UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

A MULTILEVEL INVESTIGATION OF THE SOCIAL ASPECTS OF SELF-REGULATION IN THE CONTEXT OF COLLABORATIVE ILL-STRUCTURED PROBLEM SOLVING

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

Degree of

DOCTOR OF PHILOSOPHY

By

VICTOR W LAW
Norman, Oklahoma
2012

A MULTILEVEL INVESTIGATION OF THE SOCIAL ASPECTS OF SELF-REGULATION IN THE CONTEXT OF COLLABORATIVE ILL-STRUCTURED PROBLEM SOLVING

A DISSERTATION APPROVED FOR THE
DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

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ACKNOWLEDGEMENTS

Praise the Lord who gives me wisdom, resources, and family and friends who have supported me throughout my PhD years. I thank God for blessing me with two wonderful advisors, giving me this PhD journey, and teaching me valuable life lessons.

I owe special gratitude to my committee members. Thank you to Drs. Xun Ge and Deniz Eseryel, my co-advisors. I knew very little about the field of Instructional Psychology and Technology at the beginning. Throughout the past four years, you have patiently showed me how to develop ideas, how to write, how to conduct research, and how to be a scholar. Both of you have played a critical role in developing the research ideas for this dissertation. I am fortunate to have Drs. Raymond Miller, Barbara Greene, and Doo Hun Lim in my committee, who provided me with valuable feedback throughout the dissertation process. Thank you for your flexibility and support, which has allowed me to defend my dissertation recently this summer.

In addition, I would like to express my appreciation to many other people who have helped me throughout the dissertation process. Thanks to Dr. Theresa DeBacker, Dr. Barbara Greene, and Dr. Joyce Brandes who allowed me to recruit research participants from their classes. Thanks to Dr. Joyce Brandes and Robin Robinson for sharing their expertise with me and teaching me different issues about bullying at school. Thanks to Pastor Russell Morris for proofreading my dissertation drafts.

Finally, I am indebted to my family. My wife, Lily Law, has been quietly supporting me so that my dream could come true. I sacrificed too much time that I should have spent with my daughter, Daphne Law. Thank you for your smile which brightened my days. Thank you to my mom who has been praying for me throughout these years. I know you are joyful in heaven to see me finishing. Thank you to my dad and brother who always support me in any circumstances.

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ABSTRACT

This study investigated the effect of the social aspects of self-regulation on students' ill-structured problem-solving performance in a collaborative learning environment. Specifically, two components of the social aspects of self-regulation were explored: self-regulation and co-regulation. One hundred thirty-one pre-service teachers participated in this study, which required them to collaborate with peers in groups of three or four students on an ill-structured problem-solving task. Multiple research methods were used for the study: descriptive statistics, case analysis, multilevel analyses, and correlation analyses.

The results suggested there was a wide gap between students' self-reported behaviors and the actual behavioral counted coded by the researcher regarding self-regulation and co-regulation. The students rated themselves much higher self-regulators than the researcher's ratings, particularly at the problem representation phase. Furthermore, neither self-regulation nor co-regulation had a significant impact on ill-structured problem solving. In addition, the relationship between self-regulation and ill-structured problem solving was significantly weakened as co-regulation increased. The self-report measures and behavioral count measures of self-regulation and co-regulation were significantly correlated; however, directions of the impact of co-regulation on ill-structured problem solving were opposite: the self-report measures of co-regulation had a positive impact on ill-structured problem solving while the behavioral count measures of co-regulation had a negative impact on ill-structured problem solving. Issues and limitations of the study are discussed in this chapter. The results of this study provide valuable implications for instructional design and future research.

CHAPTER 1: INTRODUCTION

We are living in a new economy which is driven by information and knowledge (Galareau & Zibit, 2007; National Research Council, 1996). US companies have been moving millions of low-skill jobs to foreign nations (Harrison & McMillan, 2010; Shinal, 2004). The US unemployment rate has been above 8.9% for three years (Bureau of Labor Statistics, 2012). The competitive labor market demands employees to be equipped with the 21st century skills, such as critical thinking, innovation, communication, creativity, problem solving, and collaboration (Partnership for 21st Century Skills, 2009). These skills will prepare employees to face the challenges of the digital society, be innovative problem solvers, and create values to the society. Educators, businesses, and governments agree that problem solving and collaboration are two important skills for the 21st century (Asia Pacific Economic Cooperation, 2008; Partnership for 21st Century Skills, 2009). Nevertheless, our students are not well prepared to solve ill-structured problems. Such problems are rarely presented or discussed in the classroom environments and, as a result, students may not be able to make appropriate decisions when they face complex and ill-structured problems in real life (Spector, 2008). Hence, it is necessary to equip our next generation with ill-structured problem-solving and collaboration skills, which will enable them to be successful in the current economy (Jonassen, 1997, 2000; National Research Council, 1996, 2000; Spector, Christensen, Sioutine, & McCormack, 2001).

Despite the importance of the ill-structured problem-solving skills, students often have difficulties in solving those problems. (Dörner, 1987; Jonassen, 1997). By definition, ill-structured problems do not have a well-defined solution with a clear solution path. There is no formula to solve an ill-structured problem. The relationships among different variables in ill-structured problems are not clear, which makes it difficult to anticipate the cause and effect of problems. Feltovich and his colleagues argue that it is important for problem solvers to see multiple perspectives and methods when solving ill-structured problems (Feltovich, Spiro, Coulson, & Feltovich, 1996). However, students often oversimplify ill-structured problems, and they tend to rely on a single perspective or a single method (Feltovich et al., 1996).

A popular pedagogical approach to address students' difficulty in solving ill-structured problem-solving skills is to engage students in small groups to solve ill-structured problems collaboratively (e.g., Lu, Lajoie, & Wiseman, 2010). Although collaboration is often assumed to enhance students' problem solving, the effect of collaboration on learning outcomes is not clear (Puntambekar & Hubscher, 2005). When students work in groups, they may not be able to utilize different perspectives from other group members (Chan, 2001). Some students may not see the benefit of collaboration, and they may perceive collaboration as a waste of time (Trautmann, 2009). In the context of ill-structured problem solving, some qualitative studies show positive effects of collaboration on ill-structured problem-solving outcomes (Ge & Land, 2003; Lou, 2004). Other quantitative studies still found the effect of collaboration on ill-structured problem solving inconclusive (Ge & Land, 2003; Xie & Bradshaw, 2008). Working with people in teams adds to the complexity of problem solving and makes the problem-solving task even more challenging (Dillenbourg & Bétrancourt, 2006). In a collaborative problem-solving situation, problem solvers need to process all the domain specific information and structural knowledge regarding the problem and regulate their cognition during the problem-solving process (Barron, 2003; Ge & Land, 2004). At the same time, they need to verbalize their thoughts, construct mutual understanding of the problem, and understand their peers' reasoning processes during problem solving.

The literature shows that self-regulation predicts students' ill-structured problem solving performance (Shin, Jonassen, & McGee, 2003). Thus, self-regulation can be a meaningful lens to understanding collaborative ill-structured problem solving. However, it is not clear how self-regulation operates in a collaborative problem-solving environment. Little research has been conducted to understand self-regulation in a collaborative problem-solving environment (Dinsmore, Alexander, & Loughlin, 2008).

PURPOSE OF THE STUDY

The current study investigated the impact of the social aspects of self-regulation on ill-structured problem solving, which included (a) the exploration of self-regulation and co-regulation in a collaborative learning context, (b) the examination of the relationships among self-regulation, co-regulation, and ill-structured problem solving, and (c) the comparison between a self-report measure and a behavior count measure regarding self-regulation and co-regulation respectively. Based on the literature of self-regulation (Pintrich, 2000; Zimmerman, 2001), ill-structured problem solving (Jonassen, 1997, 2000), peer learning and collaborative problem solving (Goos, Galbraith, & Renshaw, 2002; O'Donnell, 2006; Roschelle & Teasley, 1995; Webb & Palincsar, 1996), individual level and group level measures of self-regulation were developed to tap into both students' overt and covert behaviors in the context of collaborative ill-structured problem solving: namely *self-regulation* and *co-regulation*.

Self-regulation is defined as an *individual process* whereby a problem solver sets goals, monitors, and reflects on his/her cognition through interpersonal interactions. These interactions include self-regulation based on the input from others, as well as inviting others to make comments or provide suggestions to facilitate self-regulation in an ill-structured problem-solving process. Co-regulation is defined as *a group process* whereby multiple members dynamically plan, monitor, and evaluate their shared understanding of the joint problem space and the solution in an ill-structured problem-solving process.

With these measures, we can better understand the social aspects of self-regulation in a collaborative problem-solving situation, where problem solvers not only self-regulate their thinking based on the information provided by other members, but also engage in co-regulation activities by interacting with others. The interactions may trigger individuals to generate additional ideas and reflect on different perspectives. Since ill-structured problem solving requires multiple perspectives (Feltovich et al., 1996), it is hypothesized that co-regulation in collaborative problem-solving context will help students to solve ill-structured problems, and that self-regulation and co-regulation will have positive main effects and interaction effect on ill-structured problem solving (Shin et al., 2003).

