group problem-solving and critical incident review, provoked metacognition. The study used a combination of data collection methods in order to explore metacognition within these activities and more broadly within the activity system established within the case for the study. Data collection methods include the *SEMLI-S* questionnaire, observations, and two complementary interviews from focus groups and individual interviews. With the rich data sources collected during the study, the next section introduces the analysis process used to manage and make sense of the data.

Analytic Framework

Interpretivist approaches to research (Schwandt, 2003) suppose that as individuals construct meanings as part of their activity, there are many possible interpretations to be made of what has gone on for the individual. In particular, through this study, individuals were provoked to engage their metacognitive knowledge, skills and behaviors while engaged with others in their groups, with common experiences and problem-solving activities. Thus, the study interpreted how these aspects of metacognition were consequential for both the individual and the groups within which they operated. It is not about describing aspects of reality, but rather people's experience of various aspects of reality. This is where Marton's (1981) second order phenomenal perspective "aims at description, analysis and understanding of experiences" (p. 180), and enables interpretation of the process of how a learner uses metacognitive knowledge, skills and behaviors during group learning activity.

In this study, problem-solving activities afforded opportunities for metacognitive experiences, and then, as a follow-up to problem-solving, learners were asked to talk about their thinking and reasoning processes (Baird & Northfield, 1992; Greeno & Riley, 1987; Gunstone, 1992; Mason & Santi, 1994), elaborating individual thinking (Paris & Winograd, 1990). Here is where the second order phenomenal perspective becomes interpretive. Data from the study was used to elucidate and interpret students' individual metacognitive knowledge, skills and behaviors as they engaged in group problem-solving activities that were extensions to regular classroom activity and aligned with the provincial biology curriculum. This interpretive instrumental case study (Gallagher & Tobin, 1991; Merriam, 1998; Stake, 1995, 2000) employed data gathering methods that were chosen for their ability to capture aspects of individual metacognition, as well as group interactions within the activity system.

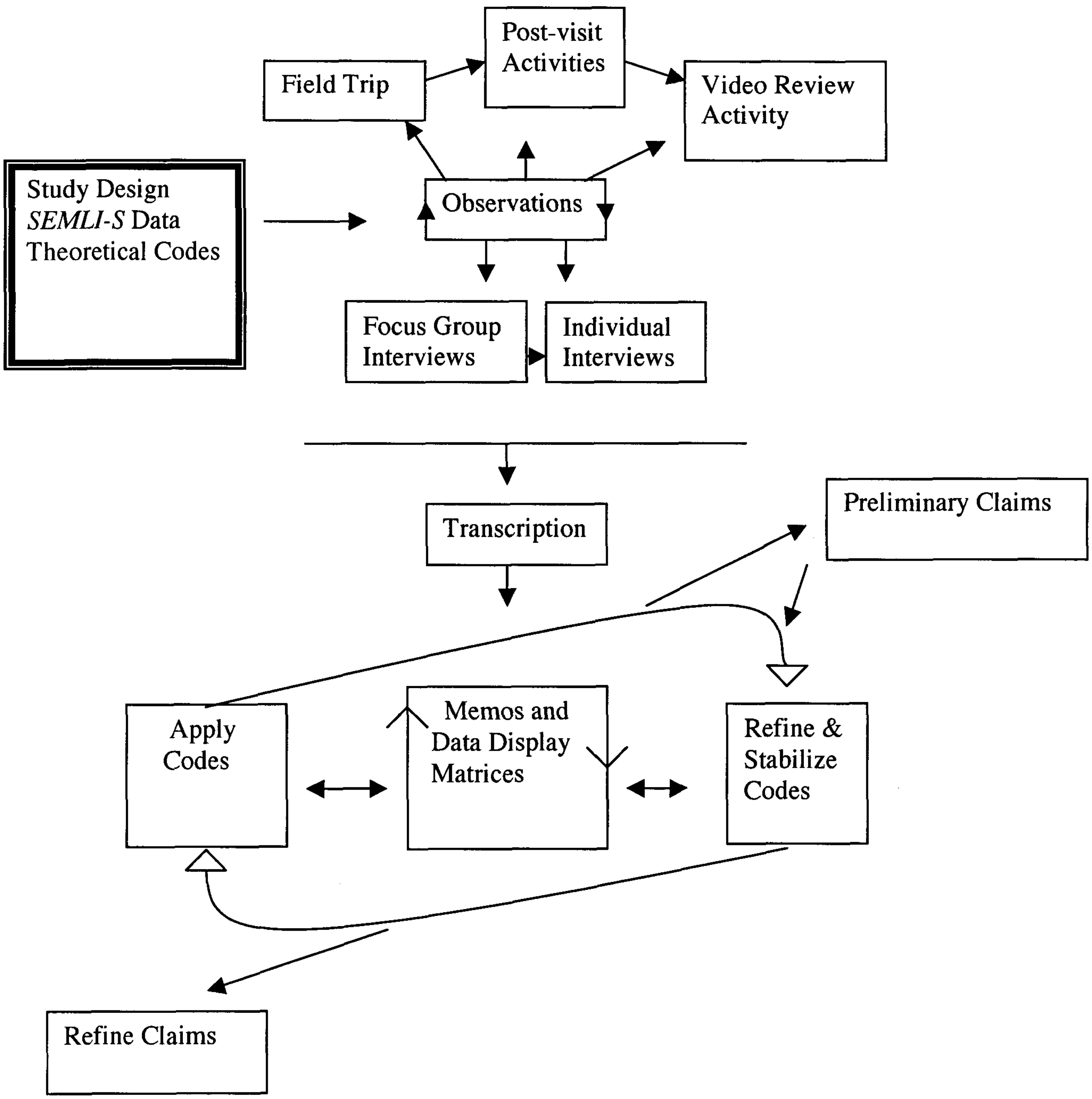
To frame analysis and interpretation in this study, I relied on perspectives from literature in science education (Anderson & Nashon, 2007; Gunstone, 1994; Thomas, Anderson & Nashon, 2007) that view metacognition as a phenomenon that manifests during rich learning experiences. The problem-solving context was framed as an activity system (Engeström, 1987; Hedegaard & Chaiklin, 2006; Julie, 2002; Repkin, 2003), where the phenomenon of metacognition manifested as mediational means within the system. I was mindful of Engeström's (1999) warning that viewing individual actors in an activity system as the unit of analysis limits the perspective of socially-distributed or mediated aspects of the system. Here is where aspects of the system open an individual view out into the group, and collective problem-solving activity is where individual metacognitive knowledge, skills and behaviors are put into use. Moving between the individual and the group as units of analysis opened the view of the system, which made it more expansive and thus inclusive of group processes during collective activity, and offered the critical window into how individual metacognition served to mediate these processes.

The overall approach to how data was analyzed and interpreted in this study developed out of the theoretical frames for the study and the need to make sense of data from multiple sources. For example, observational data complemented focus group and individual interview data. An overview of the data collection and analysis process for this study is presented in Figure 3.1

While represented in a somewhat linear fashion in the diagram, the analysis process began with the study design. Subsequent data collection was influenced by the sense made and interpretations accorded the preceding data, and so, in an iterative manner, each layer of gathering and interpretation informed subsequent gathering and interpretation. Generated data records led to the need for organization, reduction and display. The process continued as *SEMLI-S* data were analyzed and observations of group interactions begun.

Through early scans and reviews of the data, theoretical perspectives for the study guided where to look for understandings and themes emerging through the data. I watched for understandings that were consistent with or outside of the theoretical frameworks for the study.

Figure 3.1: Overview of Study Design and Analysis Process



Analysis also allowed me to test for emerging understandings. Initially, data reduction techniques, such as transcribing interviews and collating and cross-referencing all memos and observations, provided a first pass through the data. I developed a coding scheme that included codes for aspects of the theoretical framework plus emergent codes. Further data analysis procedures included developing data display matrices and charts (Miles & Huberman, 1994), and numerous passes through the data corpus to search for overall themes and patterns in a sort of constant comparative method (Strauss & Corbin, 1998).

In this study, one perspective on how the individual thinks about himself or herself as a learner was gathered through the *SEMLI-S*. Similar to Anderson and Nashon (2007), the current study used the dimensional profiles to interpret learning behaviors as metacognitive. Through the profiles generated by this instrument, additional research cycles observed how individual metacognition and learning behaviors influenced and are influenced by group activity. Observational data from later phases of the study provided complementary perspectives on individual metacognition and learning behaviors, and since the observations were of students in their groups, observations moved between individual and group levels of attention, allowing me to consider how individuals engaged their own metacognitive knowledge, skills and behaviors in the group context.

In addition to the *SEMLI-S* and observational data gathered so as to characterize how metacognition is deployed in the group context, observations and interview data gathered perspectives on group problem-solving activity. The rich data from these multiple methods represent nearly 700 pages of transcript data, paper records and memos. Data reduction techniques were also used as analytic tools, and the process of developing a coding scheme for the study was a primary tool for data reduction, as well as a starting point from which to search for patterns and emergent themes in the data.

The Coding Process

Analytic tools or devices are intended to enable a view of the data that uncover new concepts and interesting relationships. There is a necessary systematicity to the use of these tools, even though the process must be flexible and creative (Strauss & Corbin, 1998). Tools such as asking questions and making comparisons were used throughout this study. As a tool for use in mining the data, a coding scheme was developed. Developing a coding scheme was part of the process of analysis (Miles & Huberman, 1994). Coding was also a means toward data reduction and sorting the data corpus to search for themes for deeper analysis. Codes were used in the study to assign meaning to units or chunks of data, and thereby made interpretive choices about the significance of that piece of information in its given context. The coded chunks were then organized for subsequent retrieval of significant or relevant information. This organization involved developing display matrices, which then allowed the chunks to be clustered around particular research questions or emerging themes.

As described below, the codes were developed through the theoretical framing for the study, as influenced by my research questions, and by my desire to examine specific aspects of metacognition as framed within the activity system (so they were theoretically defined). But, codes were continually tested and refined as data were collected and analyzed.

Code definitions fell into three categories, which are summarized in Table 4 The first two categories reflected the theoretical frames for the study. The five codes in the first category represent the dimensions of learning behavior and metacognition from the *SEMLI-S* (Thomas et al., 2007). The six codes in the second group represent aspects of the activity system, from the adaptations made to Engeström's (1987) model for the current study. The third group of codes reflected study foci, on group metacognition (GM); how students positioned themselves socially (POS); and, the field trip experience (FTE). Each of these broad codes were used to define areas of interest within the context of the study. Codes were used to label parts of the data corpus in the next analysis phase of the thesis research.

Interpreting phrases, incidents, episodes and events from the students' interactions and conversations during their problem-solving activities and the focus group and individual interviews, stretches of data were labelled with relevant codes. All paper records (problem-solving activity worksheets and transcripts from focus groups and individual interviews) were scanned and rescanned to ensure consistent application of codes. This process of rescanning also ensured that the code definitions were internally consistent.

Applying these descriptive codes (Miles & Huberman, 1994) to meaningful units of data required identifying an appropriate unit of analysis and making choices as to the applicability of a particular code to what was interpreted as being present in the data. I followed advice from Aviv (2000) on how to label appropriate data units when analyzing data from transcripts. Study codes for the current study were applied to *physical units*, which are messages contained in the

Table 4	Analysis Codes Categories	
CO	COntrol of concentration	*SEMLI-S codes*
AW	AWareness of risks to learning	
CC	Constructivist Connectivity	
MEP	Monitoring, Evaluation and Planning	
SE	Self-Efficacy	
OAS	Object of Activity System	Activity System codes
SAS	Subject of Activity System	
RE	Rule(s) for Engagement	
COM	COMmunity	
DOL	Division Of Labor	
BEH	Learning BEHavior	
GM	Group Metacognition	Context codes
POS	social POSitioning/conduct	
FTE	Field Trip Experience	

words, and, *thematic units*, which are identified by definitions of various contexts, such as those in the coding categories identified in Table 4.

Given the interpretive nature of the study, the data indicated by the codes drew attention to aspects of the study from the theoretical frameworks, as well as to where data supported answering the research questions, in particular, the research sub-questions that dealt with how metacognitive knowledge, skills and behaviors were deployed in the group context and how social interactions may have shaped, engaged and promoted metacognition. Each of the *SEMLI-S* codes reflected observations or dialogue from the data where learners used their own metacognition, self-efficacy and science learning processes. The activity system codes reflect observations or dialogue pertaining to aspects of the system, and thus, group processes while the groups were engaged in problem-solving activity.

Coding the data according to physical or thematic units (Aviv, 2000) meant there was a possibility for overlap of examples of any particular code in a meaningful unit of dialogue, and consequently, represented a place in the data that may hold information pertinent to answering the research questions. I developed organizational tools for navigating the data as I sorted, thematized and continued to review the data corpus. Tools such as cross-reference lists (of overlapping codes), frequency tables and data matrices (Miles & Huberman, 1994) enabled comparisons through and between the various records from the study. The tables and matrices also helped in subsequent data retrieval. Frequency tables for the various codes combinations were also constructed, which helped to test the coding system, particularly the context codes. Following Miles and Huberman, I sought 'sufficiency' where the categories were well-defined and occurred frequently enough to allow a view toward emergence of some regularities.

Where codes from both the *SEMLI-S* cluster and the activity system cluster overlap in the data, further analytic attention was given, for it was within these overlaps where the data could help to answer the research questions. I recorded an audit trail to establish and follow my own thinking and processing steps that led to later interpretations of the overlaps. Further matrices were developed to record instances of when each code appeared with each of the other codes throughout the data corpus. This began the process of overlapping the *SEMLI-S* and activity theory frameworks. Where metacognition and learning behavior codes overlapped with codes for aspects of the activity system, the data revealed evidence to support answering the research questions. For example, the codes for Constructivist Connectivity (CC) and Object of the Activity System (OAS) overlap many times. This combination represented learning behavior in the context of the study's problem-solving activities. Similarly, other combinations allowed elaboration of the particularity of how metacognition manifested in the group setting. Group Metacognition frequently overlapped with several dimensions from the *SEMLI-S*: Monitoring, Evaluation and Planning, Constructivist Connectivity and Awareness of Risks to Learning. The combination of these codes indicated data points where metacognition could be considered alongside group behavior, again to the service of addressing the research questions and developing inferences and themes from the study.

Table 5 maps study codes onto the research questions for the study. This chart served as an organizational tool that provided a focal point for selecting data to support claims and then themes generated through the research.

Table 5 Study Codes Mapped Onto Research Questions

	CO	AW	CC	MEP	SE	OAS	SAS	ARE	COM	DOL	BEH	GM	POS	FTE
Research Question	X	X	X	X	X	X				X	X	X		
Sub-Question #1		X	X	X		X	X			X	X	X	X	X
Sub-Question #2	X	X	X	X	X		X			X	X	X		
Sub-Question #3	X	X	X	X		X	X	X		X	X	X	X	
Sub-Question #4	X	X	X	X	X	X		X		X	X	X	X	X

CO=control of concentration; AW=awareness of risks to learning; CC=constructivisit connectivity; MEP=monitoring, evaluation and planning; SE=self-efficacy; OAS=object of the activity system; SAS=subject of the activity system; ARE=Awareness of Rules of Engagement; COM=community; DOL=division of labor; BEH=learning behaviors; GM=group metacognition; POS=social positioning; FTE=field trip experience

As a next step in the data analysis process, a series of frequency charts, data display matrices and cross-match tables were generated in order to track data examples that seemed to offer instantiation for answering the research questions. This was also a process of searching for emerging themes through the data. Further searches through data records, charts and matrices generated an initial list of claims (Toulmin, 1958). The list emerged from the process of transcribing, memoing, developing coding schemes, and through subsequent reading and processing of the data corpus with the coding scheme. The claims emerged from the data, and required substantial refinement. Additionally, during this phase, counter-examples and contradictions were noted. Memos made during this phase helped in subsequent claims refinement.

Returning to the data displays, and seeking to substantiate the claims generated, I rescanned all data records. In a way, the preliminary claims were used as 'codes' in a renewed search through the data and all transformations (Novak & Gowin, 1984). New matrices and charts recorded all instances in the data that could be used to support the claim. From these displays, claims with substantive warrant in the data were reviewed. From this, I decided that four large themes could be supported through the data and reported as themes emerging from the study. These themes are presented in the next chapter.

Ethics Protocols

This study was conducted under guidelines for the ethical conduct of research as approved by the UBC Behavioural Review Ethics Board (Clearance attached as Appendix G) and the Headmaster of Royal Collegiate Academy (see Appendix H for the Headmaster's approval letter). Procedures used in this study for the ethical conduct of research include informed consent, ethical interaction and protection of privacy and confidentiality.

Students were informed about the purposes of the research during an introductory meeting with the class. At this meeting, students were invited to ask questions and seek clarification as to the study's goals and their participation in the study, including benefits they could expect to gain from their participation. Consent forms for students and parents were gathered from all participating students. Interactions with Mr. Brennan before and during the study were conducted ethically. I sought his advice and honoured his decisions as to classroom implications from participation in the study. I was guided by his logistical and practical knowledge of the school setting and his students.

Privacy and confidentiality of the school and its students were protected through assigning pseudonyms for the name of the school, the teacher and the students. These are used throughout. Additionally, data records from the study are kept in password-protected files on a secure computer, which is housed in a locked office within a secure area within the University.

Credibility

I wanted the analysis process in this study to record the "primordial mode of human existence" (Heidegger, quoted in Smith, 1991, p. 192). This is an aspect of establishing credibility in the research (Altheide & Johnson, 1998; Denzin & Lincoln, 2000; Guba & Lincoln, 1989), but also one of faithfulness to the words, stories and expressions of those being researched. It is not about objectivity, for there are multiple layers of subjectivities present in this classroom, among the student participants and even the research team. In this research, I present suitable detail in reporting so that, "the data help confirm the general findings and lead to the implications" (Marshall & Rossman, 1999, p. 194).

I had a parallel concern over reporting or representing experience, since experience is not distinct from interpretation (except in an artificial depiction of experience and interpretation as separate constructs). I acknowledge that in attempting to describe words and stories on behalf of those participating in the research, some separation, categorization, isolation of events or meaning and possibly reductionist thinking must be employed. To mitigate these concerns, I report findings of this case study in such a way that the reader or user of the research can determine the usefulness of and applicability to other settings. In this way, the results of this study become *transferable* (Stake, 2007). The issue is not direct transferability of research results, but rather what can be learned from the case.

Search for Disconfirming Evidence

Throughout the phases of the study, particular effort was given to search for disconfirming or contradictory evidence. As an interpretive endeavor, judgments were continually made about data that fit within the theoretical frameworks and data that did not. At

Guba and Lincoln's (1981) suggestion, I have continually asked, *are the results consistent with the data collected?* Describing multiple layers through an iterative process involved four main stages: targeting of data analysis codes in order to challenge them; use of N-Vivo (QSR International, 2002) trees and diagrams to search for examples and themes; testing themes as they emerged across student groups; and, constantly searching for inconsistencies or contrary evidence to hypotheses being tested (via themes).

Chapter Summary

The main research question for this study is, *How does metacognition manifest within the social context of group settings as students engage in problem-solving activities?* The main research question and sub-questions for the study inquired into how metacognition manifested, and sought to consider the social context and interactions therein, how metacognitive knowledge, skills and behaviors were deployed, how the social context shaped this deployment and how individuals perceived the process.

The model of metacognition used in this study included metacognitive knowledge, control, self-efficacy and awareness. These are aspects of individual learning behavior that shaped engagement with the problems to be solved and with others who may be in the same learning group. The study developed a problem-solving context whose development was informed by literature in problem-based learning in science. The context was developed to provoke metacognitive knowledge, skills and behaviors, but also to allow individuals interactive possibility within their groups. It is through interaction that individual patterns become consequential to the rest of the group.

Bounding the case meant that research attention was focused around the phenomenon under study, and, of particular interest, was the overlap between individual metacognitive knowledge, skills and behaviors and the group context as modeled through the activity system. A case study approach enabled focused attention on the case, which led to rich, detailed descriptions of the particularity of the case (Stake, 1995), where interpretive analyses (Schwandt, 2003) helped to make sense of the data corpus.

The study viewed learning through socioconstructivist perspectives, where learning involves self-organization and personal and social processes, as well as becoming part of a community in a continuous process of interacting with the world, other people and new information. This is a broad context for learning activity. Activity theory was used in this study to provide an analytic framework from which to explore the nature of interactions as mediated by individual metacognition and learning behaviors.

The design for this study was developed as a means to explore how metacognition is consequential in group learning activity. After the *SEMLI-S* was used as an initial assessment that generated profiles for each student, the individual profiles guided observations of student activity. The *SEMLI-S* profiles were a starting point for the kinds of metacognitive knowledge, skills and behaviors these students use, and other, complementary research methods adopted for this study elicited and captured student interactions during metacognitive experiences (Flavell, 1979). These experiences as aspects of the study context included a field trip to the Vancouver Aquarium, which was part of regular classroom activity, and a specially-designed problem set that provided further opportunity for students to use their metacognitive knowledge, skills and behaviors to engage with intertidal marine biology concepts.

Analysis procedures sought to make sense of the data corpus. A coding scheme used both theoretical and emergent codes to label meaningful units of data. Overlaps where multiple codes converge suggested places in the data that provide evidence in support of answering the research questions. Results from the study are presented in the next chapter. This is an interpretive study that sought patterns and themes through the layers of analysis. In reporting, I wanted to remain true to the activity theory framework for the study, and thus, found it problematic to dissect portions of the system: meaning for the agents within the system can only be interpreted within the context of activity. It is in the entirety of the system that actions have meaning for the agents with the system. This is a significant tension in reporting results, since how else does the story get told except by isolating parts of it? To honor the complexity of the system, I have organized the data into four large themes. Taken together, these four themes aim to comprehensively and inclusively describe the results from the study.

CHAPTER FOUR

RESULTS AND ANALYSIS

This chapter presents data from the study in order to explicate and interpret how individuals' met cognitive knowledge, skills and behaviors manifested during group problem-solving as viewed through the integrative framework of an activity system. This is the interface of interest in the study, where what an individual brings to the context interacts dynamically with the object of the activity system. Results are presented that describe and discuss how individual met cognition manifested in a group problem-solving context as developed for this study.

In this study, I started with the dimensions of metacognition and learning behavior as gathered on the *SEMLI-S*. This was because the dimensional profiles from the *SEMLI-S* were indicators of the background that individuals brought to group problem-solving activity, and as a starting point, offered a lens into how participants viewed themselves as engaged in learning activity. But during the study, students also participated in learning activities that were designed as opportunities to have metacognitive experiences. Additional data collection strategies, including observation, critical incident review, focus group interviews and individual interviews allowed me to elaborate and explore further how individual metacognition was consequential to group problem-solving behavior.

The analysis process used the activity system as a guiding framework, and I used the components of the activity system framework to guide attention to where and how metacognitive knowledge, skills and behaviors might play out in the group context. The components of the activity system describe aspects of collective activity, and by watching particularly the modeled aspects of metacognition as developed for this study, it became possible to elaborate how and where metacognition manifested during group problem-solving as invoked by the activities in which participants were engaged. Metacognitive knowledge, skills and behaviors are engaged in dynamic ways through group activity, and the activity system allowed a view into this dynamism.

To examine where and how metacognition was evidenced in relation to components of the activity system, I cross-referenced codes to find points of intersection between metacognition and aspects of the activity system. For example, when the codes for monitoring behavior and rules of engagement within the activity system overlapped, a place was revealed where an individual was using his or her metacognition in order to negotiate interactions with others in a group learning activity. These points of intersection reflected a manifestation of individual metacognition within the group context, and a possible data point for subsequent analysis. Through the process of data analysis, I looked for substantive places of intersection and overlap among the codes in order to generate themes for the study.

The overall themes for the study identified through the analysis process are the focus for discussion in this chapter. Because the *SEMLI-S* was the starting point for data gathering, the first section of the chapter describes how this instrument allowed a view into individual metacognitive knowledge, skills and behaviors. The dimensional profiles served as important background for subsequent observations and analysis of the data corpus. Discussion of the *SEMLI-S* is followed by a second section that describes how the context for the study invited metacognitive engagement. The third section describes the social context of group interaction. The final section elaborates the group process as a context for collective problem-solving activity.