SIGNIFICANCE OF THE STUDY

It is expected that this study will contribute conceptually and methodologically to the literature of ill-structured problem solving and of self-regulation. First, the social aspects of self-regulation are salient, but neglected, metacognitive components in the research of ill-structured problem solving. In the literature of ill-structured problem-solving, cognitive flexibility theory suggests that providing multiple perspectives to problem solvers is crucial (Feltovich et al., 1996). However, many studies just quote the cognitive flexibility theory without empirically testing the underlying theoretical assumption that the exposure to multiple perspectives leads to better problem-solving outcomes. Indeed, the presence of peers in a problem-solving situation does not guarantee effective problem-solving outcomes (Hogan & Tudge, 1999; Puntambekar & Hubscher, 2005). The previous studies did not show significant main effects of peer collaboration on ill-structured problem solving (e.g., Ge & Land, 2003, Xie & Bradshaw, 2008). Thus, the current study attempted to examine which aspect of collaboration was crucial that leads to improved ill-structured problem-solving outcomes through the lens of self-regulation.

The study also adds to the self-regulated learning literature by extending the concept of self-regulation to the group level in collaborative problem-solving environments. Studies of self-regulated learning have mostly been done at the individual level examining how students regulate their learning in a course (Dinsmore et al., 2008). In fact, self-regulation is a contextual construct (Alexander, 1995; Winne, 2010), and a collaborative learning environment provides a unique context to self-regulators. In a one-to-many lecturing environment, students only need to monitor and reflect on the information they are studying from the lecturer and the course materials. In a collaborative learning environment, peers also become part of the learning environment, and self-regulation occurs at two levels. At the individual level, while individuals can affect their own self-regulation, their actions also influence others' self-regulation. At the group level, teams co-regulate their shared understanding of a problem. Hence, it is appropriate to examine the social aspects of self-regulation at both individual and group level.

Recently, the phenomenon of social aspects of self-regulation has gained a great deal of attention. Despite the increasing attention to this phenomenon, the existing research has mostly concentrated on the motivational and emotional aspects of self-regulation (Järvelä, Järvenoja, & Veermans, 2008; McCaslin, 2009; Volet & Mansfield, 2006; Volet, Summers, & Thurman, 2009). In addition to the motivational and emotional aspects of self-regulation, the cognitive aspects of social regulation is salient in understanding self-regulation, especially in the context of ill-structured problem solving, when metacognitive and cognitive processing are required for ill-structured problem-solving (Ge & Land, 2004). The current study re-conceptualized the concept of self-regulation in the context of collaborative ill-structured problem solving to assist our understanding of the social aspects of self-regulation.

In addition to the theoretical contribution, the current study will also contribute to the research methodology on self-regulation in three unique ways: (1) a quantitative approach to examine self-regulation, (2) the multilevel analysis to examine the cross-level effects of the social aspects of self-regulation, and (3) the measurements of social aspects of self-regulation with self-report measures and behavioral counts coded by the researchers.

Although the construct of social aspects of self-regulation has been recently studied, it has been mainly studied qualitatively (e.g, Järvelä et al., 2008; Volet, Summers, et al., 2009). The current study was the first one that takes a quantitative approach to the examination of the social aspects of self-regulation. Hence, the results of the study could offer quantitative evidence on the effects of the social aspects of self-regulation on students' problem-solving outcomes.

Self-regulation and co-regulation in a social context occur at both the individual and group level. Thus, it is necessary to employ an analytical technique that is capable of studying cross-level effects of the phenomenon. Common analytical methods, such as regression and ANOVA (Dinsmore et al., 2008), are not appropriate to model relationships between individual level constructs and group level constructs (Hox, 1998). Therefore, the current study employed a multilevel modeling technique to model the cross-level effects as well as the interaction effects between the social aspects of self-regulation and ill-structured problem solving.

In the current study, both self-report and behavioral counts measures were used to understand students' self-regulation behaviors. Most of the studies in self-regulated learning use self-report instruments (Dinsmore et al., 2008), which has been argued to be one of the more reliable ways to measure self-regulated learning (Schraw, 2010). However, self-reported data are still prone to measurement errors such as social desirability issues and subjects' inability to recall facts (Boekaerts & Corno, 2005). Thus, it is more desirable to collect multiple data sets for triangulation.

CHAPTER 2: LITERATURE REVIEW

In this literature review, three bodies of literature are synthesized: literature of ill-structured problem solving, self-regulation, and social interactions in collaborative learning environments. The synthesis identifies research gaps, which warrants the study of the social aspects of self-regulation in a collaborative learning environment. The first section reviews *problem-solving* literature (e.g., Funke, 1991; Jonassen, 1997) and describes the nature of a problem and the process of ill-structured problem solving. The second section reviews self-regulated learning literature by first describing the differences among metacognition, self-regulation, self-regulated learning, and self-directed learning. Then, different models of self-regulated learning are compared (Boekaerts, 1997; Butler & Winne, 1995; Pintrich, 2000). The three main phases of self-regulated learning are summarized and the measurement issues of self-regulated learning are also discussed. Next, the chapter provides a literature review on collaborative learning (e.g., Ge & Land, 2003; Teasley & Roschelle, 1993; Webb & Palincsar, 1996) and social aspects of self-regulation (e.g., Järvelä et al., 2008; Volet, Summers, et al., 2009). After the discussion of the theories, the research gaps are identified in the line of research regarding the social aspects of self-regulation. Based on the critical analysis of the literature, the research questions and hypotheses are presented.

ILL-STRUCTURED PROBLEM SOLVING

The Nature of Problem Solving

The first step in problem solving is the construction of a problem space, which consists of a set of given states, goal states and path constraints (Wood, 1983). A problem exists when a problem solver encounters a situation where the given state of the situation is different from the goal state of the situation (Frensch & Funke, 1995; Jonassen, 2000). To solve a problem, a problem solver needs to engage in cognitive processes to move from one problem state to another (Anderson, 2005; Mayer & Wittrock, 2006). This definition of problem solving highlights the importance of goal setting in problem solving, that problem solvers need to set goals and move towards the goals throughout the course of problem solving. It implies that successful problem solvers should be able to self-regulate their problem-solving processes. Second, this definition also views problem solving as a cognitive process.

Types of Problem Solving

Problems can be categorized according to their structures on a continuum from well-structured to ill-structured (Goel, 1992; Jonassen, 1997). Some examples of well-structured problems include chess games and puzzle games like Tower of Hanoi. A well-structured problem has the following characteristics. First, there is an unambiguous and definite goal for the problem, so any proposed solution can be tested. In addition, all the states, including initiate and goal states are clear. Finally, all valid moves are defined (Simon, 1973).

Ill-structured problems have undefined goals, solution paths and moves. Most everyday life problems are ill-structured in nature. In ill-structured problems, one or more problem elements are unknown, or not certain; the goals and constraints of the problems are unclear or unstated; solutions or solution paths should not be unique or there may be no solution at all; the criteria to evaluate the solutions are not clear; the relationships between concepts are uncertain (Jonassen, 2000).

Ill-Structured Problem Solving Processes

Drawing from information processing theory (Newell & Simon, 1972), Gick (1986) modeled problem solving as a recursive process. Problem solvers started constructing a problem representation. If they did not recognize the problem type, they searched for a possible solution in the problem space. If they recognized the problem type, they activated their schema of the problem without the searching process. Then, they implemented the solution. If the proposed solution failed, problem solvers would change their problem representations or activate another schema. This process repeated itself until a successful solution was found.

Although information processing theory has been prominent in problem-solving research, information processing theory may be insufficient to understand ill-structured problem solving because of the novel nature of ill-structured problems (Reitman, 1965). Problem solving is not merely an information retrieval exercise. A pure search process is not sufficient when problem solvers do not have a clear problem state, a clear goal, nor clear solutions. Problem solvers have to be able to define the problems, look for feasible solutions, monitor the problem-solving process, and justify their decisions. In other words, in ill-structured problem solving, it is not about finding the right solution, but understanding the problem, and locating and justifying the feasibility of a solution for the problem, which is based on the interpretation of the problem solvers.