Individual Metacognition Through the *SEMLI-S*

This section visits aspects of individual metacognitive knowledge, skills and behaviors as assessed through the *SEMLI-S*. Dimensional profiles were the starting point for preliminary observation and analysis of student interactions from the field trip and problem-solving activities during the study. The dimensional profiles for each of the focus group students are presented here, along with how these profiles were used in the study to provide insights on metacognitive knowledge, skills and behaviors. As indicated in the large oval in Figure 4.1, this section focuses on the top half of the activity system model for the study, where individual metacognition was viewed as mediational means within the activity system.

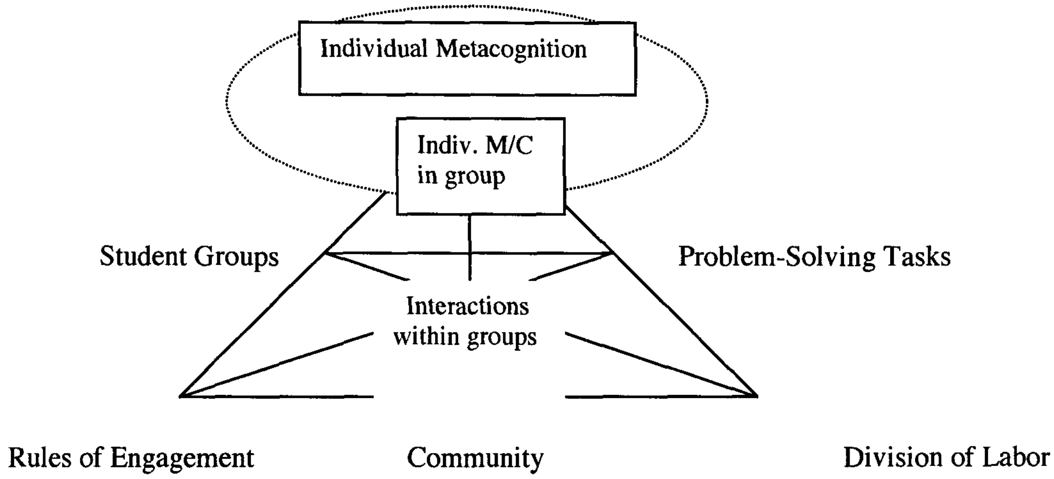


Figure 4.1 Activity System Modeled for the Study

SEMLI-S Dimensional Profiles

The *SEMLI-S* dimensional profiles provided initial indicators of how individuals viewed themselves during learning activity in science. Because the scores represented self-reported perspectives on learning behavior, the aggregate scores as generated by the *SEMLI-S* suggested where and how individuals engaged aspects of learning behavior or metacognition.

Table 6 summarizes participating students' data from the *SEMLI-S*. The table includes data for each student in relation to those of the other members of his or her focus group, and individual profiles along the five dimensions of metacognition, assessed by the *SEMLI-S*, including control of concentration [CO], awareness [AW], constructivist connectivity [CC], monitoring, evaluation and planning [MEP] and self-efficacy [SE]. Interpreting data in Table 6 involved, first, looking within each column for the dimensional scores for individuals. For example, Evan, who was a member of Group B, was almost uniformly high on all of the *SEMLI-S* dimensions. His very high dimensional scores on control of concentration, constructivist connectivity and self-efficacy suggested that he was a self-confident and effective learner (at least in this context), who worked to develop rich understandings of new information while building from what he understood already. Chris, in Group A, was almost uniformly low-to-average on the *SEMLI-S* dimensions. This suggested that she may have been somewhat

Table 6 *SEMLI-S* Profiles for Participating Students, with Group Assignments

A	Pau	Sus	Chr	Ma	B	Mark	Evan	Adie	Mel
CO	3.0	3.7	3.0	4.7		3.0	5.0	3.0	4.3
AW	2.6	3.6	2.4	4.6		3.4	4.0	4.0	3.2
CC	2.1	3.0	2.7	2.7		3.0	5.0	4.0	3.0
MEP	2.8	2.7	2.1	3.4		3.1	3.9	3.8	3.2
SE	3.0	2.2	2.0	2.7		2.8	4.5	4.5	4.5

C	Ann	Amb	Nev	Earl	D	Shel	Caz	Gly	Abb
CO	3.7	2.7	4.0	3.7		4.0	4.7	5.0	3.3
AW	4.6	3.2	4.0	3.6		3.8	4.6	5.0	4.0
CC	3.6	1.0	2.7	2.7		3.3	2.9	3.7	3.4
MEP	3.1	2.1	3.2	3.1		3.2	3.0	3.2	3.4
SE	4.3	2.7	4.8	4.5		2.8	3.5	4.7	3.7

CO=control of concentration; AW=awareness of risks to learning; CC=constructivist connectivity; MEP=monitoring, evaluation and planning; SE=self-efficacy

limited in her use of metacognitive knowledge, skills and behaviors, and may also have been a disengaged or poor learner. The *SEMLI-S* dimensional profiles were used to cue observations and preliminary analysis of video from the field trip and problem-solving activities.

A second level of analysis for data in Table 6 involved scanning the range of scores within a group for trends or patterns. The range of scores for individuals within a particular group was examined alongside the particular scores for individuals within that group. For example, Group B included three individuals who had very high scores on the dimension of self-efficacy. High self-efficacy reflects beliefs in one's own competence, and with three such individuals, there was a strong possibility for rich interactions among them, particularly within a problem-solving context that had open-ended questions for which there were no correct answers. Individuals with high self-efficacy likely hold strong beliefs about what they know and understand, and as such, are likely to share it within a group setting. Conversely, individuals with low self-efficacy scores may have exhibited much different kinds of learning behavior in a group (e.g. they may have been more hesitant to offer ideas, especially conflicting information). Thus, when making observations of group activity and listening to and noting dialogue within groups, I focused particularly on interactions where the individuals were demonstrating their own high (or low) self efficacy. Other dimensions from the *SEMLI-S* also provided focal points for observations during the study.

When individuals brought a diversity of dimensional profiles to a group, there was the possibility that constructive argumentation would further promote metacognitive engagement within the group (Nielsen, Nashon & Anderson, in press). The dimensional profiles reflected, to some extent, how individuals accessed prior knowledge and brought it to the service of current learning opportunities (Anderson & Nashon, 2007), including the group problem-solving space. In this and the ways described above, the *SEMLI-S* scores cued me to observe how individual metacognition and learning behaviors manifested within the interactional patterns established within problem-solving groups.

The Study Context and Metacognitive Engagement

The context for this study promoted metacognitive engagement, which was a necessary component of the study design, providing an overall setting for the conduct of the study. The study context included the classroom community and learning experiences within it, the field trip to the Aquarium, the follow-up problem-solving and video review activities. Data in this section describe how the activities within the phases of the study created important opportunities for the students to be metacognitive. This section provides background to later sections in this chapter, where aspects of the context are more specifically linked to the theoretical frameworks of metacognition and activity theory as developed for the study. Data for this section come from observations and focus group and individual interviews. There are three sub-sections: Follow-up to the Field Trip; The Nature of the Problems and Group Process; and, The Group Context for Problem-Solving.

The Field Trip and Follow-up Activities

During the interviews, students often made reference to aspects of their school and classroom culture. These comments provided important background information about the general context of the activity system for the student groups, as they worked within the bounds of the culture of the school and the biology classroom.

As already pointed out in previous chapters, the field trip to the Vancouver Aquarium was a normal part of Mr. Brennan's intertidal marine biology unit. He sequenced the field trip as a unit review, since the activities at the Aquarium surveyed intertidal organisms and ecosystems from the local British Columbia waters. The experience was memorable, and students were asked about this during the focus group interviews:

Int: Ok, first of all guys, tell us about your visit to the Aquarium. How did you find the experience?

Chr: It was fun. [Paula, Mary and Susie agree]

Int: What do you remember from it?

Pau: The different groups and the different things we traveled to, like all the different

Sus: and touching the stuff

Int: Touching the stuff?

All: yeah

The students obviously enjoyed the opportunity to attend the field trip, as well as the hands-on nature of the experience. They remembered traveling to different stations in the WetLab. In response to another question that sought their opinions on what they thought would be different if the field trip were before the unit in class, as opposed to where it was, as a unit wrap-up, most indicated that the aquarium was a meaningful part of their learning about intertidal biology, as indicated by Amber's response:

> I don't think I would have memorized as much as I did, because when we got the notes to everything and we looked at all the diagrams and we went to the Aquarium it was kind of like, 'Oh, I recognize that,' 'I remember that from the notes' right? and then it kind of helped make the connection. If I saw it first and then I would look at the notes maybe it wouldn't really have that much impact on me because it would be like I already saw it [and] what's the point of looking at notes?

Amber exhibited a sort of awareness of risks to her own learning here, by pointing out that the field trip had helped her to consolidate her prior knowledge gained through recall of lecture notes. Additionally, she added layers to her own thinking by building in this experiential connection. Later in the individual interview, she stated: "Yeah, it really helps us to, you know, draw those two things together to make decisions." The hands-on experience was key.

All students commented on how the experience of visiting the WetLab at the Aquarium was fun, but how this connected to their learning was important. Shelley and Glynnis, along with their Group D members, were asked about this during the focus group interview:

> Shel: I think when we got here, like to see those things and then when the person explained it to us how the different phylums, I guess, I think I remembered better [than] if I was just reading the textbook instead
>
> Int: So you remember it better if you see it?

Shel: yeah

Int: even touch. Anyone else?

Glyn: There's no pressure when there's no worksheets in front of you and you like, you have to come out, you just kind of listen and join in a way.

Caz: uh-huh

Int: So when there's no pressure of, 'you must fill out this sheet.' 'You must do this.' Do you feel you learned from that experience much better?

[everyone agrees]

Int: Tell me about filling the sheets. How does that go?

Glyn: Well you're constantly looking at the questions and want to fill it out, like the questions, and when you don't have the sheet, it's kind of like you're listening, you're having fun. There's no pressure.

An in-person explanation along with the opportunity to see and touch the actual organisms helped these students to monitor their own thinking and elaborate their understandings of invertebrate phyla. Glynnis suggested that she could better concentrate on learning if she were not focused on taking notes, like they usually did in class. At the Aquarium, students followed along with worksheets that provided space to fill in words or phrases as they were encountered in the WetLab. The types of information recorded included things such as characteristics of organisms, zones where the organisms could be found, or other information about the ecosystem. Students knew that the visit to the Aquarium was intended as a review of their intertidal marine biology unit and completing the worksheets was optional. For Glynnis, this lack of perceived pressure made the learning fun, while Ann felt that she developed better understanding by handling the organisms:

It was fun and when we got to actually do that, you know, hands-on, you got to be right

> in front of all the creatures and you can touch them and when they're describing things and they say, 'Oh, this thing has a spiny surface' or something, you can actually touch it and see exactly what they mean. So you can kind of better understand what they're trying to describe to you as opposed to just imagining.

The chance to connect the 'book-learning' with the actual appearance and feel of the organisms was an important facet of the learning experience at the Aquarium. Amber was more expansive as she talked about the learning that went on at the Aquarium:

> When you learn stuff on paper, it's really, really dry and then when we went to the Aquarium, I kind of got to see [it] in a different light. So I kind of wanted to see what I could do with that, like if I could apply the knowledge that I learned in the Aquarium, [and] see this stuff on paper, right? If it's going to work better, because it is easier to just kind of straight memorize it and then just put it on test and then kind of forget about it until the exam? Or, like with the Aquarium, when we actually got in and we got to touch the stuff and we got to learn about it in kind of a different way—which is really fun—and then seeing when we got back to class how we could apply that knowledge and the whole application of it. It's kind of what was going through my mind.

Amber and Ann were both able to articulate how they had used the experiences from the Aquarium to connect their understandings across the different contexts for learning marine biology. Thinking about how to connect understandings could be interpreted as metacognitive.

The problem-solving activities in which students engaged following the field experience were likewise opportunities for them to make further connections and extend their thinking about organisms and ecosystems (see Appendices C and D). The video-review activity asked groups to collectively identify episodes from the follow-up activities where they felt they were being particularly effective as a learning group. In other words, they were asked to attend to the object of the activity system and be metacognitive. One of the follow-up problems was particularly challenging, and Group B chose a video-clip from the time when the group was wrestling with this problem. The video-clip of this episode was cued during the focus group interview and the interviewer started the conversation:

Int#1: Let's see, 'Doing things that helped you learn' is 14:00. Is that the one? Is that a good one?

Adie: Do you guys remember?

Evan: I thought you guys remember everything?

Adie: 14:45

Evan: I can't get my head wrapped around the idea.

Int#1: Tell us what is going on there and why this is important. First of all, what's going on?

Evan: um

Adie: We didn't know what abiotic means.

Evan: We knew that 'a' means 'not' but we just couldn't get our heads around the idea that it could be a-biotic—no biologic factors.

During this episode, they were working on Question 2: "Considering the abiotic factors, as a group, decide which of the organisms will be the most successful in each of the zones." Even though the term 'abiotic' is a vocabulary word in common use in biology, these students were stumped by its use in this question. As they struggled, they engaged active monitoring and evaluating strategies to challenge each other and try to make sense of the problem. They eventually resolved this issue by asking another group what 'abiotic' meant, after which, they continued to struggle with how to apply the definition to the context of the problem. Eventually, the group came up with an idea of where abiotic factors might matter:

Evan: We thought about where [the organisms] would hide and stuff like that.

Int#2: So, did you start thinking about all those different things that might be 'abiotic'?

Mel: We were thinking of scenarios with each. We kind of eliminated some of the organisms, and put it down to two or three, and then we thought up scenarios where each would be, had the best survival instincts or the best body shapes or protection, until we eliminated it down to one organism.

In a way, Group B made this problem more complicated than it needed to be, since abiotic factors include things like weather conditions, water and air temperature, sunlight and local geography. The group's wrestling with terminology made their interactions rich, and stimulated deep thinking for all in the group. Sometimes, confusion seemed to spark productive discussion.

A key element of problems that stimulated or engaged metacognition seemed to be that they offered a place to expose discrepant information or thinking. If information that was contradictory could be brought to focal awareness for some or all of the individuals in the group, this became a point for seeking clarification. For example, Group A experienced a confusing situation that was discussed during the focus group interview:

Int#1: What about the activity that we did in the class the next day, could you see the connections between what was at the Aquarium and what we were doing in the activity?

Pau: Yeah, for some of them, but we had trouble with the questions, otter ones. Was that the one?

Int#1: Why did that stick in your mind, Paula?

Paul: I don't know. We'd get one answer, and then we kept going back and realized it was wrong and do another. We kept erasing, Chr: the intertidal thing

Int#2: Just tell me, at what point would you realize, 'Oh, this is wrong' and you better go back again?

Chr: Like when we compare to similar species, but then we were getting totally different answers.

Int#2: You go back and...

Chr: Yep. And it was Part A and Part B, wasn't it? Or something like that?

Int#1: There were 3 or 4 parts to it, I think.

Chr: And the first two parts were kind of linked.

Pau: Similar. But we ended up getting different answers for them, so they were kind of not working out.

In this example, Paula and Chris were describing the groups' experience of discrepancy on the problem-set questions, which reflected awareness of the demands of the learning context at a group level. They had placed their organism cards into various zones on Sunset Beach, as part of Question #1, and had decided which would be most successful, as in Question #2. In wrestling over the issue of the impacts of increased kelp and otter populations in the area, the members of Group A realized the need to connect their responses between Questions 1 and 2, where their reasons for placing the organisms contradicted their evaluations of organism success and implications for the ecosystem. The questions brought up the possibility of many different opinions and justifications thereof, and in the process, challenged the group to strategize to deal with the discrepancies. And, there were no correct answers for the scenarios laid out in the problem set, which added a challenge to the groups' thinking.

Group B also experienced a challenge to their thinking, but for them, the difficulty was in sorting among the many possibilities open to them. This was evident from another of their video-clips. After this video-clip was reviewed during the focus group interview, the members of Group B described their process of dealing with a confusing problem:

Mel: Um, we're, I was just thinking about the different aspects of the pictures and the pictures really helped because you had a visual of what they looked like, and I was thinking back to what the person at the Aquarium told us, that if they have harder shells, they usually live closer to the splash zone.

Adie: and color

Mel: and color too

Int#1: Ok. Just talk freely about the whole 3 minutes of this thing, talk from your own perspective or the group perspective what was going on.

Evan: One of them, we got kind of confused because part of it we'd never seen, a really colorful one, part of the splash zone, and they seemed to be much more colorful and larger than the green ones.

Mel: They were like orange and red, and the small ones.

Evan: Yeah, they were orange and purple and red. It just kind of confused us.

The group realized that the picture did not quite fit with what they had thought about in terms of color, shape and habitat. Their hands-on experiences at the Aquarium provided background for wrestling with the in-class problems, which were also interactive in a way, and these types of experiences were quite different from their usual activity in this classroom community.

By participating in the research study and engaging with the problem-solving context offered therein, the students noticed that their ways of engaging in learning and with each other were different from their regular patterns of activity in the classroom. The activities also placed different sorts of demands on them. Group A was asked about this during the focus group interview:

Pau: We don't really ever do any activities. We do labs and notes and stuff.

Chr: Grade 11 [Biology] is mostly memorizing. You don't need to, like, think about it.

Pau: It's like you know it and you don't ever think about it. You just learn it.

Int#2: And you prefer that way?

Pau: Yeah.

Sus: It's not like [you have] to think about it.

Chr: And you don't work your brain so much. It is so frustrating when you can't get the answer.

There was a certain kind of simplicity, even comfort, expressed by these students in their desire to have a correct answer to the problem, which reflected a particular notion of the nature of biology learning. Chris commented on the possibility for frustration when problems do not have a clear right or wrong answer. Not only was her belief in the need for a right answer reinforced in biology, she had developed a comfort with such a representation of learning in this subject. Her perception that learning involved finding facts or simple answers extended outward to her impression of other subjects that she perceived required harder thinking. She was asked to confirm this impression by way of a follow-up question during the interview, and admitted that she thought English as a subject area required the learner to think harder than did biology. Chris' perceptions reflect an opinion that different subjects place different demands on the learner.

Chris' low-to-average metacognitive profiles on the *SEMLI-S* had suggested that she may have been a disengaged or poor learner, but observations and interview data combined to suggest that she actively constructed understandings as she processed information from the aquarium, material covered in class, the problem set, other follow-up activities and a visit to an IMAX movie. She was also responsive to the considerations and ideas of her group mates, as will be shown in later sections of this chapter. Her comments in interviews suggested that her interest in biology as a subject area was shaped by different kinds of learning experiences, while her interest in taking in other kinds of experiences led to deeper understandings of the subject matter.

For other students, the context of the study gave them a chance to experience a different way to learn biology. They were used to completing worksheets or generating other sorts of artifacts, as noted by Group D in recalling experiences from the field trip during the focus group interview. They commented that the experience was much more fun without such pressure or distraction, and they found it easier to make connections to what they had learned in class. Gunstone (1994) lamented that learners need to 'buy-in' to the need for greater metacognitive effort. Data from this study suggests that designing activities or evolving research methods so as to initiate metacognitive engagement can support this learner buy-in (Anderson et al., 2008).

The field trip gave the students an opportunity to experience biology concepts differently, which led to growing awareness of their own learning processes, as noted by Amber and Ann during their focus group interview:

> Amb: Yeah, I think if you just see it and talk about it, rather than just memorize it, like words off the page.
>
> Ann: It actually made you understand what you had learned off the page.

Recall what these students had earlier described as benefits of the hands-on part of these learning experiences: for them, being able to engage with the material on many levels was a better way to learn and it helped them to connect information from the different learning contexts.

Given the views expressed by many students in this study, it appears that the hands-on experiences of the field trip and then the challenging follow-up problems provided experiences that were successful at engaging metacognition and for elaborating understandings of biology concepts. The study built from the content of the biology curriculum in the design of the learning activities so that the object of the activity system offered individuals an entry point to the group discussion on many levels, and as this happened, metacognitive knowledge, skills and behaviors were called upon in working together. The hands-on nature of the problems contributed in important ways to the construction of opportunities for metacognition. The next section looks more particularly at the nature of the problems as part of the study context.

The Problem-Solving Context

This section deals more specifically with the problem-solving context for the study, which was the object of the activity system. How the students understood the object of the activity system was significant here. Data for this section come from the transcripts of focus group and individual interviews, as well as observations over the course of the study. Because I was interested in how students would bring their metacognitive knowledge, skills and behaviors into the problem-solving context, this section focuses on overlaps between other study codes and the code for Object of the Activity System [OAS]. Table 7 is an example of a data table generated during the process of analysis for the study that detailed cross-references between study codes and, in this case, OAS. Other tables developed for the study summarized overlaps with other activity system codes, focusing on one of the activity system codes at a time.

Table 7 Frequency of Object of Activity System Code with Other Study Codes

CO	1	OAS	n/a	GM	7
AW	3	SAS	2	POS	4
CC	10	RE	3	FTE	1
MEP	8	COM	1		
SE	0	DOL	5		
		BEH	5		

CO=control of concentration; AW=metacognitive awareness; CC=constructivist connectivity; MEP=monitoring, evaluation, planning; SE=self-efficacy; OAS=object of the activity system; SAS=subject of the activity system; RE=rules of engagement; COM=community; DOL=division of labor; BEH=learning behavior; GM=group metacognition; POS=social positioning; FTE=field trip experience

As can be seen from Table 7, the *SEMLI-S* dimensions of Control of Concentration (CO) and Monitoring, Evaluation and Planning (MEP) co-occurred with reference to the problem-solving context (OAS=Object of the Activity System) most frequently. Additionally, cross-coding with group metacognition [GM] and learning behaviors [BEH] was also fairly common. The next section elaborates these findings by describing students' experience of the problems, the nature of the problems they solved and how interaction and persistence were encouraged through the problem-solving context.

Group B offered some sense of how group members experienced the problems:

Int#1: What about the activity that you did in class? What's the thing that stands out most for you in terms of your memory?

Adie: The one with the shoreline thing?

Int#1: Yeah. What sticks in your mind from it? Anything.

Adie: Um. Nothing much. Anybody want to make a comment?

Evan: I remember the one with the photographs.

Mark: Yeah, the photographs

Mel: Arranging them

Int#1: Did you think it was a particularly difficult activity?

All: Not really.

Mel: I think it was, the difficult part was compromising with different people's opinions and coming to an agreement. Otherwise it wasn't that difficult.

While other groups commented on how the field trip and problem set represented different kinds of activities from the usual context of their biology classroom, Mel, in Group B, recalled the task of sorting the photographs of the organisms, which was Question 1 on the problem set, and commented on an important social aspect of group problem-solving: reconciling various opinions and constructing a collective response.

Building from the research literature in problem-based learning, the questions for the problem-set were purposefully designed to be open-ended, and I expected that this would stimulate discussion and wrestling among the group members, in effect, engaging metacognition. For Group C, this wrestling involved deciding what the question asked, as Amber described during the focus group interview:

> We were kind of just having a little trouble with wording mostly, because it wasn't really…It was kind of vague. So we kind of had to, you know, pick it apart and then we had to talk about it and see what the question was trying to ask us, and then we answered it.

The above excerpt provides an example of monitoring and evaluative behavior in assessing task demands through seeking clarification and then planning for problem-solving (MEP x OAS). Discussions about planning led into later problem-solving discussions. The nature of the questions also stimulated discussion, but students also found these open-ended questions were more interesting than other sorts of classroom or group activity. Amber noted this during the individual interview:

> Int: So, if it's open-ended, then does that make it more interesting?
>
> Amb: Oh, definitely. I think it's kind of like saying a yes or no question or you know, yes-no-maybe questions.
>
> Int: The 'maybe' questions?
>
> Amb: Yeah, the 'maybe' questions.
>
> Int: And is that when people's reasoning abilities kick in?

Amb: Yeah, because I mean if it's opinion then you have to provide reasons. You have to provide proof in order to make everyone else believe that you're right. So if your pattern of thinking is logical then obviously people are going to listen to that because it makes sense. I mean if it's like way too out of left field, then no one's going to believe it. I mean it might be open-ended but it can't be that far [out].

As Amber suggested, the open-endedness of problems made them interesting, but only to a point.

Other aspects of the problems, such as context clues, served to focus learner awareness and planning behavior throughout the activities (MEP x OAS). Group C talked about the picture-placing exercise:

Ann: Some of the pictures were really helpful...

Amb: yeah

Ann: When we were trying to do the, like, instead of having just a list of the creatures, actually having a picture helped.

Amb: You could remember them from the [field trip].

Ann: [They] helped us answer the questions.

In Question 1 of the problem set, students used the images of several marine organisms to focus their attention on salient characteristics of the organisms. This assisted in deciding what was relevant in the presented information, which the group then used to solve the problems. As it did so, the group attended to an important regulatory aspect of problem-solving behavior: they made decisions about what information was pertinent and then linked that information to other experiences, in this case, from the field trip.

Another important aspect of problem-solving behavior was using context clues from the problem in order to proceed to solution. Group A used one of these built-in context clues to make decisions about persisting in debate around the question:

Chr: It seemed that the point of the question was to debate something, but then we didn't really debate.

Pau: yeah

Int: Ok, now I see. One is, you are saying, the length of time,

Chr: yeah

Pau: Yeah, 15 minutes seemed long. We had an answer in 15 seconds.

Int: And then, you felt this question requires some debate.

Chr: yeah

Int: Did you guys feel the same? [to Mary and Susie]

Mary: no

Int: When you constructed your response, did you consider time?

Sus: Well, we considered time, but still, we just think it's the right answer.

In the example above, Chris and Paula used the suggested time allotment for the question to consider that there must be more to the problem than they had initially thought. The other two group members felt no such need, having already decided they had a satisfactory answer. Attending to the context clue kept Chris and Paula puzzling over the problem for much longer than they would have if the clue were not there, as Paula admitted they had an answer in 15 seconds. Persistence, in Chris and Paula's case, was based in their perceptions about the demands of the problem. As a result, they developed different answers than the ones that satisfied Mary and Susie. To settle on these two sets of answers meant that there would be two contradictory responses recorded on their problem set worksheet. This led to confusion, as was discussed in the individual interview with Chris:

Int: In the groups that you've worked in, is it important then for the group to have one answer? Do they need to work to one answer or can they settle for two or three different ones that all make sense?

Chr: Oh yeah, they're pretty flexible. And then sometimes it leads to like, you don't know which one to choose...[and] get confused.

This issue never really did get resolved within Chris' group. The two sides to the dispute each recorded their own versions of a response to the question. Chris seemed to want to have clarity and perhaps certainty over the recorded response. But, she also felt that confusion was a possible result when several people had different ideas that were not reconciled. For Chris and Paula, the discrepancy reinforced their desire to continue to work on the problems.

Persistence in thinking about the problems extended beyond the field trip and classroom settings. Chris had been thinking more about all of these experiences in the intervening time leading up to the individual interview. She had continued to consider all of the various bits of information, and even attended an IMAX movie on ocean ecology. She exhibited highly metacognitive behavior:

> [I was] looking at the things and then asking, you guys asking questions and then having to pick one. So then it really makes me think about it more. Well, it really makes me think about how I think, right?

Others were also highly engaged with their own metacognitive processing and the activity of problem-solving. When asked about how she enters a group learning setting, Amber said that an interest in the problem makes her want to learn, out of an interest in developing understanding: "Well I mean, it's sort of like everything. The topic of our activity was kind of interesting, especially the last question. Like it really made me think so, yeah, I did want to learn." Students found the topics in the problem set interesting, which led to persistence in learning behavior.

This section has considered the nature of the problems and how open-endedness contributed to student engagement as well as stimulated metacognition. How the problems were worded, including context clues, also focused student attention on salient aspects of the problems. The students found the problems interesting (or perhaps confusing) and this mattered for willing engagement, which for several students, led to persistence in problem-solving effort.

Group Context for Problem-Solving

The group setting for problem-solving activity during the study was also a novel sort of arrangement for students in the community of Mr. Brennan's biology class. As noted previously, 'group' activity in this classroom generally involved working with one's seat-mate to study or review notes. Whole-class discussions did happen, but such discussions were generally part of the more traditional lecture-based classroom delivery. This section discusses the group context during the study, how it encouraged individual engagement and persistence and how the group setting was a place where individuals learned about and with each other.

In this classroom, where taking notes was the usual type of learning activity, the students in the study noticed differences. Group C talked about this during the focus group interview:

Amb: We don't have a lot of group activities. Period.

Ann: Yeah. School is usually pretty...not group oriented.

Amb: We usually do our own individual work.

During her individual interview, Amber was more specific: "We don't really do much group work in biology. It's more of a kind of like 'do your own thing,' 'learn your stuff off the paper' and then just kind of spit it out, you know, for the test."

Individual perceptions of the usual sorts of classroom activity were reflected in how the students applied their metacognitive knowledge, skills and behaviors to the learning context. In the context of the Biology class for this study, 'group work' most often meant working in pairs, which the students did to review notes or study for exams. This biology classroom most often operated in a transmissive mode, where the teacher, Mr. Brennan, presented information and the students listened and took notes. The students then went away to study this information and prepare for tests. The classroom presentation style was consistent with the context of this school community, and reflected a widely-held view in this school that the teacher is the expert, while the students' job is to absorb as much information as possible and then reproduce it in order to demonstrate learning through tests and other evaluation mechanisms. While this characterization oversimplifies the context, it illustrates the frame in which the participants viewed their position as students in the community of this class and this school.

When teachers employ a transmissive method of presenting information, students may not need to think for themselves, or process information to determine what is important: it is done for them. In other words, there is little need to be metacognitive, because of how material is presented, and because few learning decisions are required of students. In this study, it appeared that Chris had developed an affinity for this kind of 'learning' to the point that if the teacher's approach varied from this, she really struggled, seeing a situation that required her to do more than copy notes as multi-tasking and beyond her own comfort zone. Thus, the usual classroom approach to presenting information, coupled with Chris' beliefs about the nature of this representation, seemed to undermine Chris' perceptions of her ability to learn in other ways, consistent with Jost et al. (1998): "people's descriptive beliefs about their own cognitive abilities play an important role in actual performance" (p. 142).

Thus, at least for Chris, the style of information presentation used in the classroom investigated here seemed to encourage and reinforce a conception that knowledge is held by experts, rather than something that is socially constructed. So, not requiring students to be metacognitive may inadvertently teach them that they don't need to be, and may even make them fear novel situations (such as group activities), problems that do not have 'right' or 'wrong' answers or other situations requiring adaptation, negotiation or metacognition. The irony is that students can often be 'successful' in such a system: of course, depending on what is evaluated and how. Testing in particular ways may reinforce the community value of didacticism in teaching (Goodlad, 1984; McNeil, 2000), as appeared to be the case in this particular biology classroom. Students, such as Chris, who subscribed to this notion of knowledge representation and the means to measure its attainment, succeeded, or at least, earned good marks. The point here is that students seem to adopt particular views of the nature of learning, which are tied tightly to how the subject matter is represented in a given subject area, and these views become woven into the values and context of the classroom community.

All students in this study seemed aware of the usual classroom community context and were sensitive to how the group context during this study engaged different kinds of learning processes, such as those influencing engagement and persistence, which is an indirect theme that weaves throughout this chapter. The following excerpt from the interview with Group A revealed this engagement and persistence as a function of group behavior. Chris was less willing to accept the first answer proposed by the group as a response to any question:

Int: Did you feel this was the case in these activities? That you were willing to accept the first answer?

Chr: No, I kind of questioned a lot, I thought about it a lot: maybe it is this and not that, and usually if I work alone, it is this answer.

Int: Do you think that this activity was more challenging than you typically get in your biology class? Do you think that Chris?

Chr: um, yeah

This is a different kind of persistence than noted earlier, since it was the group context that enabled and encouraged Chris' persistence here. She kept thinking longer about the problems because she was working in this group context. For this reason, group work offered the possibility of being highly beneficial for her individual learning.

Working in a group context created opportunity for the group's knowledge and understandings to become available to the others in the group. During the focus group interview, Evan reflected that, "sometimes to connect that information you need another part." Others in the group might have contributed that other 'part' that would help him develop a more complete understanding of the topic under discussion. Abby often relied on others in her group for specific help in understanding something: "If I don't understand something and if I don't understand a question, they will tell me." Abby also felt she benefited from others' understandings because she was part of a group.

As described in this section, data from the study suggested that the group setting provided a novel context for participants. The usual classroom activity was taking notes from teacher-directed lectures, with the occasional lab or whole-class discussion. Attending the field trip, and then participating in follow-up activities back in the classroom, as well as focus group and individual interviews, created a novel context for students' work at the end of their intertidal marine biology unit. The group context appeared to be highly beneficial, as it gave the students a chance to interact with one another and think together as they worked to solve problems collectively, which for many students, seemed to lead to increased persistence in problem-solving effort.

Theme Summary

By developing activities for the study context, with the express intention of engaging metacognition, the study created opportunities to explore how individual metacognitive knowledge, skills and behaviors were brought into a group problem-solving context. From the early interactions during the field trip, to the classroom follow-up activities (problem sets and video review activities), and then conversation in focus groups and individual interviews, the participating students were offered opportunity to think about themselves as learners. They described their awareness, monitoring and evaluating behaviors, as well as how they used information from activities and the group context to connect understandings. The hands-on nature of the activities supported their use of metacognitive knowledge, skills and behaviors, as did the nature of the problems and the group context. As the next sections of this analysis chapter unfold, deeper layers in the students' interactions, their metacognition and group activity will be elaborated.

Metacognition in the Social Context of Group Interaction

Within the social context of group work for this study, students engaged their metacognitive knowledge, skills and behaviors during interactions within the groups. During group problem-solving, what individuals brought to the context was important, but dynamic interaction also fed back from the group to shape individual participation. In this section, several aspects of the sociality of the group process, as represented by the lower half of the activity system triangle (see Figure 4.2) are described. To honor the complexity of the system, and to avoid dissecting out pieces, the discussion presented here offers the reader a sense of the dynamic interactions among the study's participants, and how individual metacognition manifested within the social context.

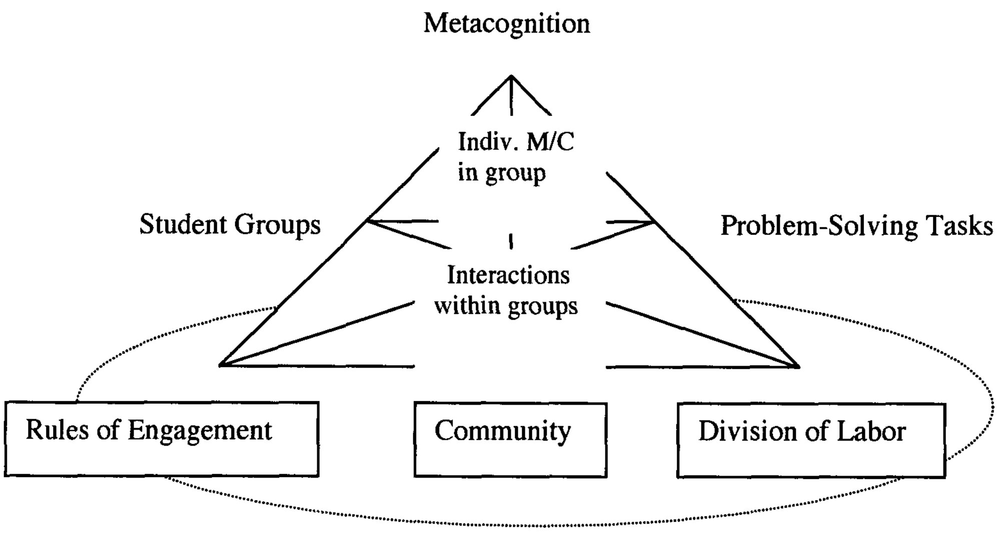


Figure 4.2 Social Context Within Activity System Model for the Study

In this section, analysis and discussion emerge from my attention to where study codes for metacognition intersected with codes representing the kinds of interaction dynamics established within the groups, as reflected in the base of the activity system triangle (see Figure 4.2). Analyzing interactions among the individuals provided a window into the experiences of individuals within groups, as well as how the groups negotiated the sociality of the classroom community. To describe the themes that emerged from an analysis of these intersections, I focus attention sequentially on how participants negotiated the sociality of the community, community belonging, rules of engagement, and division of labor. Throughout the discussion, I also interweave attention to how negotiation and mutual work developed rules or expectations for how individuals engaged with each other in the system.

Negotiating the Sociality of the Community

The group configuration for the activity system in the study, which demanded greater interpersonal interaction, made it necessary for individuals to negotiate the social space of the group. Some students were more familiar or comfortable with the demands of group work than others, and individual behavior within the group reflected students' respective levels of comfort with group interaction. How students negotiated these demands is the focus of this section.

In this section, belonging to the school and classroom communities is explored. Because the community of Royal Collegiate Academy reinforced an individualistic notion of learning, there was a strong emphasis on academic achievement throughout the school, and success was measured through grade point averages and university placement (Royal Collegiate Academy, n.d.b). The individualistic focus tended to work in tension with the demands of group activity. How individuals interacted with one another was significant, as were the relationships students had with one another, which was part of the subject of the activity system.

Familiarity with the others in the group influenced how the demands of group activity were negotiated. The members of Group B had not worked together in this particular configuration, was described during their focus group interview:

Mel: We work in pairs with the person you sit next to in class. So, I work with Ann. They work together. And Adie works with Chris.

Int: So you've not worked together with anybody in this group? [pointing to Mel and Adie]. But you two guys have worked together before?

Evan: Yeah.

For Group B, working as a group of four added an extra layer to their work. They knew each other as classmates, but four to a group was a larger configuration, and unusual for these students. Because the group included others with whom they were less familiar, they needed to negotiate working relations within the group.

Group D, by way of contrast to Group B, included a complement of girls who normally worked together, as Abby reported during the individual interview, "Yeah, we usually work together and even though it's homework or something we still try and work together and ask each other for help." Individuals in this group identified themselves as friends, and Abby liked this aspect of group work. Belonging to this social group was a regular part of these girls' experience in this classroom. Mr. Brennan indicated that he encouraged this particular group of four to work together because they were all ESL students who continued to need support for studying in English. When students were given study time in class, they invariably went off together to work through their assignments, readings or problems collaboratively. Friendships among these girls constituted an important benefit of working together, and their effective group work was based in their familiarity with one another.

Abby was used to working with this group (Group D in the study), and her friendships with the other girls had already positioned her within the group and were very helpful for her own learning, as she observed during the individual interview: "Yeah, I think I understand more deeply or clearly, because I can always ask my friends if I don't understand something." Mel, who was in a different group from Abby, reflected her awareness of group functioning when she was working with her friends:

Mel: Yeah, I think, I actually think things would be done faster because I think when you're with your friends, you tend to agree with them a lot more and you're less likely to voice what you think is different. You're less likely to voice it as much, like argue about it, you'll say what you feel, but a lot of people won't agree with you and your friends will be like, 'ok, whatever.'

Int: So you don't stir it up or cause trouble? Is it just avoiding disagreement?

Mel: in a sense

Int: To some extent?

Mel: To some extent.

Int: And is that because, um, to save the relationships, or is just for group harmony sake? Or?

Mel: Kind of for group harmony. Not, I think if you're a friend, if you are a true friend, just because your other friend is sticking up doesn't mean that you should be any less a friend. It's more group harmony and stuff, and you feel more comfortable around these people and relaxed and you want to have fun. With the other people, you're a little more serious.

This episode came from the individual interview, and Mel suggested that being with friends does not mean that you must blindly follow them or not disagree. Rather, being friends meant that there was a built-in respect and comfort that allowed the group to function effectively. The point here was that by knowing the others as friends, group interactions were facilitated, and learners could be more or less aware of this aspect of group functioning.

Abby's social positioning with her group meant that they allowed her to work in her own style. And she had an awareness of this as characteristic social behavior for her within the group:

Int: Are there other things that the group lets you do, that you couldn't do by yourself?

Abby: Yeah, they let me go off task.

Int: Let you go off task?

Abby: yeah

Int: And you want to do that?

Abby: Sometimes.

Int: You need a break?

Abby: I feel like chatting.

Int: and the group lets you do that because there's someone else to talk to

Abby: Yeah

Int: And they're probably feeling the same, that it's time for a break.

While her behavior of going off-task (and chatting) may have been distracting for herself and the others in her group in terms of achieving the learning objective, for Abby, her freedom to go off-task seemed to be a necessary part of the relationships within this group as she described during the focus group interview. And, because Abby's group members knew her well, they tolerated and even supported her style of work within the group. For example, I had observed that Abby became more attentive when others in her group repeated their statements, and I asked her about this during the individual interview:

Int: So, I wonder if maybe subconsciously or consciously you choose group mates who will let you do that

Abby: yeah [laughing]

Int: They'll give you that space to do that? 'Oh, that's Abby, she just likes to have questions asked twice.'

Abby: yeah

Abby may not have been aware of it until I pointed out my observation, but knowing she as in a group that supported her style of interaction was a particular kind of attending on her part.

There is an important connection to another dimension of metacognition reflected in Abby's comments above: evaluation. In the group setting, *evaluation* means making judgments, not only about what to attend to, but also the veracity of the ideas being presented by others. According to White (1992), personal evaluation of knowledge is an important element of metacognition, and bringing evaluative judgments to bear on ideas that the group is discussing is a key element for developing group thinking. In this study, Abby didn't really take what someone else said seriously until it was stated more than once. It was only at that point that she began to compare her own thinking to the content of what someone else was saying and started to ask questions in order to seek clarification. How she made the choice of what to attend to when someone else was talking is not clear from her comments: She may have found it difficult to hold the objects of others' thinking constant while monitoring her own understanding. In other words, she may have been easily distracted by what was going on around her. Alternatively, she may have been genuinely challenged by the need to attend to what others were saying and doing, being unsure about where she should direct her attention. It may have been challenging for Abby to share the cognitive responsibility (Palincsar & Herrenkohl, 2002) that was demanded in a group problem-solving context.

Asking questions of her group members was a step in the right direction, but Abby seemed to lack the regulatory awareness that doing so was a productive learning strategy for her. She admitted that asking questions was how she got others to help her to understand the material better. In some situations, asking may have been a simple way to get correct answers. But, she did seem to use others' responses to her own questions to develop her thinking. Her awareness of her own questioning behavior as a learning strategy seemed to be fairly superficial.

Students in other groups felt less stress because of the social relationships they had with their group mates. Chris, for example, was generally a reluctant participant in group activity. However, when she worked with others she knew, the comfort level enabled conversation, as she described during her individual interview:

Chr: Well, first I know the people.

Int: uh hm

Chr: Most of them, so we're more comfortable talking

Int: Okay, so that...

Chr: Even if it's stupid ideas we don't mind saying it out

Int: So that comfort level with them?

Chr: Yeah, if I was placed in a group of strangers, I really don't speak at all.

Chris agreed that the comfort level between the members of her group was primary in order to begin talking together. When they were comfortable with each other, they could relax and share ideas openly. However, in a group of strangers, she admitted to not talking much at all. This awareness may have reflected Chris' shyness, but it also suggested that a comfortable group situation was less stressful for her, and enabled interaction among her group members. Her discomfort among others may also have reflected her perspective on how the community should function.

Community Belonging

Based on a definition of community where individuals want to be participating members (Olitsky, 2007), in addition to having a shared goal (DuFour, Eaker & DuFour, 2004), the individuals who participated in this study demonstrated different levels of engagement and belonging with the communities established within their groups. These differing levels of engagement seemed to reflect individual as well as collective notions of why community participation might be beneficial. When describing what they valued about working in groups and the quality of group interactions, study participants identified the opportunity to share background knowledge, the presence of hardworking or smarter people, a willingness to contribute to the group effort, and thus a willingness to offer encouragement, and, a desire to maintain peaceful relations and derive enjoyment from working with others. These were aspects of community participation that created a sense of belonging for group members.

First, participants in each of the groups described how they valued the background knowledge and abilities that their peers brought to the group context. For example, members of Group B discussed 'idea contribution' during the focus group interview:

Int: Who do you think in the group was making the most contribution of ideas? Anyone in particular or was it all equal?

Adie: I say more these two [motioning to Mel and Evan; Mark agrees]

Int: So you two guys were contributing ideas?

Evan: guess so

Int: And what were you guys doing?

Evan: Bouncing ideas off of each other. Standing up for what we believe in.

This description suggests that Mel and Evan both had a great deal of background knowledge and life experience, aspects of which they offered to the group as ideas to bounce around. Consistent with the socioconstructivist frame for this study participants' descriptions of group functioning underlined contribution to learning of sharing ideas with others.

A significant question during Group B's focus group interview asked about adding a hypothetical group member to the mix:

Int: If there was another group member, hypothetical group member, that you'd like to add to this group to make it a more effective group, in terms of learning and doing the task, what kind of person would that be?

Evan: a smarter person

Mel: someone who knows everything about animals

Adie: somebody with more knowledge

Mark: like Mr. Brennan [all laugh]...A smart person maybe.

Mel: somebody with a lot of experience

Group members' responses suggested that, even though members of Group B collectively had a great deal of background knowledge and experience, they felt that adding someone with more background knowledge (such as their teacher, Mr. Brennan) and greater intelligence or experience could make their group more effective. In a way, this discounted their own knowledge and experience, but affirmed that the community valued the expertise that others brought. When asked about this during the focus group, Adie replied:

> Yeah, but there are things that we don't know, and then if we had a smarter person or [someone] with more experience, then the work would have been done faster and there'd be more stuff on the paper than what's there.

The same question was posed to other focus groups, and similar responses were offered. For example, Amber (from Group C) commented:

> Just you know, like, kind of background knowledge, so if you know that they've read all these books and did all this stuff then chances are they're probably right. So that's the kind of person I like to have in my group.

Amber also clearly valued background knowledge in terms of its contribution to achieving the group product. In terms of the group context for learning, individual background knowledge was part of the subject of the activity system, but was tightly tied to the participant's thinking about the qualities and benefits of group work (within their communities of learners).

The quality of group participation and interaction was a community value according to participants in the study. During the focus group interview with Group B, Mark reflected this community value: "If you have a hard-working person, you kind of rely on them a bit more." Mark's comment may have reflected low confidence in his own abilities, but he was also acknowledging the value of having a hard-working person in a group. And, while he may have been equating 'hard-working' with 'capable,' his comments nonetheless reflected the esteem held for individuals who contributed in a significant way to the group effort.

In this study, the expectation that participants would work together in groups posed a variety of challenges, one of which was the requirement for individuals to make contributions to the group effort. In addition to contributing ideas, beneficial (and valued) contributions took the form of guiding group discussions or offering encouragement for others. Ann wanted each group member to take this responsibility, rather than leave it to any one person, as described during the focus group interview with Group C:

> If you're the kind of person that kind of takes the lead in the group or you know, something like that, you don't want to have to be the person who says to the other person, 'Well, what do you think?' 'What do you think?' every time something happens. You want to have people in your group that'll just say what they think... and contribute.

In this interview excerpt, Ann was describing a willingness to make contributions to the group, perhaps in offering ideas, but also in offering critique to others' ideas. While Ann did not use these words, it seemed she wanted to ensure that the group had something to talk about. Amber, during the same focus group interview, described a more abstract level of willingness to participate and contribute—to engage with the group in the first place:

> But definitely everyone has to be willing to do it, like I know there's certain types of people who just don't like participating in groups. I mean that's fine—it doesn't work for them, but it's not really benefiting the other people either.

Amber seemed to imply that group participation through making contributions was of potential benefit to all, but only if everyone chose to contribute. Willingness to engage with the group seemed to be foundational to making contributions in the group setting.