Three ill-structured problem-solving models have been proposed to understand the ill-structured problem-solving process. Voss and Post (1988) illustrated different types of ill-structured problem-solving scenarios such as prediction, magistrate judgment, and political science problems. Two main components, problem representation and problem-solution, were identified. Based on a study employing think aloud protocol, Sinnott (1989) proposed an ill-structured problem-solving model with five components: construction of problem space, generation of solution, monitors, memories, and non-cognitive elements, such as emotion. Jonassen (1997) synthesized ill-structured problem-solving literature and proposed a seven-step model of ill-structured problem solving:

- Articulate problem space and contextual constraints
- Identify and clarify alternative opinions, positions, and perspectives of stakeholders
- Generate possible solutions
- Assess the viability of alternative solutions by constructing arguments and articulate personal beliefs
- Monitor the problem space and solution options
- Implement and monitor the solution
- Adapt the solution

The three ill-structured problem-solving models described above share several similarities. First, the fundamental problem-solving processes are the same, including problem representation and solution generation. Second, in all three models, self-regulation components are included. Problem solvers need to justify their solutions (Voss & Post, 1988). Monitoring is a key component in both Sinnott's (1989) and Jonassen's (1997) models. Jonassen's model also includes an assessment component. In summation, two main mechanisms are found in ill-structured problem solving: problem-solving and self-regulation processes.

Ill-structured problem-solving processes are not linear in nature. In a study examining how experts solve instructional design problems, Eseryel (2006) found that solution generation and problem representation were cyclical. Expert instructional designers developed problem representations and possible solutions in parallel. They also monitored and evaluated their understanding of the problem and their solutions simultaneously. Based on Eseryel (2006) findings, ill-structured problem-solving processes can be viewed with a self-regulation lens, in which the problem-solving processes are embedded in the self-regulation processes. When people solve a problem, they need to set goals, monitor available feedback, and reflect and justify his or her understanding of the problem, and the feasibility of a solution throughout the problem-solving processes. Hence, instead of viewing the self-regulating processes, such as monitoring, evaluating, and making justification, as phases in a problem-solving process, I argue that self-regulating processes occur during both problem representations and solution generation. The integrated model of ill-structured problem solving is depicted in Figure 1.

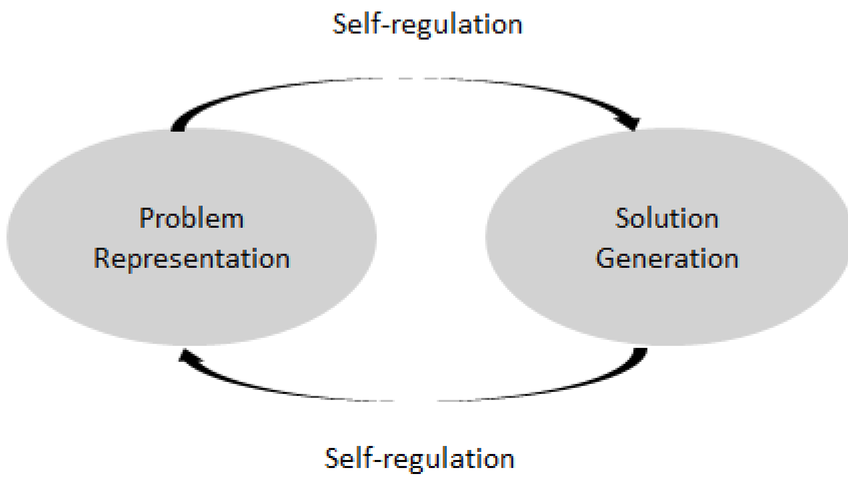

Figure 1. Ill-Structured Problem Solving Processes

Besides self-regulation, social interactions may also affect ill-structured problem solving. Cognitive flexibility theory suggests that collaboration, which allows students to see multiple perspectives of the problems, may facilitate ill-structured problem solving (Feltovich et al., 1996). In a qualitative study that examined expertise development, Ge and Hardré (2010) found that social processes such as peer interactions and feedback influenced students' learning.

From the ill-structured problem-solving literature, two key factors that affect students' ill-structured problem solving are found: self-regulated learning (SRL) and social interactions. Below, the nature of these two constructs and how they relate to ill-structured problem solving are explained.

SELF-REGULATED LEARNING

The term self-regulated learning emerged in the 90's when the concept of self-regulation was applied in the classrooms. Self-regulated learning is defined as "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment" (Pintrich, 2000, p. 453). Drawing from the information processing theory and the literature of feedback, Butler and Winne (1995) proposed a theoretical model of self-regulated learning. They suggested that feedback was generated through an individual's monitoring and the environment, and learners would modify their goals, their learning strategies, and even their epistemological beliefs after they reflected on that feedback. Boekaerts (1997) suggested a six-component self-regulated learning model, which included not only the cognitive, but also the motivational dimensions of self-regulation. The six components of self-regulated learning included goal setting, the use of cognitive and motivational strategies, domain specific and domain general knowledge and beliefs. Pintrich (2000) synthesized different self-regulated learning models to provide a comprehensive framework of self-regulated learning including four phases and four areas for regulation. His four areas for self-regulation not only included cognition and motivation as described in Boekaerts' model (1997), but also included behaviors, and context. The four phases of self-regulation are planning and forethought, monitoring, control and reflection. In sum, self-regulated learning models include self-regulation processes, such as planning, monitoring, and evaluating, which coincide with the metacognitive requirements of ill-structured problem solving (Ge & Land, 2004).

These processes are the cornerstones of self-regulated learning research (e.g., Azevedo, Cromley, & Seibert, 2004; Dabbagh & Kitsantas, 2005; Quintana, Zhang, & Krajcik, 2005).

Metacognition, Self-Regulation and Self-Directed Learning

Metacognition, self-regulation, and self-directed learning are very similar concepts, and they are often used interchangeably in literature (Dinsmore et al., 2008). In a study that examined using self-regulated learning strategies in an e-learning context, Santhanam, Sasidharan, and Webster (2008) used the terms self-regulated learning and self-directed learning strategies without distinguishing their differences. So, what are the differences among these three concepts?

Drawing from the field of developmental psychology, Flavell and his colleagues defined metacognition as thinking of one's own thinking (Flavell, 1971; Miller, Kessel, & Flavell, 1970). This definition focuses the development of the awareness of children's thought. The conceptualization of metacognition expanded in later metacognition literature to include the regulation of cognition. Schraw and Dennison (1994) adopted Baker and Brown's (1984) conceptualization of metacognition to define metacognition as "the ability to reflect upon, understand, and control one's learning" (p.460). This view of metacognition not only concerns an individual's *knowledge of cognition* but also an individual's *regulation of cognition*. Knowledge of cognition is concerned with "a person's knowledge about his or her own cognition resources, and the compatibility between the person as a learner, and the learning situation" (Baker & Brown, 1984, p.353). It includes three processes that facilitate one's awareness of self and strategies, one's awareness of the use of strategies, and one's awareness of when and why to use strategies (Schraw & Dennsion, 1994). Regulation of cognition includes self-regulative mechanisms, such as planning, monitoring, and evaluating the strategies and outcomes of learning (Baker & Brown, 1984). From this later view of metacognition, the metacognition concerns *more than* just one's thinking of thinking, but also includes self-regulative mechanisms.

Drawing from social cognitive theory, Bandura (1991) suggested that self-regulation included three self-regulative processes and self-efficacy. The three self-regulative processes are self-monitoring, self-judgment, and self-reaction as three mechanisms of self-regulation. Self-monitoring provides the necessary information for individuals to evaluate their progress. Self-judgment involves an evaluation process in which individuals compare their behaviors and outcomes with certain standards. Finally, self-reaction is a response, or lack of response, to the self-judgment. Self-efficacy plays a key role in human agency, and it influences the operations of three self-regulative processes. Zimmerman (1995) argued that self-regulation involved *more than* metacognition because self-regulation involved not only the cognitive and metacognitive processes, but also self-efficacy, motivational, and behavioral processes. In this sense, metacognition can be viewed as a sub-process of self-regulation.

Although self-regulation and metacognition come from two different streams of literature, Dinsmore, Alexander and Loughlin (2008) found that the distinction between self-regulation and metacognition became blurred. Self-regulation research began to concern the cognitive realm, while the metacognition research began to include the concern of human behaviors. The only distinction between the two concepts was the role of environment where self-regulation researchers viewed the environment as the trigger to self-regulation, while the metacognition researchers viewed individuals as initiators for the metacognitive behaviors (Dinsmore et al., 2008). In this study of the social aspects of self-regulation, Bandura's perspective of understanding the interactions among the person, the behavior, and the environment is adopted. In the context of collaboration, peers are part of the environment. Hence, an individual can trigger peers' self-regulation, which, in turn, may trigger others to self-regulate themselves.

Self-directed learning (SDL) is another concept which is very similar to self-regulated learning (Zimmerman & Lebeau, 2000). The concept of SDL was originated from the adult education literature (Kicken, Brand-Gruwel, van Merriënboer, & Slot, 2009). In the workplace, employees seldom learn in formal classrooms. Instead, they direct their own learning by identifying their own needs, setting their own goals, identifying possible resources that may help them to achieve their goals, selecting appropriate learning strategies, and evaluating learning outcomes (Knowles, 1975).