Individuals also contributed to the functioning of the group in particular ways. When individuals offered encouragement to others in the group, they were making an important social contribution to the group's functioning. In other words, group function was an object of cognition as well as social engagement. When Abby was asked what she did to contribute to the group, in her individual interview she talked about offering encouragement to others:

Abby: What do I do? Well, if someone doesn't talk for a while I ask them for their opinion, and if they have none I guess that I'll tell them what we were saying, and try to ask them questions again

Int: just to include them

Abby: Yeah, just to include them

Int: Or to make sure they're working too? or doing their share or?

Abby: Maybe to include them so they don't feel alone.

Abby's comments reflect an awareness of others' behavior, an awareness that was not limited to learning behavior. Her noticing others' social behavior seemed to indicate a desire to make sure others felt included in the group discussion. Her awareness was a manifestation of metacognition in the group context, and it reflected her *awareness of risks to others' learning* or social positioning. Encouraging others' participation was important to Abby, which suggested that she monitored others' learning behavior in terms of their understanding, but also to encourage their social engagement with the group. And, this level of monitoring was more likely in a small group, as she explained during the individual interview: "I think I'll watch and if it's a small group, but then if it's a big group, I guess then I won't, yeah, I won't do that as much."

While members of other groups wanted each individual to contribute their fair share, Abby was also concerned over others' personal feelings. As noted previously, she often worked with the same group of friends in biology class, and so, her concern could very well have been a function of her relationships with the others in her group. Her concern seems to be a manifestation of monitoring, evaluation and planning (MEP) in a group setting (when individuals knew each other well). Her monitoring and evaluating happened in a small group, but not in a large one for Abby. So, group MEP may sometimes be less about learning, and more about the inclusion of group members in the activity of the group, which reflects a concern for Engeström's (1987) *rules for social engagement* in the activity system. Including others in conversations supported the notion of group inclusion and thus harmony, and was an important part of group functioning.

Negotiating Rules of Engagement for Group Benefit

Participating in the activity system required students to establish working relationships with the others in their groups. Building relationships was part of community building, but so too developing rules for engagement. For example, Paula reflected on how her group members worked together during the focus group interview: "We're not usually people who defend our arguments, like we're not really fighting kind of people." Her group, Group A, tended to talk openly without arguing as they negotiated their work together.

Another important element of developing working relations within groups for the study involved establishing and then maintaining harmony. Evan emphasized the importance of establishing harmonious relationships when his group settled down to work together, and surfaced this as a goal when planning and strategizing together: The individuals in his group needed to negotiate how they were going to get along before they could begin to gather and process information in terms of their problem-solving activity.

Evan was aware of and prioritized establishing or maintaining peaceful relations: "I don't want to create...gaps in between people, I don't know, between other people and myself...because I have to work with them again, and there could be tensions." He was concerned over group harmony, and during the individual interview, was asked to elaborate:

Int: Are there other things that are going on when you enter a group situation?

Evan: The first thing I do is the harmony thing, sort of even to how to go about doing the information collection and the answering and then I guess as time goes on it'll get more…I guess a little more heated, so not, I guess, not heated but more arguments.

Int: uh hm

Evan: On both sides right? Because people know what they want. You know that and, yeah, you want to get it right but at the beginning you don't want to, I don't know, want to strain the group's relationship in the beginning.

Consistent with Leont'ev's (1979) focus on how activities are embedded in a social context, data from this study suggested that social relations determined what part each individual played in negotiating the rules of engagement. The point of negotiation could be where people had to sort out how they would interact together. Negotiation involved effort and concern directed right at the beginning of the group's work together, where belonging to the group was prerequisite, and then the group could proceed to the object of its work.

Enjoying each other's company seemed to be a part of several groups' relations, and hence, how they established a sense of belonging. Mel, who was also in Evan's group, saw part of the group's effectiveness in its ability to have fun together. When asked about this, she said, "It just worked." Given that the school community had a strong academic focus, this group's members all subscribed to strong academic focus. But as Mel continued during the focus group: "I would say its every class, like we're serious about our academics, but we still have fun, like, our teachers, even though they are serious, they're still fun, you know, they realize that we're only kids."

While perhaps less serious about academics than Group B, members of Group D also commented about the importance of having fun together and enjoying each other's company, as described during their focus group interview:

Int#2: You said you work together. What makes you want to work together?

Sus: She's funny.

Int#1: That's a great question.

Sus: Because she makes the work more fun. It makes it entertaining, I mean she makes jokes out of it and is pretty funny sometimes.

Int#2: [to Mary] What about you?

Mary: She has a lot of knowledge, and I don't [laughing] and she's really fun to work with.

While the girls in this group valued knowledge that others brought to the group, having fun together seemed almost more important, and was a fundamental reason why they wanted to work together in group activity. And, as we have seen in this section, willingness to work with others in the community was perceived as an important entry point to group activity by participants.

Belonging to the community involved establishing and maintaining group harmony. Harmonious relationships among group members meant that individuals had enjoyed each others' company fun together, which supported their collective effort.

Negotiating a Division of Labor

A final quality of group work that was highly valued by participants and important for negotiating the social space of the group, was the opportunity to share responsibility for work (i.e. division of labor). Participants focused attention on the need to divide up responsibility. Evan explained why dividing labor was beneficial during the individual interview:

> I think it makes it a lot easier, like a little less stress because you know that other people will take care of some jobs and you can split it up and the work so that you have [less] to go through. Instead of going through an hour of work, you can go through 20 minutes and the other person will take 20 minutes and the other person will take the other 20 minutes and it just makes it easier knowing that you don't have to think about everything rather

just honing in on one specific aspect.

For Evan, dividing up responsibility (e.g. division of labor) was partly about efficiency and getting the job done, but also about being able to focus attention on a 'specific aspect.' Presumably, he felt that he (and others) could do better, more comprehensive work on a focused aspect of a larger task.

Sharing responsibility during a group task was of benefit to everyone, but negotiating this social aspect of group work was not without its challenges. Evan liked group work because he felt the division of tasks allowed each person to do really well on one part. Evan trusted that others would focus on their respective parts since they had responsibility for just one part. This was a very interesting perspective that tied trust in others to division of labor during group problem-solving activity. He seemed to assume that in dividing tasks in this manner, each group member would then make a superior contribution to the group product. Of course, taking responsibility for a share of the responsibility also assumed a willingness on the part of each member to engage in this way.

This section has taken a philosophical view of community and reviewed the rules for engagement that groups established as they began their work together within the activity system for the study. Background knowledge and experience were both valued in terms of contributions to group discourse. But, in addition, individual willingness to engage with the group and offer contributions were both essential elements for group functioning. With this background, the individuals began their work together. Several of the study groups placed high value on having fun together, which is part of what promoted willingness to engage with each other and the problems that were set out in the problem-solving activities during the study. Sharing responsibility was one way in which groups in the study divided labor. Adopting roles within the groups was also a part of dividing labor during group activity, and this is addressed next.

Adopted Roles as Division of Labor

In this section, I examine how the division of labor was negotiated by participants through the roles they adopted within the groups. The division of labor is one of the corners of

Engeström's (1987) activity system triangle, but it cannot be considered separate from other components in viewing the system. In this section, the notion of how roles within the group were adopted (or shared) is explored. Participating students adopted certain types of roles as they engaged with the problem-solving task and others in their group. How students understood the need for these roles, their perceptions of the leadership role and how these roles divided up labor within the community are the subsections presented here.

The Need for Different Roles Within the Group

As I analyzed data from this study, I focused attention on the various roles participants adopted within their groups. I also sought to understand how students' roles were mediated by individual perceptions of themselves as thinkers and learners.

During focus group interviews, students' conceptions of their own roles were identified and elaborated. Each group was asked the same basic series of questions to help them consider the roles adopted by different members (see Appendix E for focus group interview protocols). The excerpt below, from Group B's interview, offers an example of how students identified their own roles within a group. Note that participants required some prompting during the focus group interviews to think about possible roles, so you'll see here how the interviewer offered names for possible roles to spur discussions:

Int: I'll give you some examples: the idea-giver. There are some people in groups who are good at giving ideas...There's people in groups that are the scribes... There are people that, the deep, sort-of, thinkers and they wait their time and make the contribution sparingly. So, there's all sorts of roles people adopt. I wonder if you could self-identify your own roles that you adopted in this particular group and what they would be. They don't have to be the ones I've described.

Evan: Just in this group?

Int: Just in this one.

Adie: I'm the scribe.

Evan: I'm not quite sure what I am.

Adie: You're the idea-giver and critical analysis.

Evan: Sort of a mix.

Int: You'd be a mix of what, would you say?

Evan: Critical analysis, idea-giver, deep person.

Adie: [laughing] You don't sit back and just

Evan: No, I don't sit back, but

Adie: [pointing to Mark] He's the deep thinker.

Evan: When I'm giving critique I can still think about something that's coming out.

Mel: You think before you say something. You really think about it.

Int: Mel?

Mel: Um, I would say I was kind of an idea-giver as well.

Int: Ok. [to Mark] How would you describe your role?

Mark: Deep thinker, just kind of like wait and then when I would think something, when I think I should, input my idea.

Adie: He nods when we ask him something.

Mel: He did put in input a few times.

Some guidance was necessary in order to help the students talk about the roles they had adopted in this group. Some common language was important, along the lines of the study by Thomas and Mee (2005) where they helped their Grade 3 students develop suitable language in order to talk about learning processes.

While choosing among the various roles, the focus group conversation continued, where students offered further explanation for how they saw their roles in the context of the group.

Group B is quoted here, but similar conversations occurred in all four focus groups. Students seemed to become more certain of their own positions when given the chance to talk about them, as will be seen in the upcoming section.

Idea-giving was often seen as a whole group rather than individual role. After all, the group was given a collective task, and the students were expected to work together. The members of Group D talked about this during the focus group interview:

Int#1: I want you to think about just the group work. Can each one of you tell me what role you feel you played in the group learning? Like you may have been a critic, an idea giver or a controller and so on. Let's start with you.

Shel: Maybe an idea giver.

Int#2: Would you agree?

Int#1: Does everyone agree with that? Anybody else was an idea giver?

Abby: I think all of us are idea givers.

Shel: Yeah. [everyone agrees]

Abby: We have...every one of us has some part.

In working together as a learning group, each of the members of this group contributed ideas for the others in the group to consider. Which of the group members supplied ideas became an important source of background information for others in the group. Often, it was Evan who checked facts, as described during the focus group interview with Group B:

Int: Evan, you're saying here that you made sure of facts.

Evan: yeah

Int: What does that mean?

Evan: I just know a lot of useless facts. [all laugh]

Adie: He does.

Mel: A lot of experiences.

Evan: I just have a really good long-term memory and really bad short-term memory and once I see something I can just remember it.

Evan had high *SEMLI-S* scores for self-efficacy (4.5), constructivist connectivity (4.6) and control of concentration (5.0). As manifested in this problem-solving setting, he was a knowledgeable and capable individual, who, despite a bit of self-deprecation in the quote, held a personal storehouse of background information and experiences that he offered as ideas to his group. The others in his group also acknowledged his contributions to the group effort.

When Mel was asked about her role in this group during the focus group interview, she replied:

Mel: I would say I was kind of an idea-giver as well. I think I would usually give ideas. I know it is hard to say because I don't think one person could be categorized as just one thing in a group.

Int: If you were to summarize yourself, what kind of role would you be in this group?

Mel: I don't know the word for it. [laughing]

Int: Try and describe it.

Mel: I'm not very good at analyzing myself. I guess I kind of gave ideas, but sort of led the group along the questions.

Here, Mel identified her own leadership role in the group, but also seemed to understand that there was a sort of fluidity to which role was adopted in the group. In a way, roles were categories, and since there were several individuals working together in the group, categories were more dynamic than a particular label might allow, meaning that several people might have stepped in to lead.

In three of the four focus groups, one or more individuals adopted a leadership role. It is significant that in this study students were asked to work in groups of four, with other students with whom (in many cases), they had not worked before. This meant that there was usually an initial phase of group interaction where individuals had to sort out some basic rules for engagement in order to get acquainted before getting down to work. The 'leader' was often someone who stepped in to initiate this process. In Group C, Ann and Amber both acknowledged that it was Ann who usually stepped in to lead:

Ann: I think I was the one that said, 'Yeah, that's enough—next question' [everyone laughs]

Amb: Yeah, yeah, like the leader.

Ann: I personally just kind of like take charge of any situation, unless someone else takes control then I'm like [shrugs shoulders]—'okay.'

Int: Okay. Well, that's good.

Ann: But I think the group doesn't work if everyone is kind of like

Amb: taking control

Ann: It doesn't work if everyone takes control.

Amb: And it doesn't work if

Ann: And it doesn't work if no one takes control.

Amb: Yeah.

Ann: Everyone's like, 'Who wants to say something?'

Amb: And then you just end up sitting there and no one says anything—someone has to start it.

Ann: I'm the one who goes, 'Okay, You, what do you think?'

Both Ann and Amber recognized the need for someone to initiate group activity, but also acknowledged that the group would have difficulty if too many (or not enough) people chose to exercise control in this way. The leadership role involved directing the group effort to keep it on-task, but the leader also guided responses by making sure everyone was included, and Ann was the one who stepped up to take the role in Group C.

Ann had a high score on the *SEMLI-S* dimension of self-efficacy (4.3), which seemed to also be associated with those who took leadership roles in the groups. Among the other groups, individuals who stepped in to lead also had high self-efficacy: Mel (4.5) and Evan (4.5) (both in Group B). Conversely, Glynnis, in Group D, also had a high SE score (4.7). It was interesting to note during observations that no one in this group took a leadership role, and during the focus group interview, no one identified themselves (or others in the group) as 'leader.' In the context of this group of friends who often worked together, it may have been that they did not need to have a leader in order to get the job done. Unfortunately, I was unable to explore this aspect of Group D's dynamics any further.

During the focus group interview, Mark was asked how he slipped into his role of quiet thinker in Group B. His response seemed to demonstrate a sort of group awareness, which included acknowledging the different kinds of roles played by other members of the group:

Mark: If you have a hard-working person, you kind of rely on them a bit more.

Int: So, you were sort of like the quiet?

Mark: Yeah.

Int: 'Thinker in the background' here, every so often, interjecting ideas. Is that a role that you like?

Mark: Yeah.

Int: Yeah? That's a role that you adopt in other groups?

Mark: Yeah, I don't mind it at all.

Mark's self-efficacy was lowest in his group (2.8), and perhaps because the others were very high on self-efficacy scores, their dominance may have intimidated him. But he did offer ideas to the group, and other group members acknowledged the value of his doing so. Of his *SEMLI-S* profile scores, he was highest on constructivist connectivity (3.6), which may have suggested that his quiet thinker role and apparent passivity during the group discourse was actually an effective way for him to engage with others' ideas and hence the possibility of building new and deeper understandings.

Individuals within the community of their groups adopted roles that served to focus attention, control and action over the goals for the group's activity, which in this study was the problem set as object of activity system. Individuals adopted certain roles within the group, and these may have served different purposes, yet the roles were both fluid and situational.

Within Group B, Evan saw himself as an idea-giver, Adie saw herself as the scribe, Mel stepped into the leadership role and Mark was the quiet thinker. And, as Mel suggested, these roles were situational. Later in the focus group, they were asked to comment on roles that they actually preferred:

Int: These roles that you're operating in in this group and you've self-declared, are there other roles that you would prefer to operate in?

Adie: Depends on the project that we're doing.

Int: Well, give me an example.

Adie: If it was like something that was a big chunk of our mark, I would like to be in control of it because I know I'll be doing the best I can, so the mark that I get will be what I get, the highest I can get. So, it's not that I think other people can't do as well, it's just that I feel safer if I do it myself, yeah, but then usually in small tasks, I don't mind letting other people lead. I prefer other people leading in small tasks. Makes my job easier.

When asked if there were other roles that she preferred, Adie chose to talk about the nature of the task and how *other* peoples' roles contributed to her mark. Her comments seemed to reflect a belief that the group could not do as well as she could alone, even though, as she suggested, "it's not that I think other people can't do as well." She may have been reflecting a lack of confidence in others' contributions, but also a strong interest in being in control of her own learning. It may have been that her sense of group work included a loss of control, or at least a diminished ability to substantively manage the end result.

While the primary attention during the interviews was on what the individuals and the groups were doing as they worked on problem-solving tasks together, there were occasions where the students reflected an awareness of the group's efficacy, a sort of 'group awareness' of how roles were important within the group:

> Adie: We're pretty well-rounded though, because we kind of balance each other.
>
> Evan: We all take a lot of positions.
>
> Adie: And so we can't really put another specific role in there.
>
> Mel: Yeah, I have to agree. I think we all adapted to the different roles—
>
> Adie: that's needed for group work
>
> Evan: And what one person lacked, the other person had or two people had together, they could make up for the other person.

Individual awareness of the personal roles adopted, as reflected by members of Group B, included a complementarity to their respective roles. Along with their earlier assertions that the group functioned well without the contributions of an additional person, this awareness suggested that the adopted roles were a functional component of group problem-solving behavior. But, the roles were more fluid than might be surmised by the nature of the focus group questions that asked them to identify their own roles in the group. And, even though most of the group members had not worked together previously (with the exception of Mark and Evan), they came to know each other as learners as they attended to these roles. Attending to individual roles was an aspect of group awareness that included attending to how others in the group thought and worked together.

In this section, the roles adopted by individuals within their groups for the study were identified and elaborated as an important component of the activity system of the problem-solving groups. Individuals adopted roles within their groups, and agreed that these roles served different purposes. Among these, idea-giving was a role that all group members shared. Other roles seemed to be related to individual metacognitive profiles as adopted for group problem-solving behavior in that particular group. For example, the quiet thinker in Group B was lowest in his group on the *SEMLI-S* dimensions of metacognition and he offered input sparingly. Leaders tended to be high in self-efficacy. The role of the leader was of particular interest and the next section is devoted to elaborating this very important role within the problem-solving groups from this study.

Perceptions of the Leadership Role

Within the learning groups for this study, the individual who took the leadership role had a significant influence on group activity. In this section, Group B is primarily referred to in order to focus discussion on students' perceptions of the leadership role. Through probing deeper into the leadership role in this group, a better understanding could be gained about how particular individual metacognition mediated this aspect of group learning activity.

The two students who adopted the leadership role in Group B both had high self-efficacy scores on the *SEMLI-S* (each scored 4.5 on SE). Mel and Evan both adopted a leadership role at various times within this group. Mel self-identified her position as leader in a group, and this leadership role was a key line of questioning during the focus group interview:

Int: Ok. And Mel, you said sometimes you're leading the group. Do you normally do that, do you think, in groups?

Mel: I would say yes because I have a lot of leadership experience and I've led a lot of different activities in the school and I'm the President of the Leadership Club.

And I've gone to a lot of leadership camps and learned the different skills you need to lead a group and so it's kind of a natural thing for me now. I try not to be too controlling or bossy either because a good leader should always listen to what other people have to say. So I kind of, I'd say at times, I'd maybe step in to steer the group or direct the group when needed.

Int: Are you conscious of that? Or is it that you're kind of operating on a sort of automatic level?

Mel: Well, I think it was really weird watching myself because I didn't really notice a lot of those things. I don't think it's really conscious, I think it's automatic. I guess I just kind of know how to do it, like I don't think about it.

Mel described herself as comfortable in the leadership role, which was also apparent from observing her interactions with the others in Group B during problem-solving activity and the interview. She seemed to suggest in the excerpt above that her 'natural' ability to lead had developed through her training and experience as a leader. She saw herself in this role and identified several key attributes for a capable leader. Mel was aware of the fine line between being facilitative (e.g. one who listens well) and being 'too controlling or bossy.' Mel admitted to not really noticing her own leadership behaviors (since they were 'automatic'), and her comments were a likely consequence of the research directing her attention through interview questions and video observation. With the video review activity, watching herself in action was a new experience for her. She noted a lack of conscious attention to her positioning as leader and a consequence of this may have been that it kept her from using that position to her own benefit as a learner, as described during the individual interview:

Int: When you're exercising your leadership role, kind of subconsciously, how does that work for your learning? What does it do for you?

Mel: Um, it's a difficult question.

Int: It is a difficult question.

Mel: I guess it helps my, um, I think part of being a leader is not being afraid to ask questions and so I do ask a lot of questions and when I don't understand something or I don't know something, I will ask to get clarification or even if it's the silliest thing to ask, and I think that helps with my learning. Leadership-wise, that's tough, I've never thought about that before. Um, I guess that's the way I function.

Mel seemed almost embarrassed when she realized her lack of self-analysis about the leadership role she generally adopts. But, asking her to elaborate her own perspective on the leadership role gave her a chance to make a personal connection between the role she adopted and what it did for her own learning. Her lack of understanding of her role as leader in terms of learning may have reflected her average self-awareness (AW=3.2).

Mel characterized herself as a 'natural leader.' Others in the group may have had similar natural leadership abilities, yet did not automatically step in to lead. In the case of Group B, Evan had similar *SEMLI-S* dimensional profiles to Mel (Evan: SE=4.5; AW=3.0). The similarity between Evan and Mel across these two dimensions of the *SEMLI-S* may have been linked to parallel tendency to 'step in to lead,' but their approaches to leadership were quite different. During the focus group interview, Evan was asked about his perception of the leadership role and how he came to be in this role in Group B:

Int: Are the roles that you described, your behavior in this group, the same as you can self-identify in other groups?

Evan: I kind of place myself in the situation, so if there's someone who is not up to the job of leading, I can take it, but I usually like to just go behind and give suggestions.

Int: So, you can lead, but your preference is not to lead?

Evan: Yes. My preference is the lead-follower. [others laugh]

Int: But, in the absence of leadership, you think that you would step in?

Evan: Yeah.

Evan also seemed aware of the need for a group leader, and would step into the role if he determined that there was a need for him to do so. What could account for the different approaches these two individuals took in terms of adopting a leadership role? One possibility is that Evan had a more particular personal knowledge of his own self-regulatory behaviors and strategies and their positive impact on his learning and group behavior. This seems to be consistent with Evan's very high *SEMLI-S* dimension of control (5.0), which is in direct contrast to Mel, whose own dimension of control was average at 3.0.

Evan made deliberate decisions about the role he adopted in the group, decisions that seemed to be situationally influenced by several things: his desire to develop understanding as he worked through the assigned tasks; his attention to the capabilities that other students brought to the group, in terms of ability to lead; and, his monitoring of others' perceptions of him as collegial and 'not bossy.' This type of deliberate control made for powerful learning behavior for Evan within this group context. He offered his own substantial background knowledge to the group and attended to ideas and examples put forward by others. He also played a key role in sharing workload, generating ideas, guiding discussion and elaborating thinking, aspects of his learning behavior of which he was aware. Thus, Evan's strong metacognitive knowledge, skills and behaviors within the activity system of this group significantly enhanced this group's effort. Applying conscious control to not only the task but also the role adopted in the group seems to be characteristic of Evan and less so of Mel.

As conceptualized for this study, *Control* in the group included thinking with and processing the ideas of others in the group. Evan's behavior in his group suggested that he was a careful, deliberate thinker, who listened intently to others in the group setting, processed ideas contributed by others and drew from those ideas to develop sophisticated conceptual models. This type of behavior was consistent with his dimensional profiles on the *SEMLI-S* (AW: 3.0;

CC: 4.6; CO: 5.0; MEP: 3.9; SE: 4.5). Evan strongly exhibited what could be called *Control of Concentration*, which is part of the broader control described by Gunstone (1994), and is the basis for decision-making about actions directed towards a learning goal. In self-regulating his behavior, Evan's control seemed consistent with Gunstone's view of control (i.e. attention to the nature of decisions made and actions taken), but since he was working in a group context, sometimes in the role of leader, this had potential consequences for his own and others' learning.

Asking students to talk about their roles in the group provided an opportunity for them to think more deeply about their own learning behavior in the group. Mel's preference for the role of leader was explored during the individual interview:

Mel: I kind of like to lead because I want to get things done and I usually have a particular way of getting things done, so if I can sort of direct the group, that helps me.

Int: Does it help your learning though? Do you get to be a better learner?

Mel: I don't think so because I guess this way everyone's voicing their opinion when you learn new things. Like there's a lot of new things that Evan mentioned that I didn't know before and Mark mentioned that I forget.

As leader, she encouraged each person to contribute to the discussion and interjected responses and ideas throughout the dialogue. But, as mentioned earlier, she seemed to lack awareness of how this kind of behavior was beneficial for her own learning. It was clear, though, that by drawing out others' ideas, she learned new things.

Others also perceived a benefit when Mel took the leadership role in Group B:

Int: How does it help you guys when she takes the leadership role?

Adie: Well, we get things done.

Int: The task? The job of the questions?

All: Yes.

Int: Ok, what else? Could you see Mel's role as being useful in the group?

Adie: Of course, yeah, we need leaders and not exactly followers but...in groups, there's always going to be leaders.

In Adie's view, group leaders had the job of keeping the group on task and managing progress toward task completion. She saw the leader as task-director, and even though Adie also had high self-efficacy and control according to the *SEMLI-S*, she was happy to let others lead the group.

Adopting a leadership role may have been deliberate, as with Evan, or automatic, as with Mel, or avoided, as with Adie. Chris, in Group A, talked about not wanting to be in a leadership role. Among the members of her group, she had the lowest *SEMLI-S* score on self-efficacy (2.0) and during the individual interview, I asked her to talk more about her perceptions of the leadership role in a problem-solving group:

Chr: I don't like being a leader so

Int: you don't

Chr: I'm pretty [in]decisive and not as like, um, have that confidence when I say stuff—like other people do

Int: So ... so good leaders have to be confident and bossy?

Chr: Well not bossy, but you have to know what you're doing when you tell this person to do that. I'm just afraid to say anything.

Chris' low self-efficacy was revealed when she talked about being someone who will not step in to lead. When asked if she would learn more if she were designated leader in a group of people who felt comfortable together, she reluctantly agreed: "Would I? I think so, yeah...because usually leaders have to handle everything right? And then if the members had anything to say, if they have problems, they tell you." Even though she recognized that being a leader could help her own learning, she resisted this role. Chris was also lower than average (or lowest in her group) on all of the other *SEMLI-S* dimensions. But, she was a strong student, earning a mark of 88% in Biology. In terms of Chris' learning through positioning herself in the group, she appeared to be aware of the expansive potential for her own learning through leadership, but she was reluctant to assert her own agency to take this role.

Mark was also happy to let others be group leaders. As we saw earlier, Mark was the 'quiet thinker' in Group B. Near the end of the focus group interview, each student was asked about what he/she had learned about himself or herself from watching the group on video from the problem-solving activity. Mark reflected on his own position in a group setting:

Mark: [I] kind of like to agree with people more than I like to have conflict with people. So I tend to let people who do better than me at school or [are] somewhat smarter, that I think they're smarter, so I kind of let them take leadership more than me.

Int: Is that something that you've just recognized about yourself or is it something you've always known?

Mark: Kind of always known I guess.

Mark felt that he had 'kind of always known' that he let others lead, but it was probably reinforced for him both by watching the video of himself and the interviewer asking him about this behavior. His admitted tendency was to avoid conflict, which seemed consistent with his low-to-average self-efficacy on the *SEMLI-S* (2.8). This self-efficacy rating suggested that he may have lacked confidence in his own thinking and action, and his behaviors of letting others lead and adopting a quiet thinker role seemed consistent with his low-to-average self-efficacy.

Both Evan and Mel were effective at evaluating others' ideas, considering how these ideas fit (or didn't fit) into their own thinking and then using these ideas to elaborate their own understandings. This was part of their leadership roles, and a type of learning behavior that reflected high individual self-efficacy: “people make causal contributions to their own functioning through mechanisms of personal agency” (Bandura, 1993, p. 118). But, the group also benefited when several individuals exhibited this strong sense of personal agency to offer ideas and reasoning to the group for consideration. Self-efficacy was one of several self-regulatory behaviors. Others include strategy selection, self-instruction, goal setting, etc. (Zimmerman & Schunk, 2001) that were aspects of how individuals engaged with a learning situation, and how they sought to construct meaning.

Theme Summary

Within the activity system for this study, individuals within their groups negotiated belonging to the group, rules for engagement, a division of labor as reflected both in shared responsibility for outcomes and in the roles adopted by group members. The focal point or object of the activity system for the groups in this study was the problem set that offered a group problem-solving context. The school community where this study took place encouraged individualistic values of effort and achievement. In the group problem-solving context of the study, individuals within their groups were challenged to work together in ways that they had not usually experienced within this biology classroom. Background knowledge that others brought to the group setting offered important seeds for discussion within the group context. Also, individuals needed to negotiate the terms of their interactions, both for solving problems together and to be an effective group. This involved adopting roles within the group, but also social behaviors that facilitated group interaction.

Roles in the group were adopted in order to establish a division of labor within the community. For some of the students in the study, stepping into a role was automatic, and for others it was a deliberate positioning. Individual self-efficacy was linked to adopting a leadership role within a notable group from this study. Individual metacognitive profiles on the *SEMLI-S* seemed to suggest patterns for the type of engagement in adopting a particular role in the group. The roles then established a division of labor, where individuals participated in the group discourse and problem-solving activity.

Group Processes as Context for Problem-Solving Activity

While individuals within a learning group may have had other goals in addition to learning objectives, the focus of this section is the group context where individuals worked together towards the object of their activity, namely a learning goal. In the case of this study, the object of the activity system was a set of problem-solving activities that required group interaction. Additionally, the problems enabled individuals to bring their prior knowledge and experiences into the group context. As this happened, the individuals in the group negotiated and elaborated meaning collectively. In this section, I continue to consider the sociality and interactions among individuals in the group context in an activity system (directed toward group cohesion and comfort with another, which enabled further interaction toward a learning goal), while focusing more intensely on how students' efforts were directed towards knowledge construction. Figure 4.3 illustrates how I foreground discussion and analysis on aspects of the problem-solving system as situated in the activity system established within this study.

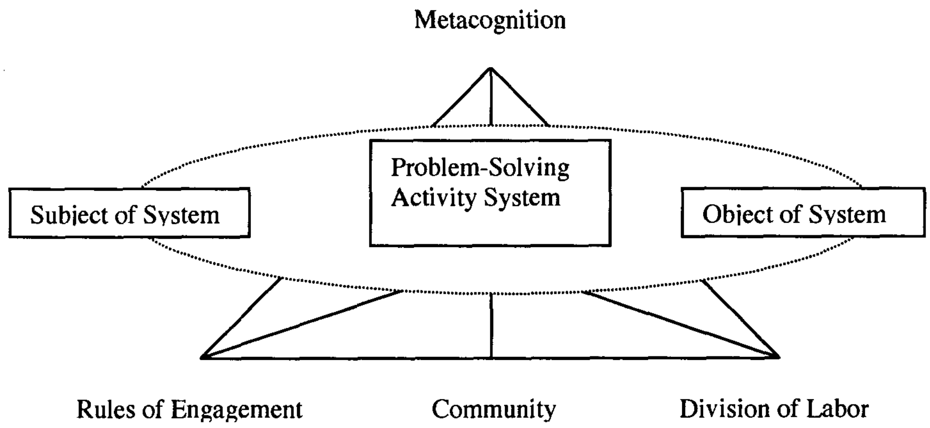


Figure 4.3 Subject/Object Dialectic Focus within the Activity System Model

In this section, the process and context of group problem-solving activity is considered through the subject and the object of the activity system (the subject/object dialectic), being mindful that it was through social interaction that the groups engaged in collective problem-solving activity. Attention is focused on how individual prior knowledge, behavior and metacognition were brought into the group context, and how they manifested as individuals in groups engaged with the problems and with each other. Sub-sections presented here describe individual agency within the group, affordances for problem-solving in the group context and the group as subject of the activity system.

Individuals as Agents in the Group

Findings from the study suggest how individuals used metacognitive knowledge, skills and behaviors to exert personal agency during group problem-solving activity. It appeared that expressions of individual agency as part of the group's activity may have been a function not only of individual self-efficacy, but also of concern over social dynamics and one's own position within the group. And, through the process of group engagement, personal awareness may have developed, which included perspectives of the self and how one thought about the self as a learner.

The group context provided opportunity for individual attention to be directed towards both individual and group learning behavior. Within the context, individuals presented their own ideas about the problems. These were then explored during the group's discussions. Group B used the group problem-solving space as a rich environment for exploring their own ideas as well as developing meaning collectively. Recall the discussion earlier, where Evan backed down from pushing his own point of view about where sand dollars lived. In this section, the interaction is revisited to consider how this series of dialogues led to group meaning-making through personal agency exerted by individuals within the group:

Int: What did you resolve?

Evan: can't remember

Mel: splash zone

Adie: the top one

Int: In the splash zone—did you think it belonged up?

Adie: We're the ones.

Mel: Evan wanted...he thought that the sand dollar was

Adie: in the second zone

Mel: like near the ocean because it needs water and

Adie: and then we thought that was at the first zone and then we prevailed

Int: How did you do that? How did you end up with your ideas being the dominant ones? That the group accepted?

Adie: We knew that the sand dollar was small and it would be in the sand, and the color is dull, so it lives in the sand. And a hard shell too

Mel: and you find a lot of them on the beach too

Adie: so we were going with those points and then he was, I forgot what he was saying

Evan: [that it] needed water

Consistent with Bandura's (1993) view of self-efficacy, Mel, Evan and Adie were all exercising their own agency in pursuing a group response to the question, as they monitored its construction. When different ideas were presented in the group, with strong personalities to back them up, group resolution became problematic.

Even the video record of the group reviewing the video of the problem-solving activity showed the group continuing this debate. Clearly, they found it difficult to come to a mutual understanding. Each individual, with the possible exception of Mark, was highly engaged both with the topic and the others in the group. In fact, during this exchange, Mark admitted: "I was just sitting back and letting them kind of duke it out because I didn't really want to get involved in that discussion." He may have sensed that his own ideas were vulnerable to attack in the exchange, while the others seemed to each want to make their points and have their views built into the group's response to the question about where the sand dollar lived. While Evan was certain of the correctness of his belief (that sand dollars live in the intertidal zone that is immersed only some of the time), just as Mel and Adie were convinced of their own (incorrect) views, Mark did not offer any opinions at all. In this exchange, Evan actually backed down and allowed Mel and Adie to 'win.' Mark was a usually quiet person, and shared his reluctance to enter such a heated discussion. To enter the fray would have been truly risky for him. Evan was willing to engage on the level of arguing with Mel and Adie, but even he, too, eventually backed down. Individual ratings on the self-efficacy dimension for Evan, Adie and Mel suggested that they would be actively engaged, and this was indeed the case. Mark's average self-efficacy rating of 2.8 suggested that he would have felt much less confident in his own learning (relative to the others in his group), and this also seemed to have a bearing on how he engaged within this group context.

There was an obvious give-and-take during the group's wrestling with the issue of the sand dollar's home. Evan admitted to a personal awareness of a limit for how far he would push his own viewpoint and showed concern for how others perceived him. He admitted later in the interview that he had seen sand dollars "in the wild" and knew that they lived in large groups on sandy beaches at the edge of where the lowest tide uncovered them. The others in the group had decided (contrary to his suggestions) that sand dollars lived higher up on the shore, more in the "splash zone" or in-shore area. Evan chose to back down, and noted, "if they feel that their answers – mine or the other peoples ideas, [work]...as long as it makes sense." He was willing to record a group answer that suited the others.

While Evan eventually gave in to the position held by Mel and Adie, during the subsequent individual interview, I asked him what went on for him as he listened or attended to the group's discussions:

Evan: I just look at the information and get to things like positive situations I guess and` sort of connect them and think of an answer or a hypothesis or guess.

Int: And so you're listening to what the others have said and you're thinking about what they were saying as they're saying it.

Evan: Yeah, I figure out what I know, what I think will happen, what the others have provided, the information and, yeah, sort of reflecting on all that.

In considering the information offered by others, Evan used his strong beliefs about his own efficacy as well as constructivist connectivity and assembled bits and pieces that built his own understanding. This was Evan's individual conception of the subject within an activity system, but, as individuals within the group talked about a collective response to the sand dollar problem, the subject of the system was the group. Evan also seemed to recognize the importance of giving everyone a say in the group's product, even if others' answers were not ideal according to his own thinking, or what he believed (or knew) to be true. And, he may have been reflecting the dual nature of the object for the system under study here: attention to the problems out of an individual perspective and, the group level where a common outcome was to be produced. Negotiations happened at both the individual and group levels, and this was a part of the problem-solving context for the study.

Evan also questioned how strongly others felt about their proposed answers, weighing his desire to be correct, while he worked to maintain his social position and acceptance within the group. He maintained his position in this group through skillful dialogue and active listening. Mel also listened carefully as others spoke:

Mel: Well, I still think my own idea is right, but I will think about what they said and sometimes what they say, if it just makes sense, I'll go with it and be like, 'Yeah, that's true. Good point.'

Int: So it kind of builds on your own understanding. Does it ever change completely how you thought about something?

Mel: Sometimes. Sometimes it will, and sometimes it will add on to my idea or change my idea a bit to incorporate what the other person said.

Int: So, if you're working in a group then, do you end up knowing more about the topic than if you were doing it by yourself?

Mel: a lot of the times, yes.

Mel seemed to be more in a comparative mode as she listened when others talked, and weighed the evidence and justification provided in comparison to what she already understood. She did acknowledge, however, that ideas contributed by others sometimes did get incorporated into her own thinking. When this happened, the real power of group activity was demonstrated: students experienced other ideas, applied a critical view and then, considered how to integrate the ideas into a more elaborated understanding. This was highly metacognitive behavior, and for Mel and Evan at least, their effort at joint knowledge construction seemed related to their high self-efficacy and their ability to use what others knew to construct their own understandings. But, sometimes, the pieces didn't fit:

> Int: How do you tell if it doesn't fit?
>
> Evan: If too many things are wrong with it—like if something's wrong from what I know, then it's contradictory, or it couldn't be true...[or] it's impossible.

As noted before, in a group, Evan sometimes acceded to a group idea, even if he recognized it as wrong. In a way, he was holding two stances (Claxton, 1993) simultaneously, perhaps even collateral views (Jegede, 1995) in his thinking: what he knew to be true, and, what the group had negotiated as a common response.

This made Evan a very interesting group member: he was highly metacognitive and exhibited self-confidence in expressing his views. He brought his wide-ranging background knowledge and experience to group discussions and problem-solving activity. But he was also aware of his own social position within the group (recall that there were two other individuals in this group with high self-efficacy) and he worked to maintain group harmony. While Evan had an average score on the awareness dimension of the *SEMLI-S* (3.0), he was highly aware of his own social position, which in the context of this activity system represented a very important facet of group behavior within the community of the classroom and the school. His risk-taking in the group was balanced with his need to maintain relationships. He didn't want to seem bossy, or do anything to build tensions, and was concerned about how others saw him. His concern over social relations and his social position was a risk to group learning (and potentially his own too). When he backed down on what was actually true about the sand dollar's habitat, he left his group members with a partially-developed and partially-justified understanding as recorded in the group's response to the problem set question. The personal risk to Evan (in terms of his group members' perception of him as bossy) outweighed the risk to the group's learning. In this case, the group did not benefit from Evan's greater understanding, which he had gained through personal experience. The desire to maintain social harmony may have been a *coyote* (Anderson & Nashon, 2007) or predator to the group's knowledge in that his concern for maintenance of social harmony prevented the development of deeper understandings by all his group members.

In his concern for group harmony, Evan analyzed the task demands and selected or adapted strategic approaches as he made these sorts of decisions (Butler, 2002; Butler & Cartier, 2004). It also seemed counter to the notion that the group was a place to develop rich and more sophisticated knowledge. But developing richer knowledge depended on the individuals within the group having rich, diverse background experience from which to draw during discussions, plus adequate concern for group harmony that included helping to enrich others' understanding through group deliberations. Background knowledge plus group discussions appear to, in combination, comprise the necessary 'something to be metacognitive about' (Brown, 1987).

Individuals in other groups also exhibited similar types of learning behavior to Evan and Mel. Abby, who was a member of Group D, was interviewed individually later in the study. She was asked what went on for her when others talked during group discussions:

Int: Are you thinking about things as other people are talking?

Abby: I'll think, 'oh, that's something new.'

Int: And it fits in somewhere?

Abby: Yeah, I'll try, and then sometimes maybe it doesn't fit, but they'll want to tell others what they are thinking.

Int: Is it so others can question it or so that they understand what you are thinking?

Abby: Both. When you question something, maybe you're questioning yourself as well and you get to learn something new about yourself.

Abby attended to what others said in the group discourse, recognized new or different ideas, and used this information to enrich her own understanding or learn something new about herself as a learner. Her comment indicated awareness of her processes of learning content knowledge, but also her growing awareness of herself as a learner. Abby is attending to both the content of the discussion and the state of her own knowledge, which is metacognitive awareness within the group context. While her self-efficacy score was about average (3.7), Abby's reflection on her own learning behavior was highly metacognitive.

Asking the students to watch themselves and then talk about what they saw in such observations made them consider their own thinking (as well as that of others), thus making the observations as objects of cognition. Watching themselves on video was an unfamiliar experience for many of the study's participants. Watching themselves on video offered an additional focus for metacognition, while at the same time engaged participants in language-making, which, according to Newman (1999), is how "we collectively and consciously create and re-create all sorts of things, including relationships, identities, narratives, decisions and ourselves" (p. 172). Awareness of the self as a learner seemed to have three aspects or perspectival views: watching the self; thinking about the self as a learner; and, risks to the self.

Observing the self on video seemed to provide an opportunity for participants to gain new perspectives on personal learning (and social) behavior. For example, when Mel and her group members watched themselves on video, they observed themselves showing excitement, demonstrating growing confidence and showing interest in communicating new ideas or understandings to each other. These were facets of growing awareness for both the individual character of consciousness directed toward the learning objective (consistent with Anderson & Nashon, 2007) and the learning processes and strategies used by others in the group during their work together (consistent with Marton & Booth, 1997), but on a group level.

The act of watching themselves (and other group members) seemed to make these students think about themselves as learners, which was potentially critical in terms of developing personal awareness of a learning situation. This kind of watching, which could have been from any observer perspective (and not necessarily video), might be a key aspect of metacognition, where one's self or one's own thoughts might be held as objects of cognition. The personal character or consciousness of the self or one's learning strategies is *metacognitive awareness* according Anderson and Nashon (2007), but this is not the same as *awareness of risks to learning* as described by Thomas et al. (2007) and assessed on the *SEMLI-S*. In the current study, watching themselves through the eye of a camera focused students' attention on learning and other behaviors, of themselves and each other. They noticed aspects of the group dynamic that were risky to themselves. This prompting of participants' attention to learning behavior was critical to the conduct of this study, for their resulting reflections offered a key window into students' perceptions of themselves and their own metacognition.

Affordances for Problem-Solving in the Group Context

Through collective activity during problem-solving, what an individual knew and understood could be brought into the group context. This section discusses what I observed and interpreted about the affordances of the problem-solving activity, which were suggested when codes for individual metacognitive knowledge, skills and behaviors overlapped with codes associated with the sociality of the activity system and the problem-solving context for the study. In this interface, the subject and object of the system dynamically interacted: individual knowledge became available to others in the group; individuals within the group contributed to the group effort while monitoring what others were doing and saying; the problems to solve were a focus of attention and fostered learning about learning; and, understandings developed collectively.

In this study, creating a group context for problem-solving activity afforded opportunities for the individual knowledge held by one person to be available to others in the group, and for the group to benefit from having different perspectives present, somewhat consistent with Johnson, Johnson and Holubec's (1990) recommendation that heterogeneous groups are usually a better arrangement for bringing in different perspectives, which involve more giving and receiving of explanations. Part of the assigned task for the groups in this study was to collectively build responses to the questions on the problem set, and as such, the group's interactions toward this end were responses to and part of the problem-solving context. The interactions that took place in this context demonstrated the dialectic relationship between the subject and object within the activity system framework: The individual was part of the group, and the group worked toward the object of the system.

In their focus group interview, Group C discussed their group effort through the picture-sorting task of the problem set. In that context, the group's interaction with the images gave individuals a chance to call up background knowledge, which was used to negotiate with others in the group. Each organism was to be placed in a zone on 'Sunset Beach,' decisions that were to be made collectively:

Ann: The chart, it says in a big way, 'I think this belongs there,' 'I think this belongs there.' I got to look at them and I grouped them together.

Amb: That's what I got.

Ann: It just kind of stuck in my head more, because I could do it myself, I could look at the chart, pick them up, place them.

Int: Were you getting this from other group members?

Ann: They kind of told me, 'Here, you arrange them,' and so I was like, okay, and then I did it, and they said, 'Actually I think this one belongs there.'

Amb: Yeah, and it was okay. This makes more sense there and then…

Ann: that makes sense

Amb: Yeah, and so of course we had a kind of an outline and then we went into detail.

In a way, the image-sorting task was a hands-on type of activity that Ann mentioned as enjoyable for her as she could personally manipulate the information. The images were also similar to, but not exactly the same as, creatures that the students had seen at the Aquarium during their class field trip. Amber and Ann talked about trying to make sense of all the pieces of information they collected through the problem-solving activities and from their prior knowledge, during the focus group interview:

Int: When do you concede that something is making sense?

Ann: Well, if it works with what you already know.

Amb: What you are trying...if based on your previous knowledge, and then somebody brings up a point and you're like, 'oh, I remember that from a while ago,' and then, that works with the new point, then you know it's right, it's kind of like cross-referencing.

This 'cross-referencing' became possible when many different ideas were put out into the group's discussion space and each of the group members contributed information from their own background knowledge. Paula and Chris, who were in Group A, also talked about an episode from the group's work on Questions One and Two of the problem set ideas were offered into a group discussion space which then constituted a site for collaborative knowledge construction. In this case, the group appeared to have had difficulty reconciling the various views that had been offered in the group:

Chr: We were choosing...we were doing the same species again and then, the answers in Questions One and Two are totally different, but they should be linked.

Pau: Yeah, that's how I remember it. We just had all our first answers down and we went to the second question, which is basically part of the first question, like kind of repetitive, and we got all different answers, so we had to go back and realized that one of them couldn't be there.

It was significant in this example that there were a number of ideas, some contradictory, in the group discussion space, which the individual members were monitoring as the discussion proceeded. Paula's group (Group A, which also included Chris, Susie and Mary) became aware that a result wasn't making sense overall, which was a consequence of how individuals in the group were engaged with each other and the problems. The 'making sense' part was developed through dialogue, as they realized collectively that their answers were inconsistent. Questions 1 and 2 on the problem set caused a challenge when the group realized inconsistencies in their responses and the need to link their responses to the two questions. In other words, the response that had been recorded *didn't make sense*, and it was the group context that enabled this realization. Establishing that the recorded response did not make sense represented monitoring on a group level, which may have been a function of one or more individuals coming to this realization of not making sense and sharing it. Jost et al. (1998) argue that individuals are very "sensitive to social and situational demands for novelty, informativeness, accuracy, relevance and clarity" (p. 143), and the making-sense efforts in this group reflected how the social and problem-solving contexts mattered.

In this study, the group context offered opportunities for individuals to make contributions to the group effort. For Glynnis, the group helped her to monitor her own knowledge construction process. During the focus group interview with Group D, the interviewer asked the students if they had learned anything about themselves by watching the video during the video review activity. Glynnis noticed that others in her group were not making sense of what she had proposed:

Glyn: I guess it is embarrassing looking at yourself because I kind of found that I said a lot of things that didn't make sense. Like I would be saying something and nobody would really get it and it's like, 'Why do I do that kind of stuff?'

Int: How did you know that the things you said didn't make any sense?

Glyn: I think it was the interpreting about something like that and then after I said it, everyone just looked at me like blank face and I was like, 'yeah, okay that didn't work' kind of thing.

Int: Tell me more about that, when you said something and everyone looked at you blank face? What would it suggest to you?

Glyn: Well, kind of like, maybe I should keep quiet for a while.