The processes in SDL are very similar to the self-regulated learning processes. In understanding how problem-based learning (PBL) facilitates SDL skills, Hmelo-Silver (2004) identified four SDL sub-skills, which included ability to set learning goals, ability to plan his/her learning, having metacognitive awareness of what a learner does or does not understand, and selecting appropriate strategies to achieve his/her learning goals, and ability to monitor and evaluate his/her learning outcomes. Those SDL skills matched with the self-regulation processes. Kicken, Brand-Gruwel, van Merriënboer, and Slot (2009) defined self-directed learning skills a little bit differently.

They included assessment of one's performance as one of the key skills. In order to successfully assess one's performance, learners should be able to be aware of the level of performance, and monitor and evaluate their performance. The other two skills are specific to SDL, which are formulating learning needs, and selecting human and material resources.

Despite the similarity between SDL and SRL, one major distinction between SDL and SRL is the concept of design features of the learning environment (Loyens, Magda, & Rikers, 2008). Because the root of adult education, SDL not only concerns the processes of learning, but also concerns the design feature of the learning environment so that learners can be self-directed in their pursuit of learning outcomes. Gilbert and Driscoll (2002) conducted a case study in college settings to examine how different design principles, such as having authentic community goals, having collaborative groups, and using technology tools for communication, influenced acquisition of self-directed strategies. Other researchers examined how development portfolio and simulation supported self-directed learning skills in secondary education (Kicken et al., 2009; Veermans, de Jong, & van Joolingen, 2000). Because the current study was situated in a formal learning environment where the focus of the study was the self-regulation processes instead of the design of the learning environment, the SRL framework was adopted.

Measurements of Self-regulated Learning

In this section, four major ways to measure self-regulated learning are reviewed. The advantages and drawbacks of each measurement method are discussed. Finally, the rationale of choosing self-report measures and the self-regulation behavioral count measures are explained.

Think-aloud protocol, interviews, traces of mental process by observing participants' behaviors, and self-reported questionnaires are four major ways to measure self-regulated learning (Boekaerts & Corno, 2005; Schraw, 2010; Winne, 2010). In a think-aloud session, problem solvers are required to describe their self-regulation processes by verbalizing their self-regulation processes or keeping a concurrent log (Schraw, 2010). As a result, researchers can observe participants' covert self-regulated learning processes by analyzing participants' verbal transcripts of the think-aloud processes or their concurrent logs. This is a way to capture the self-regulated learning process in real time, which does not depend on the participants' ability to recall and/or aggregate their experience. Despite the advantages of think-aloud protocol method, it is not easy for the participants to continuously think aloud while paying attention to the task they are asked to perform. It might take a long time to train participants to report their thoughts accurately. It also adds cognitive load to the participants because they need to solve problems as well as to think of reporting their thoughts. The act of recording the self-regulated behaviors may disturb the natural progress of problem solving. Moreover, the act of think-aloud may inflate the problem-solving outcomes if the participants are asked to reflect on their behaviors (Schraw, 2010).

Another way to measure self-regulated learning is by conducting interviews (Winne, 2010). The researchers ask participants questions regarding their self-regulation experience, and the participants can describe what they have done during problem-solving sessions. Researchers can also ask clarification questions if they cannot fully understand the interviewees' thinking process. Hence, the researchers do not need to rely only on the real time verbalization of the participants. However, interviews are conducted after the problem-solving processes. The reliability of the data can be affected by participants' ability to recall and describe their experience.

Self-regulated learning can also be inferred by observing problem solvers' self-regulative behaviors (Schraw, 2010). Behavioral count data do not rely on participants' ability to recall and/or describe their experience. Nevertheless, the absence of behaviors may not necessarily indicate the absence of self-regulation. For example, someone may have monitored his or her peers' input and decided not to use that inputs without explaining his or her reasons. If only overt behaviors are observed, the covert self-regulation behaviors are not captured.

Finally, self-regulated learning can be captured by self-report instruments (e.g., Pintrich, Smith, Garcia, & McKeachie, 1991; Schraw & Dennison, 1994). While, it is an efficient way to capture a large volume of data, the validity of the self-report measures can be affected by participants' ability to recall their behaviors and their self-assessment ability (Winne & Perry, 2000). Some researchers argue that self-report measures are less problematic in measuring self-regulated learning because it does not require a large amount of time and multiple coders to analyze the data (Schraw, 2010; Sperling, Howard, Miller, & Murphy, 2002).

Self-regulated learning is a complex process that is difficult to capture accurately with one single measure. Therefore, in the current study, two measures, a self-reported questionnaire and the behavioral counts using problem solvers' discussion logs, were used to capture the social aspects of self-regulation. Using these two measures allowed me to capture both the overt and covert facets of self-regulated learning. Because the context of the current study was ill-structured problem solving, which put a lot of cognitive load on the participants, think-aloud protocol, which adds additional cognitive load to the participants, might have affected their problem-solving performances. Furthermore, it would be very difficult to verbalize someone's thoughts and participate in a collaboration situation at the same time. Interviews would not be an effective way to capture more than one hundred students' experiences in order to conduct analysis to examine the relationship between the social aspects of self-regulation and ill-structured problem solving.

Self-Regulated Learning and Ill-Structured Problem Solving

In understanding self-regulated learning in the context of ill-structured problem solving, it is argued that the cognitive dimension of self-regulated learning is required for problem solvers are to regulate their cognition, including monitoring and reflecting on the information they receive, updating their understanding of the problems and possible solutions, and justifying their decisions (Ge & Land, 2004; Jonassen, 1997). Shin, Jonassen and McGee (2003) also found that regulation of cognition had a significant impact on ill-structured problem-solving scores. Indeed, many studies suggested that students who regulate their cognition performed better in learning and problem solving (e.g., Azevedo, Guthrie, & Seibert, 2004; Manlove, Lazonder, & de Jong, 2009a). Thus, the current study focuses on the cognitive dimensions of self-regulated learning. Some empirical studies are reviewed to illustrate the relationship between self-regulation and ill-structured problem solving.

Azevedo, Guthrie and Seibert (2004) examined the role of self-regulated learning in students' understanding of complex systems. Twenty-four undergraduate students were asked to label components in a human circulatory system, to draw paths of blood circulation, and to write an essay about their understanding of human circulatory systems. Chi-square analyses suggested that students who had better understandings of human circulatory systems regulated their learning more than those students who had lesser understandings of circulatory systems did. This study provided evidences that self-regulated behaviors had a positive relationship with learning in complex knowledge domains, and the results also agreed with other studies that suggest that some students lacked self-regulatory skills (e.g., Azevedo, Winters, & Moos, 2004; Greene & Land, 2000).

Manlove, Lazonder, and de Jong (2006) examined how regulative support influenced high school students' understanding of complex knowledge domain in a discovery simulation environment. Self-regulation tools for planning, monitoring and evaluation were embedded in the simulation. Students who were given the self-regulative scaffolds performed better than the students who did not have the scaffold. They found that students used the planning tool frequently, but used monitoring and evaluation tools sparingly. Their results suggested that students regulated themselves in inquiry-based learning environments, and self-regulation had a positive effect on understanding of complex knowledge domains. However, monitoring and evaluating might be still too difficult even when scaffolding was provided. Their results reconfirm that self-regulation contributes to learning, but scaffolding may be needed to foster different aspects of self-regulation.

Self-regulation not only has an impact on learning of complex knowledge domains, but also on problem-solving performance. Hoffman and Spatariu (2008) tested the effect of self-regulation prompts on problem-solving performances. Eighty-one college students were randomly assigned into two groups: one group with self-regulation prompts and the other one without self-regulation prompts. Then, the students were asked to solve fifteen mathematics problems. Regression analyses results suggested that the students in groups with self-regulated prompts performed better. The results implied that students who were scaffolded to self-regulate could perform better in mathematics problems.

Kauffman, Ge, Xie and Chen (2008) examined the effect of problem-solving prompts and self-regulation prompts on ill-structured problem solving. They found that problem-solving prompts guided students through the problem-solving process, such as asking them to define the problem and generating possible solutions. Particularly, the reflection prompts encouraged students to reflect on their problem solving and evaluate their understanding of the problem and quality of their solution. The results suggested that problem-solving prompts were related to students' clarity of writing and the quality of the arguments, whereas the reflection prompts had a significant positive effect on ill-structured problem solving only when they were provided together with the problem-solving prompts. The study of Kauffman et al. (2008) indicated that students needed to have clear understanding of the subject matter, which was facilitated through the problem-solving prompts in their study, in order to be able to reflect effectively.

In summation, the above studies provide evidences that self-regulation can lead to better learning and problem-solving outcomes. Nevertheless, self-regulation is not easy; it can be even harder if the learning environments involve many resources, and tools (Azevedo, Guthrie, et al., 2004). Even when scaffolding is available, students may still not be able to use the regulation tools or scaffolds provided (Ge, Planas, & Er, 2010; Manlove et al., 2006), or they may not able to reflect when they do not have enough domain knowledge (Kauffman et al., 2008). One possible way to scaffold students problem solving is putting them in a peer learning environment, so that they can help each other by (1) providing subject matter knowledge to the peers, (2) challenging each other to reflect deeply, (3) questioning each other's thinking and reasoning, and (4) helping each other to consider multiple perspectives (Ge & Land, 2003; Saye & Brush, 2002).