As described in this excerpt, Glynnis monitored others' reactions as she contributed ideas to the group discussion. Her monitoring of the group's reaction to her was an extension to the individual dimension of monitoring as metacognitive behavior on the *SEMLI-S*, where not only the information or content of the group's object was being attended to, but also the sense of the situation, as it was being developed, by the others in the group and the group as a whole. On one level, Glynnis' behavior seems to reflect Scraw, Crippen and Hartley's (2006) 'imitative' stage (e.g. the lowest stage) in the development of self-regulated learning. But, taking Glynnis' *SEMLI-S* scores into account here suggests a linkage between her high self-efficacy (4.7) and Scraw et al.'s 'self-regulated' stage (the highest stage), even though her behavior appeared to be more influenced by external social factors, at least from observations and discussions I had with her. Her behavior seemed to represent a version of *control of concentration* that resulted from attention to personal engagement with others in the group, and depended on monitoring the group dynamic. Jost et al. (1998) sound a caution: "subjective feelings, sensations and direct experiences are often misinterpreted and give rise to erroneous metacognitive inferences" (p. 146). In this case, Glynnis' perceptions of her self-knowledge may have been no more or less reliable than her perceptions of others' knowledge, skills and behaviors, but her interpretation of her own behaviors in the group (as well as perceptions gathered through others' behaviors) directly influenced her own self-perceptions, and hence, her behavior in the group. These self-perceptions were thus a result of feedback from the group.

In the above example, the interviewer went on to ask the others in the group what was going on for them as Glynnis recognized they were not making sense of what she had said. Caz suggested, "Maybe we're thinking about what you said?" Caz, as she attended to the way Glynnis reacted to her group members, may have responded appropriately, for Glynnis' lack of making-sense may in fact have been an appeal to her group for help in making her own version of sense.

While Glynnis and her group were actively making sense through one another's perceptions, a possible consequence of not attending to the sense made could have resulted in an early abandonment of wrestling with the material to the point of becoming satisfied rather easily that a result was adequate or 'made sense.' Early closure is also possible if discrepant information goes unnoticed or is ignored. Such a result may also a function of metacognitive monitoring and evaluation. Baird and Mitchell (1987) listed 'premature closure' as an inadequate learning behavior that was due to inadequate decision-making and poor processing habits. But, as in the above example, when several of Glynnis' group members also monitored and evaluated the on-going dialogue, there was a greater opportunity for discrepant information to come to conscious awareness for all. Monitoring others' reactions in terms of sense being made during group discussions was an important part of self-regulatory behavior (Butler, Beckingham & Novak Lauscher, 2005), but applied to the group problem-solving context, for scrutinizing others' ideas and subjecting one's own ideas to such scrutiny could be elaborative for group dialogue and here, it opened potential for developing deeper understandings during the group's problem-solving process.

As another example of premature discussion closure, Group C became satisfied with their responses quite quickly, and this satisfaction seemed to center on the adequacy of response rather than sophistication of thinking. To them, consensus indicated that they had reached a correct response. As Amber reported during the focus group interview, "if four people can agree on one thing, they must be onto something." Group C, more than any of the others, was looking for a 'right' answer, which had the result of stopping further questioning. The group completed the entire problem set in about 15 minutes. Their written responses to the problems suggested a superficiality to the group's thinking, with an obvious focus on task completion. Their group monitoring and evaluation of the problem-solving process did not include attention to the suggested time duration for each question. The members of this group were all low-to-average on the *SEMLI-S* dimension of monitoring, evaluation and planning (Ann: 3.1; Amber: 2.1; Nevin: 3.2; Earl: 3.1). In this group, Ann and Amber were more in charge of the group effort, and their low-to-average MEP scores may have been related to the group's ease at achieving quick consensus along with their willingness to be satisfied with the response: Their *SEMLI-S* MEP scores suggested Ann and Amber may have lacked sophisticated evaluation and monitoring behaviors as individuals and thus were unable to bring them to the group context. This lack of evaluation and monitoring may also have accounted for their task focus, in that they seemed to perceive completion of the assignment as the goal, rather than building deeper understanding through problem-solving activity. Ann and Amber's group seemed to adopt a performance goal orientation, as compared to mastery goal orientation, as examined by Turner and Patrick (2004). Students with a 'mastery goal' focus tend to value the effort of a learning opportunity, even if it is difficult, and use mistakes as opportunities for learning, while students with a 'performance goal' orientation prefer easier tasks in order to demonstrate their competence by making it look easy. Task completion is itself a primary goal within a performance orientation.

Even though she seemed to adopt a task focus, Amber perceived accessing a range of ideas and perspectives to be of benefit:

> I feel like I need to bounce my views off other people for information, because I'm not always sure if I'm right and the security of having a group, to support me with my ideas or to correct me if I'm wrong, is really good for me.

Amber was a student who really benefited from being with others in a group learning situation. She could see how others drew on their background knowledge as well as metacognitive knowledge, skills and behaviors, and had a chance to interrogate these, and thus learned more about herself as she gained a deeper understanding of the material being studied. For Amber, participating in a group activity offered rich learning opportunity.

Learning about the self as a learner was an important possible outcome of group activity in this study. Some individuals felt that when they worked together in a group, they got more work done than they could have when working alone. Shelly and Abby offered this perspective during the focus group interview:

> Int: How did you find [these] discussions? Anything you learned about yourself?
>
> Shel: I learned that I guess I work better with, in groups than alone. We get more things done.
>
> Int: So is that something you realized? You realized...
>
> Abby: yeah after [doing the activities]

This study enabled individuals to attend to their own learning and thinking processes, and participation in the study resulted in growing awareness of the self as learner through the experiences presented in the study. For example, working in a group, allowed Chris to attend particularly to new things she learned about herself as a learner. Towards the end of the focus group, Chris wondered about how others handle learning situations, and this brought a realization that it depended on who you were working with. Chris seemed to understand that individual personalities in the group mattered for individual learning efficacy. Indeed, when analyzing individual learning in a group setting within this study, it became difficult to sort out where individual thinking (or action) stopped and started. The gap between the individual and the social is a contested issue in social cognition research (see for example, Hutchins, 1991; Resnick, 1991), yet seems grounded in how an individual comes to attend to his or her own thinking within the wider group context for learning activity.

Being aware of others in the group, in terms of their learning behaviors may have been productive for engagements in the group, but it may also have served a more social, inclusive function when someone in the group was being quiet. Amber expressed concern in this regard during the individual interview when she was asked about difficulties she perceived with group work:

> I guess sometimes, with a group there's so many opinions, so much to say that one person can finally get as much to say as other people, like if one person is kind of shy, you know doesn't really talk a lot, but their ideas might be really really good but they're not really heard—that's the only problem I think with a group.

Chris had also noticed when others were quiet. I asked her about this noticing during the individual interview:

> Int: Do you think that in that interview setting that there were things that didn't get said? Because there was a group there?

Chr: like for?

Int: for you or for anybody …

Chr: well I know Mary didn't say anything

Int: she was very quiet yeah

Chr: she's, like she's not...usually [she's] very, very loud

Chris had noticed that during the focus group interview Mary had been very quiet. For Mary, this was unusual behavior, and although Chris didn't really offer an explanation for Mary's reticence, it may be that the focus group setting was unusual and perhaps disruptive to Mary's thinking so that she was unable to talk about its impact on her behavior during the focus group. In the more familiar setting of her own friends and colleagues, she presented herself quite differently, as a loud, boisterous and active contributor to her group's effort. Both Chris and Amber noticed others' quietness, which became an opportunity to try to include them and bring them into the conversation and indicated a strong social component to the group's problem-solving activity.

If we want students to understand themselves as learners, both in terms of understanding risks to their own learning and how they attend to aspects of the learning environment (and value this self-understanding so as to put it into service for learning activity), the examples cited in this section suggested that knowledge of self as learner can be developed, or at least prodded along in its development, by asking students to be reflective about themselves during group problem-solving activity. In this study, drawing attention via video records, and through problems that required ways of interacting that were out of the ordinary, or were novel in terms of how information was presented, offered rich possibility for learners to think about their own metacognitive processes and skills and how this awareness could later be put to use to better understand themselves as thinkers and learners. On an individual level, this information was important, but as it came into the group setting, an additional social layer was added.

Students also commented on knowing about others' learning styles. Amber commented about her knowledge of Ann, who was also in her group: "I know that Ann is a pretty visual person like I am, so I think we both kind of learn visually." Attaching a label of similarity in terms of learning style, in a way, helped build an alliance between these two students. But learning about differences also seemed to help some students to understand themselves better. For example, Chris noticed that her peers used different kinds of strategies in other situations, and asked about this at the very end of the focus group interview. She not only appeared to have a growing awareness of how others were learning, but she also suggested sensitivity to how learning is influenced within a group settings, in her question: "Does it vary with who they're working with?" It may have been that because she was in the situation of a focus group interview where conversation was happening around aspects of learning behavior, that own questioning was brought to the surface for discussion.

Amber suggested that information about others' learning could be remembered for future reference:

> You might learn a lot of new things to go with the project and you're going to learn a lot of new things about the people too, so if you know how they work—if you know someone's really good at what they do, you can use that later on...in another group situation.

Gaining a level of familiarity was a possible entry point to future working together. Being aware of difference, but also about others' strengths or weaknesses, was important background knowledge for future encounters. Thus, in this study it appeared that social awareness was a discernment skill for interaction in a group setting, and that it could develop when working with others who were not familiar, and that it involved metacognition applied to a group setting.

One aspect of this discernment was recognizing others' learning behaviors. Mark was aware of who the hard-working people were in his group and used this to advantage: his own, and arguably, the group's too. Hard-working people made sure the job got done. They often did the key organizing tasks and encouraged others' contributions, or in Mark's case, allowed him to contribute when he was ready, rather than pressuring him for responses. It seemed that all individuals in the study valued hard-working others, but some <u>are</u> such while some merely regarded it highly in others. And, when performing together, participants were in a position to witness others' learning. The opportunity to witness was an important aspect of metacognitive awareness in the group context.

Asking students if and how they recognized others' learning may have been odd for them. I asked Evan how he recognized that there was learning going on:

> Evan: I guess everyone accepts the same answer and all say, 'oh yeah, that seems the answer.'
>
> Int: It seems reasonable?
>
> Evan: It seems reasonable, yeah.
>
> Int: Is that where that making-sense comes in?
>
> Evan: Yeah, because everyone can connect so then we know.

Connecting the generated answer to what each group member considered reasonable also made sense: the group could then feel satisfied with their response.

The questions on the problem set themselves mediated students' engagement with others in the group. For example, the questions were open-ended, and thus, there was more reason to be engaged with others in the group. Amber called these types of questions "maybe questions," and they were interesting because they elicited a group process of meaning-making:

> I mean if it's opinion, then you have to provide reasons. You have to provide proof in order to make everyone else believe that you are right, so if your pattern of thinking is logical then obviously people are going to listen to that because it makes sense.

In her comment from the focus group, Amber suggested that reasoning ability, on an individual level, was necessary in order to convince others in the group of an opinion. This ability was important for group meaning-making.

Working through the problems as a group may have also enabled deeper engagement with the material. Chris reflected on her own engagement when she was asked if things were done differently because it was a group activity. During the focus group interview, she offered, "we don't think critically when we are working by ourselves. We won't ask ourselves questions." Chris recognized that individuals within the group questioned ideas under discussion, and as a result, a deeper thinking was prompted. When she worked alone, she did not have access to the range of critical questions that others might have asked. By way of contrast, others could similarly benefit from her critical questions. With the question asking (and answering) came the potential for connecting understandings through the group problem-solving context.

In the group context, there were potentially many more ideas in the group discussion space, some of which may have been contradictory. They may also have been elaborations of other ideas or pieces that could be fit together and used to build more sophisticated understandings (Driver, Asoko, Leach, Mortimer & Scott, 1994). Here is where individual metacognitive knowledge, skills and behaviors came into the group setting, as individuals turned their personal knowledge, awareness, monitoring, evaluation and planning and control into collective effort. These were important cognitive and behavioral strategies for learning (Friedel et al., 2007), and the problems to be solved created these affordances for a group level of engagement.

Group Processes and Negotiating the Object of the Activity System

This section describes general processes that were used by the groups in the study to problem-solve together. Processes included engaging critically with the problems, elaborating thinking by working together, attending to aspects of the problems and negotiating the object of the activity system.

As the student groups negotiated the object of the activity system in the context of solving problems together, the nature of the questions and the need for dialogue within the group seemed to facilitate more critical engagement. For example, in the following exchange, which occurred during their focus group interview, the members of Group A described their process of negotiation:

Pau: I just want to say that when we were working together as a group, we were kind of bouncing ideas off each other and then we kind of get feedback, and when you're working by yourself, I just usually write my idea down and don't think about it again.

Int: Do you think working together in a group would make the answers better?

All: yeah

Int: Than if you worked individually?

All: yeah

Int: Why is that?

Chr: But they're sometimes more confusing because you don't know which one...

Pau: Yeah, that would be the thing. Sometimes we all had different answers, then we didn't know what was right.

Int: And what did you do when you had different answers?

Pau: Wrote them all down.

Int: You wrote them all down?

Chr: no,

Sus: We would talk about it and come to a conclusion, where it's just one answer.

Int: But how would you do that? So, you got different answers and then you would discuss, but what's actually going on in the in-between stages there, as you remember it?

Sus: We would talk about what we feel, and then the other person will say, 'oh, well, that's not right because, blah blah blah' ...and you will think about it, and say, 'oh, yeah, that's kind of true.'

Part of this group's process was a strategy where they collected all the ideas from each person (by writing them all down) and from there, proceeded to negotiate a collective response. Because there was a possibility for many different answers in the questions posed on the problem set in this study, there were ample opportunities for each person to contribute ideas. The process of gathering all the group's ideas involved monitoring and evaluation on both individual and group levels, where every idea needed to be justified and other group members convinced that the idea was a good one.

During the individual interview, Abby described a consequence of how group activity was consequential for her learning:

> Int: Do you see yourself as understanding things better when you have the chance to work in a group?
>
> Abby: Yeah, I think I understand more deeply or clearly because I can always ask my friends. If I don't understand something and, well, sometimes they just, if I don't understand a question, they will tell me, and sometimes what they tell me is more than the question.

Being able to ask others to elaborate their thinking was obviously helpful to Abby, but she also realized that as others explained their ideas, she had a chance to gain deeper understanding. Her questioning strategy also helped to elicit others' understandings, and the potential remained for her to develop her own thinking through monitoring and evaluating others' responses.

Another monitoring and evaluation strategy involved attending to others' capabilities in terms of strengths and weaknesses of learning behavior. Witnessing how other learners went about the process of interacting with the problems to be solved (or interacting with each other) was also part of the group process. Interactions among group members included recognizing and evaluating others' strengths and weaknesses, but also how others' strengths and weaknesses compared and contrasted to one's own. And, how individuals used this information had the effect of making the learner more or less successful in the group setting. Amber commented on the impact of what she knew about her group members' learning:

> You have to know what works and what doesn't—I mean if one person is really good at spitting out dates then you know you use them for that and if one person's really good at the whole visual thing, then you know that's the aspect that they're going to be working on. You know you have to split it up because if somebody is doing something they don't like or they're not good at, or they're not good at learning, then it's not going to work.

There was a sort of instrumentality in Amber's admission of why this type of strategizing was beneficial. Even so, she was aware that individuals brought different kinds of strengths and attributes into the group setting, and this was an important component of good group work. It represented a different kind of knowledge connectivity, one that built from understanding of the social context and how it impacted the learning situation.

The object of the system and focus for metacognitive effort was the problem set and groups wrestled with the content of the questions posed on the problem set. Group D talked about their strategy of developing a common understanding of the questions, which was how they negotiated the object of the group's activity, during the focus group interview:

> Caz: We were discussing the question and trying to understand what the question was asking.
>
> Int#2: Were you discussing as a group? Or was each one of you trying to make sense of what has happened?
>
> Abby: I think we're trying to think in our own way first, and then we got in our group to share to see what we think as a group, and then maybe we're trying to put the ideas into one big idea.

Int#1: What is the purpose of discussing the question?

Glyn: To be sure we understand it the same way.

Monitoring how others in the group made sense of the wording of the questions enabled a negotiation of the object of the group's activity, but also group sense-making, and gave others insight into how interpretations were made. This was very important information for group members, as it served the dual goal of interaction for the purpose of problem-solving and negotiating the object of the activity system.

Other strategies within the group process involved listening as others spoke. Chris talked about this during the individual interview:

Int: So, when you think about what those other people are saying, what's going on in your brain? What are you doing?

Chr: Usually I [consider] if it makes sense or not and then if it doesn't then I think like I'll come back with something,

Int: uh hm

Chr: and oppose it, and then if they do, I'm like, 'Oh yeah, that's true' and I might add some stuff.

Int: When you say it 'makes sense,' what does that mean? Is it familiar? Can you explain to me what that means to you?

Chr: Maybe if I get it. You know some people are so deep right? Usually I just like link other people's ideas to my own beliefs.

Chris felt that other people's ideas made sense when they worked with what she already knew. Chris appears to be making an important constructivist linkage that harkens back to Matthews' (1994) criticism of constructivism: how did the first things get in there? Amber brought up previous knowledge and how when somebody else raised a point, the individual recalled related information in a sort of cross-referencing. Amber's apparent monitoring and evaluating behavior required monitoring of what others were saying as the ideas were presented, and whether they were making sense (or not), with what the individual already understood. By cross-referencing what others have suggested, it seems that sense was being made at the group level.

To make use of others' ideas meant that the ideas were somehow satisfactory in terms of what was already understood. Here is a connection to the *SEMLI-S* dimension of constructivist connectivity and Vygotsky's (1978) zone of proximal development in a group context. Satisfaction, or 'making sense' was sometimes elusive, and rarely could learners describe how decisions were made in order to arrive at a satisfactory point or conclusion. Sometimes satisfaction was tied to the answer being correct and this seemed to be the case among students with a strong performance orientation, but other times involved the use of context clues in the problems. Individual self-efficacy also tied in here, since feeling confident in one's own ability within the group context was part of effective group activity.

When others offered opinions about the topics under group discussion, spaces were opened for negotiating deeper thinking. Group members monitored and evaluated discussions and asked questions, seeking clarification. For the groups in the study, working together was a social learning process, as Amber summed up during the focus group interview:

> We might get to know each other even more through a group. I think it's not just like learning, it's kind of like a bonding experience because you get to know the people you work with, especially if it's a really long group project and you have to work outside the school. You might learn a lot of new things to go with the project and you're going to learn a lot of new things about the people too. So if you know how they work, if you know someone's really good at what they do, you can use that later on if you're working in another group situation and you already know. So it just kind of helps you get the project done.

Learning about the people with whom you worked was part of how the group built new understandings through their interactions and activity. Learning about group members was an outcome of group activity that involved metacognition, as was effort directed toward a group product. And, taking advantage of what each individual contributes to the group product can make for powerful learning. By way of follow-up, during the individual interview I asked Amber to elaborate her perspective on the group product:

Int: Does that mean that the group actually produces a better product than you could by yourself?

Amb: Well, I think sometimes it all depends on the group and the people you're working with but in a really good group situation, everyone will pull their weight and everyone will come up with something really good.

In this excerpt, Amber is acknowledging the contributions that others can make, as well as her own awareness that a good product also depends on the social dynamics within the group. Group effort directed toward a strong product was a common theme throughout this study. Many students understood that bringing many ideas into the group discourse and negotiating a common understanding made for a better product, but that additional social effort was necessary.

Within the groups for the study, additional social effort went into sorting out alliances and complementarities among the members of the group, and sorting seemed to happen naturally through the process of interacting within the activity system. Within a group, it was possible that allegiances were divided in the process of negotiating a solution to a given problem. For example, Group A often split into two pairs, where one pair were the deep thinkers who were often dissatisfied with a simplistic answer, while the other pair happily recorded a simple response and moved on to other questions. The pairing did not appear to be purposeful, but rather may have reflected how the individuals within the group came to the point of thinking the work was 'good enough,' and thus closed down any further consideration. An irony here was that the two who accepted simplistic answers were also the more metacognitive, according to the *SEMLI-*

S. A possible explanation for this apparent discrepancy may be that these individuals did not bring their metacognitive capability into this group setting.

There may, however, have been a more nuanced difference in the example cited above as to how each of the individuals approached a personal learning task that required different kinds of skills than a task that specifically asked for discussion and negotiation. How individuals understood the nature of the group task and thus determined acceptability or correctness of an answer were also important aspects of the discussions within Group A. Discussions within Group A reflected individuals' own perspectives and background knowledge, and thus negotiating task understanding (or belief in correctness) within the group context was a more complicated process, since the several individuals each had their own abilities and interests in managing this negotiation.

In this study, group activities enabled the sorts of monitoring and evaluating that take advantage of what each group member knows. When the members of Amber's group were discussing her ideas, their monitoring and evaluation behaviors offered opportunity for feedback from them, which may have enriched their own understanding through the act of teaching someone else, as in reciprocal teaching (Palincsar & Brown, 1984), but were also meaningful for her own learning. Although whole-class and small-group discussions could have served many of the same purposes in terms of making many different ideas discernable to others, group activities were preferable to working alone, as Amber volunteered during the focus group interview:

> I think it's just better to be in a group than by yourself. Because, if you're by yourself then you have your own ideas and that's great, but you don't really get to talk about it with anyone else to see if they share the same ideas. Maybe you're wrong. Maybe you're right. And I think you can have four different people with four different ideas, and it's just better because you get different views.

As in the example cited, having the chance to talk out ideas in discussion was important for individuals to elaborate their understandings. Discussion could have led to evaluative possibility, where the value or credibility of the idea was judged. Having an idea critiqued is important because working alone could end up in a dead-end, where the individual gets stuck after running out of ideas and ways to engage the problem at hand. Working with others could meant that there is been help available to get past this 'stuckness.' Learners also needed this kind of challenge so that their thinking did not become dogmatic:

Amb: Because you're not always right.

Ann: And you don't always know everything.

Amb: And like when you're stuck,

Ann: Yeah.

Amb: When you're stuck, you're stuck.

Ann: Yeah.

Amb: But when you have a bunch of people and you're stuck, they can get you out of your stuckness.

Ann and Amber recognized the importance of having other ideas available to them through group discussions, ideas to which they could apply their own metacognitive monitoring and evaluation strategies.

As part of the study, individuals brought their own understandings of themselves as learners to the group problem-solving context. Students' metacognitive knowledge, skills and behaviors that had developed over time were also part of the background as they entered the group problem-solving activity for this study. Others' background knowledge resulted in more information to attend to (for others) in the group setting. Taking advantage of the range of information available became an additional facet to the group process, which can then also be part of the object of the group's attention.

In exploring how the social aspects of group function utilize or contribute to metacognitive knowledge, skills and behaviors and ultimately, the building of collective understanding, this section elaborated the group as the subject of the activity system. Negotiations within the group engaged learning behaviors in response to what others in the group were doing and thinking during collective activity, which involved general problem-solving processes and more particular kinds of social engagements, all of which were mediated by individual metacognition. Processes included negotiating the social aspects of the group; listening to others' ideas; monitoring the group process; and, using the group setting to advantage for learning.

Theme Summary

The group processes for problem-solving together emerged out of the social context of the classroom and school communities to which the students belonged. Values held by these communities were reflected by the students and the group activity, in terms of attention directed to the group problem-solving effort during this study. But, individuals belonged to many communities, and the individuals within a group that was tasked to solve problems together may or may not have shared purposes or goals within the problem-solving group. Individuals approached work in the group differently, and this was also a place where they could experience difference. When working with friends in a learning group, the purpose may have been to enjoy each other's company. With unfamiliar others, the goal may simply have been task completion. In this study, groups seemed to self-organize around their objectives, which became the objects of the activity system. The individuals in the groups negotiated how they worked together, and this was how the sociality of the context was negotiated. Negotiations included developing processes and strategies whereby the object of the group's activity became problem-solving activity and group functioning.

Chapter Summary

This chapter began with a discussion of the *SEMLI-S* data that was the basis for observations and subsequent interpretation of student metacognition through the activity system for the study. Subsequent sections of the chapter elaborated themes that developed from the study: metacognitive engagement was promoted through the study context; the social context of the groups' interactions was a negotiated space; and, the problem-solving context as activity system engaged metacognitive knowledge, skills and behaviors on both individual and collective levels. The sociality that is the group (Blitz, 2000) provided the backdrop for all of the interactions among the group members as they worked together on problem-solving tasks during the study.

In this study, the problem-solving context provided a space for individuals to bring their background knowledge of different experiences as well as metacognitive knowledge, skills and behaviors into the group context, offering further possibility for individuals to learn from a wider resource base, as well as to observe how others used different approaches to learning. The context of the activity system allowed consideration of multiple facets to group interaction, including promotion of metacognitive engagement through the study context and the sociality of individual positioning within the group context. Further, the context of the system included individuals who were willing to enter the group problem-solving setting and have their ideas challenged by others. Individuals also brought their background knowledge to the group setting wherein engagement with other group members could thus result in the co-development of meaning, and potentially, a richer understanding of the self as a learner.

The group context was subject of the activity system for this study and interactions within the groups were a function of individual metacognitive knowledge, skills and behaviors. Individuals adopted roles within their groups that seemed to reflect aspects of their metacognitive profiles. Students' learning behaviors manifested out of these characteristics, and the *SEMLI-S* profiles offered a backdrop for observations of aspects of individual metacognitive knowledge, skills and behaviors within the activity system.

By viewing interactions among individuals within their groups, a window was opened into how they used metacognitive knowledge, skills and behaviors to negotiate the sociality of the community. The sociality included the values held by the community of the classroom and school and how individuals positioned themselves within the community spaces. Negotiations established the rules for engagement within the group and labor was divided through roles adopted by individuals within the group context.

How individuals within their groups engaged metacognition during problem-solving activity was at the center of this study (Engeström, 1987; Leont'ev, 1979). Individual agency within the group appeared to be a function of self-efficacy and awareness, and group discussions and interactions offered rich possibility for creative problem-solving. Individuals seemed to benefit from group participation when they used their monitoring, evaluation and control strategies and engaged with the group discourse. The subject of the activity system was the group of students and interactions among the group members were mediated by individual metacognitive knowledge, skills and behaviors. Other aspects of the activity system served to inform how metacognition mediated group processes.

CHAPTER FIVE

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

Through the previous chapter and into this one, the underlying writing and organizational challenge has been how to talk about the system as a whole without breaking it into parts and thus objectifying aspects of the system as if it were possible to make sense of one part independent of the others. When the Marxist notion of *activity* is the basis for how humans exist in the world (Repkin, 2003), the activity system is not merely the sum of its parts, but rather an interweaving of goals, actions, interactions and mediating influences including those past, present and future, which is the cultural and historical context of the activity system. Observing and then describing how learners use metacognitive knowledge, skills and behaviors in the context of this cultural and historical background is challenging. But, aspects of this background were significant as they emerged from the students' interactions and dialogue during their collective problem-solving for this study.

This chapter brings the thesis to a close. The first section revisits the research questions for the study, providing an overview of what was learned relative to each one. The next sections summarize limitations to the study and surface some implications that derive from the study, outlining recommendations for teaching and learning, for curriculum and for methodology. The last sections of the chapter raise questions for further study and offer some final comments.

Revisiting the Research Questions

This section revisits the research questions in turn, synthesizing discussion from the previous chapter.

Sub-Question One: What was the nature of the social context and interactions in which active group learning manifested?

Interactions within the activity system observed for this study were enacted within a particular, multilayered social context. Evidence presented above suggests that the community of the classroom and school set values (e.g. the value of working hard) that were reflected in how individuals described their participation in group interactions, suggesting that members of this activity system had potentially internalized values set in the larger social context. The object of activity (i.e. the problem-solving activities) became the focal point for group or individual work, and within that context, negotiations contributed to establishment of rules of engagement within the system. These rules were subsets of the wider classroom rules for engagement, and were subsumed within them. Labor within the system was divided according to individual needs, preferences and abilities and the roles adopted by participants were mediated by individual personalities and metacognitive knowledge, skills and behaviors. These findings suggested that metacognition provided tools, in the Vygotskian sense, for mediating activity within the system. The problems that constituted the object of the group's activity in the system bound the individuals into collective effort, but were also subject to individual forms and levels of engagement.

In this study, problem-solving groups comprised social settings, where individual behavior seemed to influence the actions of others in the group, and where group learning processes could be observed. The social interactions included all of the individual and collective actions that were sometimes directed toward the group product, but that were also sometimes related to other aspects of the social dynamic, such as interpersonal relations. For example, participants described how their interactions were shaped by their relationships with friends, their individual social positioning and interest in group harmony. Individuals also brought background knowledge (Driver, 1983; Driver & Erickson, 1983) and metacognitive knowledge, skills and behaviors to the group setting, such as confidence in their own abilities and self-efficacy, that served as mediational influences on how social processes were negotiated. The social dynamics established with the activity system seemed to play a significant role in a groups' ability to function as learning groups. Individual awareness was expanded to encompass a wider awareness of group processes, including what other learners were doing, both individually and as applied to the group effort.

Another key theme that emerged in the data from this study was that participants were aware of how others interpreted the problem context, which often resulted in the need to negotiate a collective sense of meaning. This could suggest an important benefit of group discourse, when the members of a group help each other to focus on an object of the group's activity. In this study, however, achieving this benefit seemed to depend on awareness and monitoring of what others were thinking and use of appropriate language and dialogue to communicate. In this study, individual metacognitive knowledge, skills and behaviors seemed to become useful to others when they were shared through discussion or perhaps modeled during problem-solving activity. In a very real sense, sharing these kinds of metacognitive skills and behaviors with others in the group allowed each person to be involved with ideas, and consider how others were thinking about and contributing to learning and problem-solving, which then served as a focal point for development of group thinking. Individual thinking became an object for the metacognitive attention of others in the social sense that Jost et al. (1998) described.

Sub-Question Two: In what ways were metacognitive skills deployed within group settings to empower learners' knowledge construction in novel problem-solving contexts?

Findings reported here suggest that group interaction around the object of the activity system established in this study seemed to enable the possibility of deeper thinking than might have been possible when learners worked alone. Group problem-solving activity offered the possibility for social interaction in which collective metacognitive knowledge, skills and behaviors could be put to use both by individuals and others in the group. Individuals also brought their highly individual backgrounds of knowledge and experience to the collective activity, and these were key focal points for group attention directed toward problem-solving.

But, findings here also suggest that, in order for ideas, background experience and knowledge to have been useful to the group, individuals must have been willing to contribute them to the group discussion space. Only then were monitoring and evaluation skills and behaviors applied to the discussion points as part of the activity system. This may suggest the need for individuals in groups to be open and willing to be challenged, both by direct challenge to their ideas and through challenge created by the ideas that others might present. Social learning experiences might be intentionally designed to enable this sort of participation and learning behavior, so that learners can fully utilize the potential of a social learning experience and individual metacognitive strengths can be of benefit to the whole group.

But, if ideas are not engaged, such as was apparent in this study when some participants deferred to others who were perceived to be smarter, interactions in a group may come to a close prematurely. This suggests a need for the activity of the group to be open-ended, but also, and prerequisite to this, for individual willingness to hold ideas up for scrutiny and to continue engaging with others as different ideas are presented, akin to White's (1998) 'fourth dimension of metacognition.' Willingness may contribute to the social dynamics foundational to the work of a community, since those who were part of a group can be made to feel more or less included by the behavior of others. In this study, this was not necessarily behavior directed toward a learning objective (although it could have been), but rather, a response to the social positions of the various members of the group and the needs and goals of the community. It may have been that a quiet person had a great deal to say, and just needed an opportunity and perhaps encouragement to contribute. Willingness to include everyone was also important, and it was individual monitoring of others' engagement that became consequential here.

In this study, some students, when given the opportunity to work together in a group in an unusual context for this class, realized that they preferred working in groups. This finding suggests that these students were open to the learning situation, and were willing to learn from the experience. But, group activity is not without its challenges. Mel's comment about the need for compromise being the real difficulty of the problem set was telling. When each person had a different idea about the question under consideration in the group, it could be a fruitful place for engagement with each other and the problems. But, it could also be a source of acrimony and disagreement unless the individuals in the group negotiated their way into cooperative and collaborative behavior. Through negotiation, individual metacognitive knowledge, skills and behaviors entered the group context. The nature of the problems, as well as others' metacognitive knowledge, skills and behaviors, became objects for individual metacognition. And, it is through interaction that this negotiation occurred. Davis, Sumara and Luce-Kapler (2008) suggest that interactions are where ideas bump up against one another and therein, "the juxtaposition of various representations might trigger other interpretations" (p. 199). When we design group learning experiences, it is just this bumping and triggering that we hope for.

In this study, working together on a group learning activity provided opportunities for individuals to use their metacognition to monitor, evaluate, and in a way regulate, others' contributions. In this study, monitoring others' reactions to ideas as they were presented seemed to be an important aspect of metacognition in the group context. Often, monitoring and evaluating behaviors were used to ask questions of others while attending to the group discourse, which appeared to then benefit individual understanding. Additionally, individual awareness and attention, as they were devoted to the group process, became highly influential for personal involvement with the group and the learning activity.

As groups in the study began to focus their work on the task at hand, an important negotiation often went on in collaborating to make sure each person understood the nature of the task. It seemed that this activity was important to strategizing for problem-solving within the group. Negotiating task understanding was 'planful' behavior that helped to clarify starting points, individual interpretations and possible ways forward. It is interesting to note how in this study it was the group that included individuals who were all very close on their dimensional profiles for monitoring, evaluation and planning (e.g. Group D: MEP, range 3.2 to 3.4 on the *SEMLI-S*), that adopted a shared approach to their strategizing. Collaborative strategizing appeared to be an effective group learning behavior, and enabled this group to be more highly metacognitive than were the individuals within it.

Another conclusion supported by the evidence presented here is that group effort supported continued persistence on problems. Persisting longer in problem-solving activity within a group had the potential to result in the development of deeper understandings. Findings reported here suggest important linkages between individual dimensions of metacognition and how they were manifested in the context of the problem-solving activity for the study.

For example, Mary recognized that being with others kept her from giving up easily on learning tasks. Perhaps her persistence resulted from a favorable kind of peer pressure, but it is also possible that it was a function of her high levels of metacognitive awareness. Mary's awareness score on the *SEMLI-S* was 4.6. She seemed aware that working alone was a risk to her own learning, since this was when she gave up easily and settled for a simplistic answer. But her recognition of the benefits of working in a group may have been related to her low-to-average levels of constructivist connectivity (2.7) and self-efficacy (2.7). For her, belonging to a group helped her to stay with a task longer, which was of potential benefit for learning.

Persistence also appeared to be a function of self-efficacy, which is consistent with Bandura's (1988) theory, where belief in the ability to succeed is a prime motivational factor for continued effort. Persisting in problem-solving activity in a group context also seemed to require an on-going process of monitoring others' opinions and ideas, which for some subjects in this study appeared to dispose them to developing deeper understanding of the concepts under discussion. Ann's comment from the focus group interview is pertinent here: "What I find is, when I do group work, if I think everyone's ideas are good, I'll keep them in my head and then I can use them later." Being able to recall conversations or discussion topics and then build them into later representations of learning is an individual behavior, but one that may well evolve out of the social context of bringing information into open discussion where individual monitoring and evaluation strategies can then be put to use. Additionally, individual effort as applied to connecting the various pieces of information together can build a coherent view. A wider, more coherent view may then be available later when other kinds of assignments or experiences manage to tap into it. Connecting these various pieces is how individual students in this study appeared to consolidate their thinking. Building on Turner and Patrick's (2004) list of student work habits that indicate participation in classroom learning activity, encouraging students to specifically engage with the thinking of others could reasonably be added to the list.

Another important conclusion suggested by the evidence in this study is that getting to know how others understand information during collective engagement is metacognitive. Attending to others' information processing abilities is a kind of knowledge applied to the group setting. While Amber had the lowest scores on the *SEMLI-S* dimensional profiles among her group members (CO: 2.7; AW: 3.2; CC: 1.0; MEP: 2.1; SE: 2.7), suggesting that she was not very metacognitive, her group behavior may have been more adequately reflective of her own social position within the community of this learning group: there were two top students among her group members, both of whom were well respected for intelligence and thoughtfulness. For her to 'succeed' in this group meant listening carefully as these others spoke, so as to incorporate their ideas into her own thinking and the group product. She may have also learned about how they were thinking, but she used her own monitoring and evaluation skills to take what they said in order to construct responses to the questions. She was also in a position to learn how others used learning behavior effectively, and could then, perhaps, model her own behavior after them, thus extending her own capabilities. This is one way in which shared thinking (Brown & Palincsar, 1989) matters.

Finally, findings from the study also suggest that high individual self-efficacy brought into group problem-solving activity may lead high SE individuals to be more willing to allow others in the group to challenge their ideas. For example, strong beliefs in their own agency, as evidenced by Evan and Mel, seemed to make them resilient as group participants, even when faced with adversarial or contradictory information. Resilience in the face of challenge may thus be one of the values of being highly metacognitive (Anderson & Nashon, 2007). Similarly, resilience could readily be seen as an effect of these students' inclination to seek to develop deeper understandings. And, working as a group meant that these individual understandings evolved through a process of group sense-making.

Sub-Question Three: How did social interactions in group-learning contexts serve to shape, engage and promote metacognitive thinking?

Findings from this study suggest that social interactions in group learning contexts did indeed shape, engage, and promote metacognitive thinking. For example, one conclusion supported by the data reported here is that the nature of the activities established for this study created opportunities to be metacognitive. Hands-on interactions during the field trip and in follow-up activities focused students' attention on the problem-solving activity for the study. Students appreciated the chance for hands-on interaction to round out what they had learned in-class before visiting the Aquarium. The follow-up activities also complemented the earlier classroom and Aquarium experiences. Recalling these experiences served to focus attention on the learning activity, which by asking the students to talk about it, through the context of the study design, revealed their metacognitive processing and strategizing. Because the students were engaged in a series of group activities, the social dynamic also encouraged engagement with their own as well as others' metacognition. This appeared to be a direct consequence of the methods used in this study (Anderson et al., 2008).

When friends worked together, often, the goal of their activity was to have fun together, as Abby admitted. Perhaps being with friends in a learning setting held the same sort of expectation as if they were in a social setting. For the study, students self-selected their groups. In some cases, the groups were comprised of friends. This desire for social interaction may have reflected what McManus (1987) concluded, that the social context and opportunities inherent there offer motivation for engagement in learning activity. But, even in those groups where individuals did not know each other well, there was expressed concern over friendly relations. It may also have been that the novelty of this type of group activity promoted interest in having fun together: Positive relationships (whether the students were 'friends' or not) provided a rich context for problem-solving or other group activity. Then, as the individuals got to know each other, the familiarity and desire to have fun together became a backdrop for the support they could offer each other. Developing positive relationships was an entry point to metacognitive effort at the learning task, but I argue here that this development involved monitoring behavior in a sort of group metacognition, where relationship building and maintenance were important for continued collective effort.

This study suggests that establishing friendly relations was important to working in a group and became a focus of awareness related to the group's functioning. Individuals may have been more or less aware of this aspect of group functioning, or even, as with Chris, have chosen to avoid groups. Chris was uncomfortable in group settings and it may have been that her lack of personal awareness of the possible benefits of group interaction to her personal learning made her uncomfortable in groups. Other students in the study were more attentive to how others functioned socially within groups and this sort of attention was metacognitive at the group level. The need or desire to learn about others' learning could have served to promote metacognition on the group level, and as was suggested by the findings reported here, may have been beneficial to individuals in a group learning context.

While Chris emphasized her discomfort with group work, she did have a growing awareness of differences among people, which appeared to emerge as an interesting result of her involvement with the group and the conversations with her group mates through the data gathering phases of the study. Chris' original *SEMLI-S* score on the awareness dimension was 2.4, and during the study, this awareness shifted toward opportunities for learning, which included how she meaningfully engaged with others in the group. This finding suggests a link between her growing awareness during the study and the claim by Anderson et al. (2008) that research methods can promote participant control and autonomy, which are aspects of becoming more metacognitive. Chris' question at the end of the interview, "Do you think everyone has their own strategies?" was followed by "Does it vary with who they're working with?" These statements put forward at the end of the study suggest a growing awareness of: 1) the difference among and between contexts for learning; 2) the potential fruitfulness of knowing more about yourself as a learner; and, 3) the possibility of selecting approaches to learning situations depending on what is demanded in each. Developing a deeper awareness of the learning context and one's position in it may make for empowered understandings about oneself as a learner, aspects of which were facilitated through the study context. Chris might also have used these ideas as seeds of possibility to consider how an effective learning group might be of positive benefit for her, both in terms of developing rich understanding of the subject-matter content, and for understanding more deeply her own learning processes and capabilities.

Sub-Question Four: What were individual group members' perceptions of their roles and metacognitive skills within the learning group?

In significant ways, in this study, the roles individuals adopted were fluid and the choice to adopt a particular role was situational. Individual roles were both mediated and defined by interaction, which emerged through the activity system as the group (the subject) engaged with the problems (the object). Participants' adoption of roles seemed to be both a function and a consequence of individual metacognitive profiles and learning characteristics. Other aspects of the activity system were also mediating factors for the roles that individuals adopted. For example, the groups of students within this study existed as a subset of a classroom community, which was also a subset of a school community. Students belonged to various other communities too. These communities created overlapping and intersecting spaces that had both tangible and imaginary characteristics and boundaries that served to influence how individuals situated and positioned individuals within them.

This finding is consistent with Leont'ev's (1979) description of the importance of social relationships to the functioning of an activity system. So, the place of the individual in the system is tied up with individual social positioning out of which individual actions within the system arise and tasks and labor are divided. Operations and actions within the system are the result of different goals and motivations, as perceived by the individual, but enacted in the social context through roles adopted.

Each of the groups in the study identified idea-giving as a key role in group work. Idea-giving, in a direct way, is how individuals contribute information to the group. If all members felt confident to make their contributions through idea-giving, the group had a range of ideas to talk about in their work together. Contributions then became part of the social discourse of group work, from which a web of relations and interactions was built among the members of the group as they worked together.

Another key role within groups was that of 'leader.' In this study, individuals within the groups may have seen the role of leader as situational. There was, after all, a task to complete, and if discussions in the group were too unfocused or wide-ranging, the task may have become lost in the wandering. In this study, task completion as a goal generally focused on producing a single, correct answer (even though the problems were open-ended), and leaders took on those roles to facilitate task completion.

For example, during group activity, Mel, as leader, attended carefully to the situation and noticed processes under way, similar to what has been called *awareness* by Marton and Booth (1997). In this case, Mel's awareness was less about risks to learning than it was attentive awareness. Attending to and monitoring the actions and operations of the group seemed to be skills at which Mel was very adept, and in the group, Mel's awareness had benefits for the others in the group because the act of asking questions aloud enabled the others in the group to participate in Mel's own explorations. Thus, *awareness* in the group context appeared to be more than an individual character of consciousness (Anderson & Nashon, 2007) or awareness of risks to learning (Thomas et al., 2007): It also included awareness of individuals' positioning in the group and how adopting a leadership role might contribute to learning activity within the activity system. And adopting a leadership role in this case seemed to be called for by how group processes were unfolding in this particular situation.

The roles that individuals adopted and played out in groups also seemed related to the kind of awareness exhibited during monitoring the group process and elements of control exerted by others. Recall Evan's statement: "I kind of place myself in the situation, so if there's someone who is not up to the job of leading, I can take it, but I usually like to just go behind and give suggestions...my preference is the lead-follower." Evan's situational leadership seemed to confirm the fluidity of roles adopted within the group, but also suggested the need for additional kinds of monitoring behavior in the group context. In an individual problem-solving context, MEP is about monitoring, evaluating and planning around the learning object. But in this study, monitoring in a group setting also involved monitoring the learning or sense-making of others, which included an individual's position in the group and the role that he or she was willing (and, maybe, able, from a personal awareness and self-efficacy perspective) to adopt. In some cases, role adoption may have been a default position, or one that was adopted out of necessity when another person was not up to the task.

Section Summary

This section revisited the research sub-questions and sought to summarize key themes that emerged from the data. In response to the first subquestion, I considered major themes relating to the nature of the social context and interactions in which active group processing resulted. Major themes reported here focused on how interactions among group members mediated learning behavior in the group, particularly the metacognitive aspects of monitoring, evaluation and planning. Additionally, I considered how individual awareness of the learning context opened into a wider awareness of the interactions among people within the group.

In response to the second subquestion, I considered how metacognitive skills were deployed in group settings for the purpose of knowledge construction. Major themes reported here focused on the *SEMLI-S* data as well as observations of group activity. In the study, metacognition was deployed on both individual and group levels. With many ideas and opinions in the group discussion space, individuals held others' ideas and opinions as objects of their own cognition. Individuals exhibited willingness to contribute ideas and challenge those of others. Additionally, the group may have allowed for a greater persistence in problem-solving behavior than was possible when learners worked alone. Finally, the group setting enabled individuals to bring their own varieties of learning behaviors into the group context.

In responding to the third subquestion, I explored how social interactions shaped, engaged and promoted metacognitive thinking. Themes reported in this study explored the social context and the problem-solving context. Within the social context, metacognitive awareness, monitoring, evaluative and planning behaviors were key to social interaction. Through several different research methods, as modeled from Anderson et al. (2008), the group problem-solving context in this study enabled students to connect understandings built from many experiences. The hands-on activity during the field trip and the organism-sorting task in the follow-up activity served to build connections between the social and problem-solving contexts. The problem-solving activities enabled social interaction, and many individuals in this study saw attending to the social context as more important than learning objectives. During social interactions in the group, individual differences and learning strategies became objects for others' attention.

Responding to the fourth subquestion, I considered group members' perceptions of their roles within the learning group. Themes emerging from the study's results here attended to how individuals came to their identification of a particular role within their groups. These roles were related to the individual's learning behaviors and the metacognitive dimensions of self-efficacy, control of concentration, awareness and monitoring, evaluation and planning. To a large extent, the roles adopted by individuals dictated the types of interactions they had in their groups, and the adopted roles were related to their individual metacognitive profiles. In particular, willingness to take on a leadership role appeared to be related to self-efficacy and control, and this role was important for task completion and group function.

Limitations

As in any research study, a number of limitations must be acknowledged. In the study, the majority of the limitations revolved around aspects of the study context and the problem-solving context. The study was conducted in a particular school context, with one classroom and a particular group of students. Themes and patterns that emerged are thus localized to this one site. To search for any wider patterns that may cut across other contexts, similar studies would need to be conducted in other sites. Further to the particularity of the site and context for this study, Royal Collegiate Academy was a private school. Schools each have their own characteristics and culture (Bruner, 1996; Evans, 1996; Lortie, 1975), and private schools are often quite different from public schools.

This study based its pre-screening of metacognitive knowledge, skills and behaviors on the *SEMLI-S* instrument, which used particular definitions of metacognition and learning behavior, and using this instrument was a limitation of the study. Gathering perspectives on metacognition from a wider set of definitions (or even from different instruments) could inform observations of learner behavior in ways that were not possible in the current study. However, the instrument's ability to point to individual students' metacognitive potential is still very important.

The problem-solving context for this study was developed in part because of unanticipated limitations that sprang from the environment of the field trip at the Aquarium, where data recording was challenging, and the possibilities for group interaction were unfortunately limited. Thus, the problem-solving task in which students were engaged was simulated and abstracted from the actual hands-on experience of the field trip. The layer of abstraction (e.g. imagining a shoreline vs. actually observing organisms in natural environments) represents a limitation for how engaging the problem set might have been. The nature of group interactions, and students' engagements in learning, may have been different had it been possible to make the problem-set more authentic by situating it within the actual environment or even a laboratory environment such as the WetLab.

Implications and Recommendations

This section elaborates aspects of the results discussion into implications and recommendations for teaching and learning science, for curriculum and for research methodology. Some of the implications and recommendations are speculative, while others are based more particularly on data from the study or results from other research.