SOCIAL INTERACTIONS IN ILL-STRUCTURED PROBLEM SOLVING

Social interaction is the other key factor that affects students' ill-structured problem solving. One type of social interaction is peer collaboration, which is defined as "students working in groups and interacting with peers, mutually searching for understanding, solutions, or meanings, or creating a product" (Xie & Bradshaw, 2008, p. 149). Iiskala, Vauras, Lehtinen, and Salonen (2011) described high-level collaborative processes as "the co-construction of meaningful knowledge and understanding in which the members of a group not only share information but are also engaged in representing each other's mental activities used to process content knowledge" (p. 380). Teasley and Roschelle (1993) defined collaboration as "a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared concept of a problem" (p.235). In sum, collaboration involves putting individuals together in a team to accomplish some tasks, where they continuously co-construct meanings, understandings, and/or products.

Some empirical studies suggested a positive relationship of collaboration with well-structured problem solving. Okada and Simon (1997) compared subjects in pairs and single subjects of twenty-seven undergraduate students. The results of the study suggested that pairs performed better than singles in discovering scientific laws, and pairs participated more actively in explanatory activities, such as entertaining hypotheses, considering alternative hypotheses, and justifying their own hypotheses, than the singles did.

In another study, Fawcett & Garton (2005) asked 6-7 year old children to engage in card sorting activities and they found that young children who worked collaboratively performed better than those who worked alone. In the collaboration groups, only the children who explained their actions to their peers showed significant improvement in their problem-solving performances (Fawcett & Garton, 2005). Fawcett and Garton's study provided the evidence that collaboration enhances learning outcomes through peer interactions, such as justifying one's positions and considering others' positions. In general, collaboration has a positive effect on solving well-structured problems that have clear goals and deterministic solutions.

Although the effect of collaboration on well-structured problems is positive, its effect on ill-structured problem solving is not as clear. Some studies supported the positive effect of peer interactions on ill-structured problem solving, but other studies did not find conclusive evidences for this relationship. Uribe, Klein, and Sullivan (2003) compared students working in groups and students working alone in ill-structured problem-solving tasks in a study. They found that student dyads outperformed students who worked alone. In another study, Ge and Land (2003) compared undergraduate students working in groups with undergraduate students working alone and found no significant differences between the two groups in their ill-structured problem-solving performances. Ge and Land (2003) argued that students might need collaboration skills in order for them to solve ill-structured problems successfully in a group environment.

Collaborative Problem-Solving Processes

In this section, the underlying mechanisms and processes during collaborative problem solving are examined. Two main mechanisms, socio-cognitive conflict (Piaget, 1970), and internalization of social processes (Vygotsky, 1978), are suggested for collaborative learning (Webb & Palincsar, 1996). Piaget (1970) suggested that children interacted with their environments, and cognitive disequilibrium could be created, which then led to assimilation or accommodation. In a collaborative environment, learners interact with peers by discussing relevant issues and solutions. Because learners have different prior knowledge and perspectives, disequilibrium can be created, and learners may assimilate and/or accommodate their schema during the discussion.

Vygotsky (1978) took a social approach in understanding of learning mechanisms. He suggested that a zone of proximal development is created by "awakening a variety of internal developmental processes that were able to operate only when the child was interacting with people in his environment and in cooperation with his peers" (Vygotsky, 1978, p.90). Social events allow students to internalize skills and meanings. The socio-cultural perspective emphasizes the social components of peer learning (O'Donnell, 2006), which suggest the importance of an understanding of the social aspects of learning.

Piaget and Vygotsky provided a theoretical foundation of peer learning. These foundations have led to more research in collaboration and understanding of collaborative problem solving. To understand collaborative knowledge construction, Teasley and Roschelle (1993) developed a simulation program, The Envisioning Machine. The program displayed simulation of ball movements and allowed students to manipulate different parameters to allow students to learn the concepts of velocity and acceleration. Through observing high school student dyads working together using the Envisioning Machine, Teasley and Roschelle (1993) found different interactions that might lead to knowledge constructions. The collaborative interactions that related to the construction of joint problem space included introducing and accepting knowledge, monitoring ongoing activities, resolving impasses and misunderstanding, and constructing shared understanding of the problems (Teasley & Roschelle, 1993).

Other studies have focused on the self-regulation aspects in collaboration. Iiskala, Vaura, Lehtinen and Salonen (2011) investigated socially shared metacognition in the context of collaborative mathematical problem solving. A socially shared metacognition episode was represented by the student dyads, who jointly regulated their cognitive processes towards a common goal. They found that high achieving student dyads identified possible problem elements and situations related to the problems, evaluated ideas, accepted or rejected ideas, and changed the course of direction. In another study that examined secondary school students in a mathematical classroom, Goos, Galbraith and Renshaw (2002) found high school students clarified, elaborated, and justified their ideas, sought feedback, invited others for critiques, offered critiques to others, and requested explanation during colla8borative problem-solving exercises. In summary, students in collaborative problem-solving situations communicate their ideas to others, invite others to participate in the problem-solving processes, and integrate others' ideas into their own. At the same time, they also set goals, monitor peers' input, and reflect on the ideas generated by the group. The collaborative processes in an ill-structured problem-solving situation are summarized in the Table 1:

Table 1. Collaborative Processes in an Ill-Structured Problem-Solving Situation

Self-regulation phases	Collaborative processes
Goal Settings	• Identifying problems and solutions by providing definitions, sharing information • Requesting feedback • Inviting others to identify problems and solutions
Monitoring	• Elaborating on others' ideas • Being aware of others' ideas • Requesting others to explain and clarify their ideas
Reflecting	• Agreeing or disagreeing on an idea • Justifying or refuting an idea • Resolving misunderstanding • Summarizing of an idea • Choosing a solution

Computer-Mediated Communication in Collaborative Problem Solving

Communication is a key aspect of collaborative problem solving, and computers bring in a new way for people to share knowledge and understanding, and thus, are often used to promote collaboration. Many studies found computer-mediated communication (CMC) groups performed better and also reflected better than face-to-face (FtF) groups because students were more focused on their tasks (Jonassen & Kwon, 2001).

Empirical studies suggested that computer-supported environments can help students to focus on their tasks. Two different studies compared college students who worked in CMC environments with students who worked in FtF environments, and both got positive results showing that students who worked in CMC groups outperformed the students in FtF groups (Jonassen & Kwon, 2001; Tutty & Klein, 2008). In the study conducted by Jonassen and Kwon (2001), engineering students were assigned into six three-member groups to solve Harvard Business Cases. They found that the CMC groups focused on their task more, and reflected the problem-nature better than the FtF groups did (Jonassen & Kwon, 2001). Tutty and Klein (2008) also conducted their experiment in a college setting, and 120 pre-service teachers dyads used Microsoft Excel to develop grade books. The results suggested that the CMC groups also had better group performance than the FtF groups. Both of those studies confirmed that college students could benefit from using CMC in small group collaboration. The better results could be due to the flexibility and convenience that was provided by the CMC mode, which allowed students to reflect and think deeply (Jonassen & Kwon, 2001). In another study, Van der Meijen and Veenman (2005) examined the effect of CMC on primary school children's math problem solving. The researchers found that the CMC groups had more reflective communication than the FtF groups had. Indeed, the CMC groups produced three times as many reflective utterances than the FtF groups produced. This result suggested that the CMC environment might help students' reflection.

THE SOCIAL ASPECTS OF SELF-REGULATION

The social aspects of self-regulation are not new in the literature of self-regulation, which acknowledges that people regulate their cognition, behavior, and emotion in social contexts. Early self-regulation literature views self-regulated learning as an individual process in which learners set goals and regulate their cognition, behavior, motivation, and emotion in response to the environment (e.g. Pintrich, 2000). Everything other than the individual learners is considered part of the environment. Pintrich's self-regulation model (2000) includes help seeking and peer learning, but those social constructs only refer to the identification of possible help, willingness to ask for help, and willingness to work with peers. The interactions among the peers and the interplay between individual self-regulation and collaboration are neglected from those early self-regulated learning models. However, self-regulated learning situated in a social environment can be different from self-regulated learning that occurs in solitude (Alexander, 1995). Hence, it is important to extend our understanding of self-regulated learning to include social contexts.

Despite the call for the attention to the social contexts in the understanding of self-regulation, only a few studies have tried to address the social aspects of self-regulated learning in the 1990's (Alexander, 1995). In the 2000's, some studies of self-regulated learning were situated in collaborative learning environments (Dabbagh & Kitsantas, 2005; Salovaara, 2005; Volet & Mansfield, 2006), but the focus of self-regulated learning was still on students' individual behaviors and strategies. For instance, in the study conducted by Salovaara (2005), participants were situated in a collaborative learning environment, in which high school students worked in groups to complete writing projects. In spite of the collaborative context, self-regulated learning was only measured at the individual level by examining individual students' planning, monitoring, and strategy use. Very little has been known regarding self-regulated learning at the group level.

Recently, the topic of the social aspects of self-regulated learning is gaining in attention in the self-regulated learning and collaborative learning literature. To understand the social aspects of self-regulated learning, researchers come up with different constructs such as co-regulation, shared regulation, other-regulation, socially shared metacognition, and social metacognition (Chiu & Kuo, 2009; Hurme, Merenluoto, & Järvelä, 2009; Iiskala et al., 2011; Järvelä & Järvenoja, 2011; McCaslin, 2009; Volet, Summers, et al., 2009). Although those constructs describe the same phenomenon, there is little agreement regarding the understanding of the social aspects of self-regulated learning. Nevertheless, researchers agree that the underlying constructs in the social aspects of self-regulated learning are very complex because of the complexity of the social processes embedded in both individual and group levels (Volet, Vauras, & Salonen, 2009). When the context is extended to ill-structured problems, the complexity increases because peers may have different understanding of the problems and different solutions.

Hadwin and Oshige (2011) synthesized self-regulation literature to provide a framework to understand the social aspects of self-regulated learning. They suggested that the social aspects of self-regulated learning can be understood from three different perspectives: an individual perspective, an other-regulated perspective, and a co-regulation perspective. An *individual perspective* is one in which learners self-regulate their cognition by “monitoring and regulating metacognitive, motivational, and behavioral aspects of one’s own learning” (Hadwin & Oshige, 2011, p. 258). From this perspective, the individual learning processes are focused. In a collaborative problem-solving context, individuals have to regulate all the inputs from their peers. At the same time, their behaviors may trigger others’ self-regulation behaviors.

An *other-regulated learning perspective focuses on the acquisition of* self-regulated learning skills through a transition process (Hadwin, Oshige, Gress, & Winne, 2010; Volet, Summers, et al., 2009). This kind of regulation refers to “instances when teachers guide or prompt students to do the regulating themselves, or students request, or prompt teachers to show them how to self-regulate…students begin to take ownership of self-regulatory actions and thought but rely on the teacher to help out.” (Hadwin, Wozney, & Pontin, 2005, p. 420). This perspective focuses on the acquisition of self-regulated learning skills instead of viewing other-regulation as a process in which students regulate their own cognition during the collaborative processes. In the current study, the concept of other-regulation is not very useful because the focus of the study is to explore the relationship between self-regulation and ill-structured problem solving. The acquisition of self-regulation skills should be helpful for the individual and/or the team on the long run, but it may not have an immediate effect on problem-solving outcomes.

Finally, there is the *co-regulation perspective*, in which multiple people regulate their shared understanding. Some researchers call it socially shared regulation. In this perspective, individuals regulate their shared understanding at the group level to achieve group goals consensually (Hadwin & Oshige, 2011). Multiple members of the team should constantly monitor and regulate their joint activities during co-regulation (Iiskala et al., 2011; Volet, Summers, et al., 2009). In other words, co-regulation is not just the sum of individual efforts to regulate the members’ activities, but it involves the interactions among the team members. In a collaborative problem-solving context, multiple problem solvers set group goals *together*, monitor the ideas from *all the members*, and discuss and evaluate *the team understanding* of the problem and the solution. Drawing from the Hadwin and Oshwin (2010) framework, I term the individual perspective of social regulation as *self-regulation* and group perspective of social regulation as *co-regulation.* The following reviews the literature related to self-regulation and co-regulation.

Self-Regulation in a Social Context

Peers are part of the learning environment. As a result, learners not only need to attend to all the information from their peers in a collaborative problem-solving situation, but they also can trigger their peers to attend to or reflect on certain ideas. Järvenoja and Järvelä (2009) argued that in self-regulation in a collaborative environment "individuals assisted one another's regulation… they were seeking to affect others and being affected by others with the intention of achieving their own goal" (p.464). In a collaborative problem-solving situation, learners solve problems with other group members. They learn from others, and also assist others to learn. Therefore, self-regulation in a social context involves not only the regulative activities by a learner, but also his/her actions that trigger others' regulative behaviors. Hence, in the current study, self-regulation is defined as an *individual process* whereby a problem solver set goals, monitors, and reflects his/her cognition through interpersonal interactions, which include the regulation of the input from others, and inviting others to make comments, give suggestions or other interaction activities to facilitate the regulation of their own cognition in an ill-structured problem-solving process.

Studies have found that students have exhibited self-regulation behaviors in collaborative learning environments. In a qualitative study, Salovaara (2005) interviewed twenty-six high school students to elicit their self-regulation strategies during a collaborative learning environment. The students worked on projects by conducting individual research, sharing knowledge and ideas with peers, commenting on one another's work, and writing up a final report. From the interview, the Salovaara (2005) found that students reported different kinds of self-regulation strategies such as goal settings, activation of prior knowledge, and monitoring of learning processes. They also searched the shared database, which was constructed by the students as a group, to find information. They sought help from their friends, and tried to look for others' perspectives and also shared their ideas with others.

Although prior studies confirmed that students self-regulated in collaboration, only a few studies examined the relationship between self-regulation and learning outcomes in a collaborative learning environment. Prior studies suggested that the use of self-regulated learning strategies, such as planning and monitoring, facilitated students' learning in complex science systems (e.g. Azevedo, Winters, et al., 2004). In their study, high school students solved ecological problems collaboratively in a web environment. Azevedo et al (2004) included peer questioning as one of the dimensions of monitoring behaviors to reflect the social aspects of self-regulation. They found that the use of self-regulated learning strategies was positively related to students' learning. When learners regulated their behaviors in a collaborative problem-solving environment, they would also perform better. In the study conducted by Azevedo et al

(2004), the individual components and the social components of self-regulation were aggregated as one measure of self-regulation. It was unclear which of the variables of self-regulation (the individual components or the social components) led to learning outcomes. Until now, little research has specifically examined the impact of self-regulation in a social context on learning outcomes.

Co-Regulation

In a collaborative problem-solving situation, regulation of cognition not only occurs at the individual level, but also at the *group level* that involves all or most of the group members regulating their collective activities. Hadwin, Oshige, Gress, and Winne (2010) highlighted the collective features in co-regulation and defined co-regulation as “the processes by which *multiple others* regulated their *collective activity*” (p.801). In understanding how high school students solved mathematics problems collaboratively, Iiskala, Vauras, Lehtinen and Salonen (2011) referred to co-regulation as the *consensual monitoring* and *regulation of joint processes* in collaborative problem-solving situations. Järvenoja and Järvelä defined co-regulation as a process that “some or all of the group members aim to regulate themselves together in order to reach a shared goal” (Järvenoja & Järvelä, 2009, p. 464).

There is other co-regulation literature that conceptualizes co-regulation differently. Drawing from the Vygotskian theory (Vygotsky, 1978), Hadwin, Oshige, Gress, and Winne (2010) conceptualized co-regulation as “a *transitional process* in a learner’s acquisition of SRL, within which experts and learners shared a common problem-solving plane and SRL was gradually appropriated by the individual learner through interpersonal interactions" (p.799). In other words, co-regulation involves an individual who is learning self-regulation from another person, a more capable other (MCO). From this perspective, the cognitive and metacognitive demand of the problem is first shared by the MCO. Then, when the learner is able to perform the task independently, the MCO withdraws his/her support. In a collaborative problem-solving environment, everyone contributes to self-regulation, instead of having one or more MCO(s) scaffolding other's self-regulation needs. Hadwin's view of co-regulation as a transitional process may be more useful when an instructor tries to scaffold learners' self-regulation in a learning environment.

Based on Vygotskyian theory, McCaslin (2009) refers to co-regulation as "the relationships among cultural, social, and personal sources of influence that together challenge, shape, and guide "co-regulate identity" (p.137). Instead of understanding how learners regulate their activities, McCaslin focuses on the effect of the combined forces of cultural, social and personal forces on an individual's identity. McCaslin views identity as the heart of the co-regulation process, and the focus on identity may not be useful in the context of problem solving.

Volet, Summers and Thurman (2009) took a broad understanding of co-regulation as "a process by which social environments supported or scaffolded individual participation and learning" (p.129). Their framework of the social aspects of self-regulation includes two dimensions – the cognitive processing dimension and the co-regulation dimension. The cognitive processing dimension refers to the level of students' cognitive engagement in the task, and co-regulation refers to the number of people who make verbal contributions to the discussion (Volet, Summers, & Thurman, 2009). Their framework encompasses two major components of co-regulation: first, the members of the team have to actively engage in the regulative processes such as planning, monitoring, and reflecting; second, multiple members of the team have to be engage in the activity. If only one or a small proportion of the team is engaging in the regulation activity, it cannot be viewed a successful co-regulation because the goals are not shared through a consensual process.