Implications and Recommendations for Teaching and Learning in Science

It is possible to consider teaching and learning as opposite sides of the same coin, meaning that one cannot be described without the other. Apparently, in the Russian language versions of their books, Vygotsky and Leont'ev used a word (*obuchenie*) that was widely mistranslated into English as 'learning,' when in fact, both writers meant "teaching-and-learning" (Stetsenko, 2005). This section includes several recommendations for teaching and learning.

My first recommendation in this section is for students to be engaged in explicit instruction in metacognitive skills and behaviors. Students who earn strong marks in biology, but whose metacognitive profiles on the *SEMLI-S* reflect weak metacognition, might really benefit from being taught to be more metacognitive. Organization for instruction could include building activities that engage thinking about the process of thinking, asking students to reflect on their own thinking, talking about episodes where they noticed that they were actively engaged in thinking about thinking, and participating with other students in open-ended activities that require bringing in other kinds of knowledge (or knowledge acquired from other places besides school). There is also need to specifically attend to how to work with others in a group learning setting, consistent with Johnson, Johnson and Holubec (1990).

To support their development of instructional practices, I recommend that teachers' attention be drawn to the value and possibility of students' more effective use of metacognitive knowledge, skills and behaviors. Lessons and classroom activities could better incorporate skills reflected by the *SEMLI-S* dimensions in order to facilitate students becoming more effective learners and problem-solvers, recognizing that student participation in classroom learning activities are the window that teachers use to gain an understanding of students' thinking processes (Turner & Patrick, 2004). Where a student's *SEMLI-S* score is low-to-average, particular attention could be drawn to that aspect of learning behavior.

Third, novel learning contexts and group problem-solving activities should be developed so as to be engaging and motivating for students, which can then be beneficial for developing metacognitive knowledge, skills and behaviors. Group activity offers the possibility for greater engagement, on many levels, among the group's members. Activity within these contexts needs to call up prior knowledge, allow students to recall personal experiences, share and compare thinking with others, and allow for elaboration of individual thinking. During problem-solving group activity, students can witness problem-solving and thinking strategies used by others, thus potentially building their own capacities for such learning behaviors.

Additionally, there is need to attend to group configuration. When configuring student groups for group activity, teachers should guide leaders to be encouragers and motivators that focus on collective learning. A group leader who actively solicits involvement from group members will more likely help the group to develop a more sophisticated product, along the lines of what Turner and Patrick (2004) referred to as having 'mastery goals.' It is also possible that a leader has a 'performance goal' perspective, and wants to be in control of the group's activity out of concern for the mark to be earned, rather than for learning goals more generally. This perspective may prevent or discourage involvement of others, especially if their own goals are contrary to those of others in the group. The need for negotiation of a common goal (and difficulty in doing so) may thus limit the learning potential of the group and individuals within it.

The learning potential is enhanced when the group members know each other, which suggests that relationship building could fruitfully be built into group problem-solving tasks, even if the problems are intrinsically interesting and challenging. For some learners, an interesting problem is not in itself sufficient to engage with the group. Rather, the problem may be an entry point to which individual judgment is applied for task requirements, often in terms of maintaining a class mark. For some students, engaging with the subject/object dialectic has a prior requirement: the individuals comprising the group must like working together. The social aspect of the group work may take precedence over the learning potential, but the social aspect is prerequisite for active learning together.

And, by deliberately asking learners to be metacognitive, they are prompted to become more so. While on some level this is an obvious conclusion (and easy-to-make recommendation), it is nonetheless significant. By participating in the study, and being given opportunity to consider how they think about themselves as learners, participating students continued to be engaged with the process of devoting attention to their own cognition and metacognition. A student such as Chris carefully attended to her own thinking processes when she was asked about them, and then continued to develop a more reflective awareness of herself during the study and beyond. The design of the study fostered this, but so did Chris' inherent curiosity about her own learning processes. This curiosity may be how someone whose *SEMLI-S* scores are quite low can learn how to focus attention in particular ways in order to develop stronger metacognitive knowledge, skills and behaviors. This line of research has great potential for helping students become more empowered as learners, which as Baird (1986) and Swan (1988) have said is what metacognition enables. Thus, developing stronger metacognitive knowledge, skills and behaviors through deliberate attention to them ought to be an important goal of classroom learning activity.

Students with stronger metacognitive skills and behaviors may be better able to handle the demands of a 'multi-tasking' environment. Many students in the study expressed difficulty with 'multi-tasking' (for example, thinking and taking notes at the same time). It may be that they do not know what to attend to. It could also be that note-taking in this classroom covers too much pre-digested material in too structured a manner. This would mean that learners do not have to pick out salient information and make decisions about it. In a way, this situation suggests the lack of a need for metacognition, which then reinforces static learning behaviors. In the dynamic environment of a social situation (or complex problem-solving activity), there is much to be metacognitive about offering important potential for developing problem-solving skills.

Directed instruction seems so contrary to the high-speed, highly interactive world we live in. Perhaps it is time to consider the complex networked nature of knowledge construction that is usually not acknowledged by highly structured formats for information presentation, particularly in classrooms. This leads to consideration of where and how learners learn what they ought to attend to during classroom activity. Young adults live in a richly connected, highly interactive world where there is much to cause distraction. Learning requires 'a certain slowness' (Cilliers, 2006) for the 'networked brain' to have time to build connections. Groups as learning contexts also have many more things to attend to and it is this dynamism that makes the group a learning space unlike a traditional classroom and more like the wider world.

Implications and Recommendations for Curriculum

In terms of implications and recommendations for curriculum, this section advocates the use of open-ended problems for group learning activity, wherein a broader conception of the nature of knowledge (and biology knowledge in particular) can be the goal for a curriculum design project that engages students metacognitively.

Particular attention on the part of curriculum developers needs to be devoted to the nature of the problems being generated. The nature of the problem matters for enabling the kinds of group processes that engage metacognition: when multiple layers of meaning can be ascribed (out of personal experiences, field trips, text references, other resources) and the problem has no clear correct answer, many perspectives can be brought to bear on the group's problem-solving activity. Groups, like individuals, also need something to be metacognitive about. The problem context needs to enable students to think together in a group, as well as about themselves as learners in a group. It would be reasonable to suggest that the group context can be valuable in expanding students' thinking about themselves and the biology content. The kind of open-ended engagement with problems that had no clear right or wrong answers gives students a context with which to work in an unfamiliar environment (a group setting).

The problem-solving context of the study also offered possibility for the participating students to see the subject matter differently. The problem-solving context also has the potential to enable learners to meaningfully engage with the content and each other, and made them think about their own approaches to learning in a group context, as compared to how they would do it individually, or in a different subject area. This was a limited glimpse into a more open-ended kind of science classroom or form of instruction, but one that could be argued was immensely beneficial for the students who needed to have their opinions valued in order to engage with the subject matter. Students also need to be challenged to broaden their conceptions of the nature of knowledge.

Perhaps individuals within a given group hold differing views on the nature of both learning and knowledge. It is reasonable to suggest that for students to build broader understandings (as well as a broader knowledge base), they need to encounter information on many levels and then be given opportunities to interact with one another to co-elaborate deeper understandings. This is Ausubel's (1968) version of 'understanding' and is widely supported in the science education literature (Claxton, 1993; Driver, 1983; Duit & Treagust, 2003; Greeno & Riley, 1987, Gunstone & Mitchell, 1998; Hodson, 1998).

Students in this study, by and large, held an instrumental view of the nature of biology knowledge that was reinforced through 'traditional' classroom activity. This had the effect of limiting the need for metacognitive knowledge, skills and behaviors to learn biology and it was disconcerting to hear Paula's declaration that "you don't ever think about it, you just learn it." This statement lends credence to the notion that as science educators, we need to more particularly attend to how the curriculum has been responsible for propagating and reinforcing particular views of the nature of knowledge.

This view is consistent with Turner's (2006) suggestion that student activity in terms of self-regulatory behavior ought to extend beyond what the learner is thinking to what the learner is doing: "This dynamic view of student activity and regulation is both theoretically interesting and practically useful for both teachers and for curriculum design" (p. 296). Attending to how learners develop self-regulatory skills and behaviors, using group problem-solving activity as a learning context, becomes a goal for science curriculum development.

Implications and Recommendations for Research Methodology

Consistent with Anderson et al. (2008), methods used in this study significantly influenced participants' metacognition and learning behaviors. Further, this study responds to Anderson et al.'s call to research group learning contexts in order to explore the phenomenon of collective group metacognition. More particularly, the current study used activity theory as a framework to analyze group learning behavior and open-ended problem-solving as the context for learning. This part of the implications section elaborates these two aspects of the study in terms of methodological implications.

What learners do during learning activity will remain an interesting and provocative space for research in metacognition, and dynamism of group learning activity will continue to make this type of work challenging. Through various problem-solving contexts, the potential exists to explore metacognition more generally and seek to elaborate how situationally-developed knowledge, skills and behaviors are applied across contexts. Different kinds of problem-solving activities could be used, for example, as methodological tools for uncovering metacognitive knowledge, skills and behaviors. This study engaged metacognition out of the framework offered by the *SEMLI-S*. It would be interesting to apply similar methods to inquiry models for learning or problem-based learning activity in science or other subject areas. The key aspect of group science learning activity that stimulates metacognitive engagement seems to be providing opportunities to make individual thinking explicit, which when articulated, offers ideas for others to think about and reflect upon, and thus, engaging others' metacognitive knowledge, skills and behaviors.

Questions for Further Study

This study raised a number of questions. This section outlines four questions that would be interesting to pursue as future lines of inquiry arising out of findings from the current study.

The current study was conducted in a school community context that highly valued individual achievement and effort. Classroom organization and teaching reinforced this value. It would be interesting to conduct a similar study in a school that holds different cultural values, for example, where group or communal activity is valued as part of a usual context for learning.

In the biology classroom for this study, it was possible for students to get a good mark yet have low-to-average scores on the *SEMLI-S*. This seems contrary to what Swan (1988) and Baird (1986) have suggested, that those who are more metacognitive are more empowered as learners. The case of Chris is interesting here, because, according to the *SEMLI-S*, she was not very metacognitive about learning in science, but did seem effective or empowered in terms of her mark in biology and her behavior during the study as a highly engaged learner. It may be that in a different context, Chris' *SEMLI-S* scores would be more closely correlated to her achievement. In other words, perhaps other subject areas or courses require the learner to be more metacognitive. This seems consistent with many of the issues raised by Veenman, Van-Hout and Afflerbach (2006), where metacognitive knowledge and skills are distinct, yet defined, described and researched through a series of tensions: conscious/automatic; general/domain specific; developmental, and in complex relation with cognition. Unraveling the case of Chris or learners like her, by exploring her learning behavior in other contexts and through some of these tensions would be another interesting study.

Through the activity system framework, this study suggests a need to attend to aspects of the learning system that are generally not developed in traditional classrooms or curriculum frameworks. This is a major connection to complexity thinking (Davis, 2007; Davis & Sumara, 2006; Davis, Sumara & Luce-Kapler, 2008) and the nature of learning as a collective enterprise.

The current study (and related *Metacognition and Reflective Inquiry Project*) worked with high school students in science classrooms. The notion of metacognition as empowering for learners could fruitfully be extended to an exploration of how adult learners, including teachers, understand themselves as learners in terms of metacognitive knowledge, skills and behaviors and the implications this has for adult learning. In the case of teachers, understanding themselves metacognitively may mean that they can help their students develop stronger and more explicit metacognitive knowledge, skills and behaviors.

Final Comments

This study has contributed to understanding in these important ways. First, I have extended study of metacognition in groups by applying an activity theory framework. Activity theory enabled a view into the context of problem-solving interwoven with the social context of group activity. Group problem-solving activity opened individual thinking to challenge from others in the group, where rich discussions were fostered and collaborative effort was encouraged. The social context provided multiple layers to group interaction. Second, I have illustrated the value of employing multiple methods to the study of metacognition, with a focus on individual and group processes in a way that doesn't divorce them from the social context or the content of science instruction. Finally, I have offered important implications for teaching, learning and curriculum. Implications include the importance of open-ended problems that focus learners' attention within learning groups and engage metacognitive knowledge, skills and behaviors as effective learning behavior within the group context.

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Appendix A: Self-Efficacy and Metacognition Learning Inventory—Science Subscales and Items

(from Thomas, Anderson & Nashon, 2007)

Learning Risks Awareness (AW)
AW1: I am aware of when I am about to have a learning challenge.
AW2: I am aware of when I am about to lose track of a learning task.
AW3: I am aware of when I don't understand an idea.
AW4: I am aware of when I have learning difficulties
AW5: I am aware of when I am not concentrating.

Monitoring, Evaluation and Planning (MEP)
MEP1: I adjust my plan for a learning task if I am not making the progress that I think I should.
MEP2: I plan to check my learning progress during a learning task.
MEP3: I stop from time to time to check my progress on a learning task.
MEP4: I consider whether or not a plan is necessary for a learning task before I begin that task.
MEP5: I consider what type of thinking is best to use before I begin a learning task.
MEP6: I assess how much I am learning during a learning task.
MEP7: I evaluate my learning processes with the aim of improving them.
MEP8: I try to understand clearly the aim of a task before I begin it.
MEP9: I try to predict possible problems that might occur with my learning.

Control of Concentration (CO)
CO1: I adjust my level of concentration depending on the learning situation.
CO2: I adjust my level of concentration depending on the difficulty of the task.
CO3: I adjust my level of concentration to suit different science subjects.

Self-efficacy (SE)
SE1: I know I can understand the most difficult materials presented in the readings of this course.
SE2: I know I can master the skills being taught in this course.
SE3: I am confident I can do a good job on the assignments and tests in this science class.
SE4: I believe I will get an excellent grade in this course.
SE5: I am confident of understanding the most complex material presented by the teacher in this course.

Constructivist Connectivity (CC)
CC1: I seek to connect what I learn from what happens in the science classroom with out of class science activities (field trips or science visits).
CC2: I seek to connect what I learn from out-of-school activities with what happens in the science classroom.
CC3: I seek to connect what I learn in my life outside of class with science class.
CC4: I seek to connect the information in science class with what I already know.
CC5: I seek to connect what I learn from out-of-class activities (e.g. field trips, science museum visits) with what happens in the science class.
CC6: I seek to connect what I learn in other subject areas with science class.
CC7: I seek to connect what I learn from what happens in the science classroom with out-of-school science activities

Appendix B: Prescribed Learning Outcomes pertaining to Intertidal Marine Biology from British Columbia Integrated Resource Package

(BC Ministry of Education, 2001)

- *Examine members of Phylum Porifera and Phylum Cnidaria and describe characteristics that unify each*
- *Demonstrate knowledge of the ecological roles of sponges and cnidarians*
- *Demonstrate a knowledge of the adaptations of molluscs and echinoderms*
- *Demonstrate a knowledge of the diverse ecological roles of mollusks and echinoderms*
- *Describe factors that limit and control population growth*
- *Suggest reasons for cyclic population fluctuations*
- *Solve simple population problems based on changes in natality, mortality, immigration and emigration*

Appendix C: In-class Post-visit Problem-Solving Activity

You and your group are headed to **Sunset Beach** to do some exploring. Your task on this visit is to:

1) Draw on your experiences of marine creatures from the Vancouver Aquarium;
2) Draw on your knowledge of classification systems, invertebrate biology and geography you have learned in your biology and other school classes; and,
3) Draw on your knowledge of ecology, biology, plants and aquaculture from your life experience.

Sunset Beach includes a variety of abiotic and biotic factors, and has four distinct zones that each have their own unique characteristics:

a) Inshore: In addition to the usual "splash" zone, a freshwater stream enters the ocean at Sunset Beach, which has a large seasonal outflow that varies considerably over the course of the year. The streambed is mostly at sea level until quite a distance back from the shoreline. The stream runs through a mostly forested area, until it reaches the shoreline, so the inshore area is host to a variety of organisms, including otters, predatory birds, large and small mammals.

b) Shoreline: The shoreline of Sunset Beach is comprised of large rocks, which at the highest tide of the year are covered by water. At low tide, the rocks are completely exposed to the air. In some areas along this shoreline, tree branches overhang the water, and during the highest high tides, the roots of the trees are covered in salt water.

c) Near-shore Rocky: This zone is mostly covered at high tide, and mostly exposed at low tide. The rocks making up this zone are small (relative to those on the shoreline), and are mostly smooth. For the most part, any tree branches sticking out into the shoreline zone do not reach as far as the near-shore rocky zone.

d) Sandy bottom: Most of the time, this sandy bottom area of Sunset Beach is covered in water. During the extreme tides of the year, some of the sand is exposed to the air. Most of the time, though, waves crash in this zone, and there is great seasonal variation to the size and energy behind the waves. Storm waves frequently rearrange the ocean bottom in this zone, leaving depressions and/or mounds in the sand.

With this information and the attached diagram, work with your group to debate and answer Questions 1-4 below.

1. You have 12 organism cards that represent marine creatures that are thought to live around Sunset Beach. As a group, sort the organisms into the zones where you think they will predominantly exist.
Give reasons and justify why your group put the organisms where you did. (15 mins.)

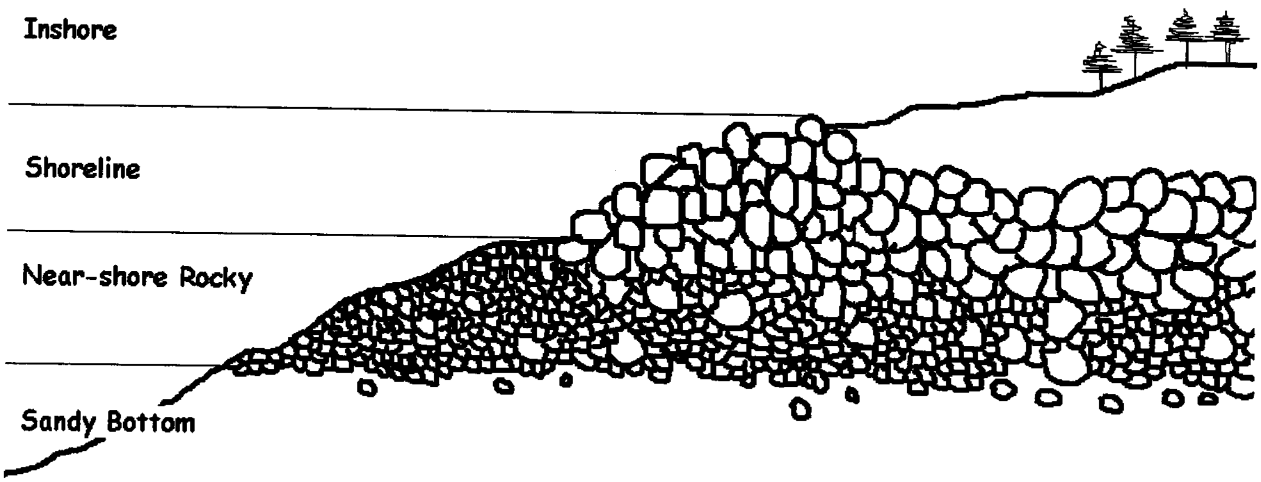
2. Considering the abiotic factors, as a group, decide which of the organisms will be the most successful in each of the zones. (10 mins.)

3. Recently, there has been an unprecedented growth in kelp at the deepest section of Sunset Beach (Sandy Bottom), which a local citizens' group has attributed to an increase in fertilizer and pesticide runoff from a newly developed farming operation 30km up-river. The increased amount of kelp has attracted more otters than usual to the area. Discuss the implications of this on the ecosystem.
(15 mins.)

4. Environment Canada *is debating as to whether they ought intervene to remove the kelp. As a group, decide and justify why this course of action ought (or ought not) to be taken.* (15 mins.)

<u>*Extra Question:*</u> *(if needed) You can normally expect to find crabs in your area of Sunset Beach. However, during a particular season, no crabs can be found in your section. What reasons can you suggest for this? Discuss as many as you can.* (15 mins.)

Appendix D: Diagram of Sunset Beach, for Follow-up Activity



Appendix E. Focus Group Interview Protocol with Relevant Research Questions Identified

[relevant Research Sub-Question in brackets]

1. How did you find your visit to the Aquarium last week? What key things stick in your mind from your experiences during the post-visit activity? [1, 3]

2. How did you find the task of looking at yourself and listening to what was said? [2, 4]

3. Show us your three video clips and tell us why you selected them. [3]

4. In the video activity, how did you each see your role in the group? Probe roles: has the group worked together in other settings? Were you happy with the outcomes and answers you got? Would you do anything to change how the group functioned? What? Is the task of watching the group work better done by a group or by an individual? [1, 3, 4]

5. What did you learn about your own thinking from looking at and hearing yourself? [2, 3, 4]

6. What have you learned about the ways others are thinking in your group? [2, 3, 4]

7. Can you tell us the most important thing that you've told us today?

Appendix F. Individual Interview Protocol with Relevant Research Questions Identified

[relevant Research Sub-Question in brackets]

1. How do you pay attention to what you are learning about your group members as fellow learners? [2, 3]

2. How do you know when **you** are learning from your partner(s)? How do you use this information? Is it valuable for you? Why? How is it valuable? [1, 3]

3. How do you recognize when **your group members** have learned something new? How do you use this information? [1, 2, 3]

4. When entering a group setting (such as this unfamiliar one for the post-visit activity), what kinds of things do you do to help the group function? How do you decide what to do? What does this have to do with your own learning? What other factors come into play when you work in a group? [1, 2, 3, 4]

5. What does the group setting allow for you that doesn't happen on your own? (in terms of learning) [1, 3, 4]

<u>Other possible questions</u> (time permitting)

What have you thought about the group learning process since we last talked? [4]

Does group work help you learn better? How? [2, 3, 4]

How does the task at hand influence how you think about group work? What kinds of things do you consider? How does the nature of the problem you have been asked to solve affect what you do to try to solve it? [1, 2, 3]

Appendix G. UBC Behavioural Research Ethics Board Certificate of Approval

The University of British Columbia
Office of Research Services and Administration
Behavioural Research Ethics Board

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	NUMBER
Anderson, D.	Curriculum Studies	B03-0487

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT

UBC Campus ,

CO-INVESTIGATORS:

Briseno, Adriana, Counselling Psychology; Ellenbogen, Kirsten, ; Nashon, Samson, Curriculum Studies; Nielsen, Wendy, Curriculum Studies; Thomas, Greg,

SPONSORING AGENCIES

Social Sciences & Humanities Research Council

TITLE:

Metacognition and Reflective Inquiry: Understanding Learning Across Contexts

APPROVAL DATE	TERM (YEARS)	AMENDMENT:	AMENDMENT APPROVED:
05-11-03 (yr/mo/day)	1	Aug. 8, 2006, Co-Invest./ Access to data / Consent form	SEP 1 9 2006

CERTIFICATION:

The request for continuing review of an amendment to the above-named project has been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approved on behalf of the Behavioural Research Ethics Board
by one of the following:
Dr. Peter Suedfeld, Chair,
Dr. Jim Rupert, Associate Chair
Dr. Arminee Kazanjian, Associate Chair
Dr. M. Judith Lynam, Associate Chair

This Certificate of Approval is valid for the above term provided there is no change in the experimental procedures

Appendix H: Headmaster's Approval to Conduct the Study

myUBC

Welcome to myUBC
Your personal gateway to information and services at UBC!

▪ **Logout** ▪ **Customize** ▪ **Help**

zoomed in on: myUBC Web Mail

myUBC Web Mail **zoom out**

Inbox | Folders | Compose | Mail Preferences | Check for new mail | Address Book

Read Email

Reply | Reply All | Forward | Delete | Expunge | File in Folder

96 of 125
Inbox

From: ____________________

To: nielsen <nielsen@interchange.ubc.ca>

Cc: ____________________

Subject: RE: Biology Study

Date: Thu Dec 08 13:54:27 PST 2005

Attachments: attachment0.htm

Good afternoon Wendy. Thank you for sending me all the pertinent documentation for your biology study.

I apologize for the delay in my response to you; you have been on my 'flagged' email list of high priority tasks needing attention. Unfortunately, as of late, you've been on that list with about 73 others.

I am impressed with the work you intend to complete and fully support your interaction with our students and teacher(s) for the purposes you've described.

__________ will of course continue to work with you as the two of you see fit.

Good luck and kind regards,