Lajoie and Lu (2011) employed the two dimensional co-regulation framework by Volet and her colleagues to understand co-regulation in the context of medical decision making in emergencies. To operationalize co-regulation, Lajoie and Lu coded students' metacognitive activities into orientation, planning, execution, monitoring, evaluation, and elaboration, and assumed that these actions reflected the degree of co-regulation. They qualitatively examined whether the regulative behaviors were indeed exhibited by multiple members of the groups. Lajoie and Lu's work demonstrated the application of the two-dimensional framework, and their results provided evidence that better co-regulation could lead to better problem-solving outcomes.

In conclusion, drawing from the literature of self-regulated learning (Pintrich, 2000), and the definitions of social regulation (Hadwin et al., 2010; Iiskala et al., 2011; Volet, Summers, et al., 2009), some common characteristics of co-regulation can be summarized. First, it is a group process. Therefore, co-regulation should be conceptualized and measured at the group level. Second, most of the members of the groups should be involved in the process. Third, the members should engage in some discussion or negotiation to obtain consensus during co-regulation. Finally, the group should have a group goal. In the current study, *co-regulation is defined* as *a group process* whereby multiple members dynamically set goals, monitor, and evaluate their shared understanding of the problem and the solution, in a problem-solving process.

In the following section, some studies regarding co-regulation in collaborative problem-solving situations are reviewed. To understand students' self-regulated learning behaviors and strategies in collaborative problem-solving situations, Salovaara (2005) interviewed twenty-six students who participated in collaborative problem-solving exercises. The results of one hundred and sixty-one interviews suggested eighteen different cognitive strategies, such as goal setting, planning of learning procedure, prior knowledge activation, seeking information from the collaborative database, revising the work, and cognitive self-evaluation of the learning processes and learning content (Salovaara, 2005). Although her work does not provide an exclusive list of co-regulation behaviors, Salovaara's work suggests that students exhibit different types of co-regulation behaviors in a collaborative problem-solving environment.

In another study, Lajoie and Lu (2011) tried to understand co-regulation in the context of decision making in simulated emergencies. They defined co-regulation as "a process by which a social environment serves to support or scaffold individual participation and learning" (Lajoie & Lu, 2011, pp. 2-3). The qualitative study investigated how fourteen third year medical students solved emergency medical cases in a small group environment. Operationally, Lajoie and Lu (2011) coded students' metacognitive activities to reflect the degree of the team's co-regulation, such as orientation, planning, execution, monitoring, evaluation, and elaboration, based on an online communication log. Adopting the Volet's two dimensions' co-regulation framework (Volet, Summers, et al., 2009), Lajoie & Lu (2011) counted the self-regulation activities and examined the interactions among the group members qualitatively to confirm that the regulative behaviors were indeed exhibited by multiple members. Their results suggested that co-regulation could lead to better problem-solving outcomes.

Another type of co-regulation studies focuses on the scaffolding strategies in a collaborative environment. Molenaar, van Boxtel, and Sleegers (2010) examined the effects of scaffolding self-regulation activities in small groups. Molenaar et al. (2010) randomly selected 18 triads from three schools of 4^{th}, 5^{th} and 6^{th} graders. The computer scaffolds guided the students to plan and monitor different steps in their writing projects. Students' discourses were audio-taped and coded into different self-regulative behaviors, such as orienting, planning, monitoring, evaluating, and reflecting. Using Mann-Whitney tests, Molenaar et al. (2010) found that self-regulation scaffolding had an effect on both the number of self-regulation activities and also the writing performance, and the effect lasted after the scaffolding was faded. This study supports the premise that self-regulation and co-regulation in a collaborative context have an impact on ill-structured problem solving.

Although Molenaar et al. (2010) provided evidences to support the relationship between the social aspects of self-regulation and ill-structured problem solving, they did not distinguish between individual-level self-regulation and group-level co-regulation in their conceptualization and coding. For instance, they coded the following two examples as monitoring: "I do not understand", and "You are doing it wrong". In the first example, it was a self-regulation, which showed one student did not understand a concept. The second example involved an initiation of interactions: a student pointed out a mistake of another student. If the other student responded, the group would engage in a co-regulation behavior. When those two items together were aggregated as a self-regulation measure, it was not clear whether self-regulation or co-regulation contributed to the problem-solving outcomes.

In conclusion, the research of the social aspects of self-regulation is still in its infancy. Two major gaps have been found in this literature review: (1) the lack of understanding of the cognitive dimension of self-regulation and co-regulation in a social context; (2) the lack of research that distinguishes the individual level self-regulation and group level co-regulation. First, most of the studies regarding the social aspects of self-regulation focus on motivation (e.g., Järvelä et al., 2008; McCaslin, 2009) and emotion (Volet & Mansfield, 2006; Volet, Summers, et al., 2009). Few studies examine the cognitive dimensions of self-regulation in a collaborative environment. Although motivation and emotion are important dimensions for the social aspects of self-regulated learning, it is also important to understand the cognitive dimension of it because cognition is a major component in the ill-structured problem-solving process (Ge & Land, 2004).

Second, the studies of the social aspects of self- regulation do not clearly separate the individual level and the group level regulation. For example, Molenaar and her colleagues (2010) did not distinguish regulation behaviors at individual or group level in their study. The social aspects of self-regulation can occur at both the individual level and the group level (Järvelä et al., 2008). Individuals can regulate their own behaviors, and the group members can also co-regulate their shared understanding. The group level and individual level self-regulation may interact. For instance, individual self-regulation in a collaborative environment may trigger other members to self-regulate, which, in turn, triggers the group self-regulation. If members see the whole group actively plan, and monitor and evaluate their group learning outcomes, they may be more engaged in self-regulation. Hence, in the current study, I examined two types of self-regulation behaviors –self-regulation and co-regulation in a social context. In addition, I also examined the interaction effect of self-regulation and co-regulation on ill-structured problem solving in a social context.

OVERVIEW OF THE STUDY

Therefore, the purpose of the current study was to understand self-regulation and co-regulation in a social context and to explore their relationships with ill-structured problem solving. Particularly, this study extended the understanding of self-regulation to the group level and allowed the research community to understand the cross-level interaction between self-regulation, co-regulation, and ill-structured problem solving. Moreover, this study examined a neglected mechanism during collaborative problem solving —self-regulation. Finally, the current study compared two different ways to measure self-regulation and co-regulation in a social context. The following questions were investigated:

1. How do students regulate their own cognition during different processes of collaborative ill-structured problem solving?
2. How does a team co-regulate its understanding of a problem during different processes of collaborative ill-structured problem solving?
3. Does self-regulation influence students' collaborative ill-structured problem-solving performance?
4. Does co-regulation influence the group's collaborative ill-structured problem-solving performance?
5. Is the relationship between self-regulation and students' collaborative ill-structured problem-solving performance influenced by different levels of group's co-regulation?
6. Do the self-report measures and the behavioral count measures of self-regulation yield similar results in the context of collaborative ill-structured problem solving?
7. Do the self-report measures and the behavioral count measures of co-regulation yield similar results in the context of collaborative ill-structured problem solving?

Based on questions 3-7, the following hypotheses were generated:

Hypothesis 1: Students' self-regulation will have a positive effect on students' ill-structured problem-solving scores.

Hypothesis 2: Students' co-regulation will have a positive effect on students' ill-structured problem-solving scores.

Hypothesis 3: The interaction between self-regulation and co-regulation will have a positive effect on students' ill-structured problem-solving scores. The higher the students' self-regulation and co-regulation, the better the students will score on ill-structured problem solving.

Hypothesis 4: The self-report measures and behavioral count measures of self-regulation will yield similar results in the context of collaborative ill-structured problem solving.

Hypothesis 5: The self-report measures and behavioral count measures of co-regulation will yield similar results in the context of collaborative ill-structured problem solving.

CHAPTER 3: METHODOLOGY

INTRODUCTION

The aim of the current study is to examine students' self-regulation and co-regulation in the context of collaborative ill-structured problem solving. This chapter explains the research design, participants, measures of the variables, materials, implementation procedures, and data analysis.

RESEARCH DESIGN

The current study has three major objectives: (1) to describe the social aspects of self-regulation, (2) to examine the relationships between the social aspects of self-regulation and ill-structured problem solving, and (3) to compare two different ways – self-report questionnaires and researcher coded behaviors – of measuring self-regulation and co-regulation. Descriptive statistics and a quantitative study (correlational design) were used to address these objectives. The research questions, corresponding designs, variables, analytical techniques, instruments, and data sources, are summarized in Table 2.

Table 2. Research Questions, Study Design, Variables, Data Analysis, Instruments, and Data Sources

Research Question	Study Design	Variable	Data Analysis	Instrument	Data Source
1. How do students *regulate their own cognition* during different processes of collaborative ill-structured problem solving?	Descriptive study	*Self-regulation* in problem representation & solution generation (Goal settings, Monitoring & Reflecting)	Descriptive statistics and Case analysis	A questionnaire (see Appendix C & Appendix D) A Rubric (see Appendix E & Appendix F)	Self-report Discussion logs
2. How does a team *co-regulate* its understanding of a problem during different processes of a collaborative ill-structured problem solving?		*Co-regulation* in problem representation & solution generation (Goal settings, Monitoring, & Reflecting)			
3. Does *self-regulation* influence students' collaborative ill-structured problem-solving performance?	Correlational design	IV: *Self-regulation* DV: ill-structured problem solving	Multilevel analysis	A questionnaire (see Appendix C & Appendix D)	Self-report
4. Does *co-regulation* influence the group's collaborative ill-structured problem-solving performance?		IV1: *Self-regulation* IV2: *Co-regulation* DV: Ill-structured problem solving		A Rubric (see Appendix E & Appendix F)	Discussion logs
5. Is the relationship between self-regulation and students' collaborative ill-structured problem-solving performance influenced by different levels of group's co-regulation?		IV1: *Self-regulation* IV2: *Co-regulation* DV: Ill-structured problem solving		Balanced Propositional Matching (Ifenthaler, 2011)	Students' individual essays
6. Do the self-reported measures and the behavioral count measures of *self-regulation* yield similar results in the context of collaborative ill-structured problem solving?	Correlational design	IV: *Self-regulation* DV: Ill-structured problem solving	Multilevel analysis & correlation	A questionnaire (see Appendix C & Appendix D) A Rubric (see Appendix E & Appendix F)	Self-report Discussion logs
7. Do the self-report measures and the behavioral count measures of *co-regulation* yield similar results in the context of collaborative ill-structured problem solving?		IV1: *Self-regulation* IV2: *Co-regulation* DV: Ill-structured problem solving		Balanced Propositional Matching (Ifenthaler, 2011)	Students' individual essays

In an effort to describe the social aspects of self-regulation, descriptive statistics were used to describe the central tendency of self-regulation and co-regulation. Furthermore, groups with *high*, *medium*, and *low* problem-solving scores were chosen for cross-case comparisons.

A correlational design was chosen to examine the relationship between students' social aspects of self-regulation and ill-structured problem solving. The independent variables in this study were self-regulation and co-regulation. The dependent variable was ill-structured problem-solving performance. Self-regulation and co-regulation were measured by a self-report questionnaire, and a count of researcher coding of participants' behaviors. Thus, two parallel sets of analyses were conducted using those two measures. Finally, the correlation design was also used to compare those two types of measures for the social aspects of self-regulation.

SAMPLING AND PARTICIPANTS

One hundred thirty-one college students enrolled in Educational Psychology courses from a mid-western university participated in this study (92% female and 8% male). These courses included *Educational Psychology of Childhood and Adolescence, Cognition, Motivation, and Classroom Management for Teachers*, and *Understanding and Accommodating Students with Exceptionalities*. The participants received course credits for their participation in the study.

Since the current study was to be conducted in a technology-supported collaborative environment and students were required to solve ill-structured problems, it was important for the participants to be comfortable with (1) collaboration, (2) communicating via technology tools, and (3) solving ill-structured problems. The participants of this study fit the above requirements. First, the participants were comfortable with collaborative tasks. Most of the participants were in their third or fourth year of college, and they had frequent opportunities to engage in group work in their freshman and sophomore years. The participants should be fairly familiar with using the selected information and communication tools – Desire-to-learn (D2L) – because D2L was a course management system adopted by the university. Finally, the students in the educational psychology classes should be familiar with ill-structured problems because many issues covered in these courses were ill-structured in nature.

MEASURES

In this section, the operationalization of the three key variables – self-regulation, co-regulation, and ill-structured problem solving – is explicated. Both self-regulation and co-regulation were measured by two different instruments: a self-report measure and a researcher coding of participants' behavioral counts to capture the overt and covert self-regulation and co-regulation behaviors.

Self-Report Questionnaire

Self-report Measures for Self-Regulation

To answer the first research question, the Questionnaire for Self-Regulation (see Appendix C) was developed to measure participants' perception about their self-regulation in a collaborative problem-solving situation. Drawing from the literature of self-regulation (Pintrich, 2000; Zimmerman, 2001), ill-structured problem solving (Jonassen, 1997; Sinnott, 1989; Voss & Post, 1988), and collaborative problem solving (Goos et al., 2002; Iiskala et al., 2011; Roschelle & Teasley, 1995), I suggest that self-regulation in a collaborative problem-solving context has two dimensions: the self-regulation dimension and problem-solving dimension. The first dimension of self-regulation involves three phases of self-regulation: goal setting, monitoring, and reflecting; the second dimension involves two problem-solving phases: problem representation, and solution generation. The blue-print of the construct is shown in Appendix B.

Based on the blue print, items from the self-regulation sub-scale of Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1991), and the problem-solving skills' questionnaire (Ge, 2001) were adapted to measure self-regulation in a social context. The new seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree) measures how learners regulate their cognitive process based on their peers' input and how they invite others to regulate their own cognition during an ill-structured problem-solving situation. The full questionnaire is shown in Appendix C and some examples of the items are listed below:

- *"When I solved the problem, I explained my interpretation of the problem to my peers."*
- *"I was aware that my peers had a different understanding of the problem."*
- *"After my peers explained their understanding of the problem, I shared my understanding with them"*.

The Motivated Strategies for Learning Questionnaire (MSLQ) is one of the most frequently used instruments measuring self-regulation (Winne & Perry, 2000), and it is a well-developed scale for motivation and self-regulation with good reliability and validity (Duncan & McKeachie, 2005). It has 81 items in total, consisting of 15 sub-scales to measure how well individuals regulate their learning in a classroom environment (Duncan & McKeachie, 2005). MSLQ has shown good reliability and validity consistently in different studies (alphas over .7 for most of the sub-scales; Duncan & McKeachie, 2005; Schunk, 2005). For example, Sperling and her colleagues (2004) compared MSLQ with another metacognition instrument, Metacognitive Awareness Inventory (MAI). The coefficient alphas of the MAI sub-scales were over .85 (Schraw & Dennison, 1994). They found that the metacognitive self-regulation scale of MSLQ was significantly correlated with knowledge of cognition and regulation of cognition factors of the MAI. In the current study, six sub-components of self-regulation were computed: goal settings in problem representation, monitoring in problem representation, reflecting in problem representation, goal settings in solution generation, monitoring in solution generation, and reflecting in solution generation. To answer Research Questions 3,4,5, and 6, self-report self-regulation was computed by averaging the six sub-components of self-regulation. Cronbach alphas were calculated to ensure the reliability of the scales.

Self-Report Measures for Co-Regulation

To answer research question 2, the Questionnaire for Co-Regulation (see Appendix D) was developed to measure participants' perception of their teams' goal setting, monitoring, and reflecting as a group. Co-regulation is a similar concept to self-regulation, where self-regulation focuses on students' regulation at the individual level, and co-regulation focuses on groups' regulation. Operationally, co-regulation occurs when multiple group members regulate the group's behaviors and their shared understanding.

To operationalize co-regulation, the Questionnaire of Self-Regulation was modified for capturing the group processes by asking the participants their perception of the *team's regulation behaviors* instead of their own regulation behaviors. In other words, the instrument for measuring self-regulation asked problem solvers their perceptions of their own regulation behaviors in a social context while the instrument for measuring co-regulation asked the problem solvers their perceptions of the team members' regulation behaviors. For instance, an item measuring reflection behaviors for self-regulation was "*I* summarized the group's understanding of the problem." The above item was modified to "*My team* summarized our understanding of the problem" to capture co-regulation. The full questionnaire is shown in Appendix D, and some of the items are listed below:

- *"My team thought about whether we understood the problem correctly."*
- *"During our discussion, my team asked ourselves whether we understood the problem correctly or not."*
- *"My team discussed whether our problem interpretation was appropriate."*

Like self-regulation, six components of co-regulation were created: goal settings in problem representation, monitoring in problem representation, reflecting in problem representation, goal settings in solution generation, monitoring in solution generation, and reflecting in solution generation. Those co-regulation scores were calculated by averaging team members' co-regulation sub-scores. To answer the research questions 4,5, and 7, a co-regulation score was aggregated by averaging all the co-regulation sub-scores for each team.

Behavioral Count Measures

Behavioral Count Measures of Self-Regulation

To capture participants' self-regulation behaviors, three graduate students inferred their self-regulation behaviors from the participants' discussion logs using a rubric. The coding rubric and the procedures of coding are described as the following.

A coding rubric was developed according to the blueprint (see Appendix B) to code participants' self-regulation behaviors in the collaborative problem-solving sessions (see details of the rubric in Appendix E). The coding rubric included six behavioral count measures: three measures about students' self-regulation behaviors during the phase of problem representation (goal setting, monitoring, and reflecting), and three measures about students' self-regulation behaviors during the phase of solution generation (goal setting, monitoring, and reflecting). Table 3 presents some examples of the coding rubric.

Table 3. Examples of Coding: Codes, Description of Items, and Examples of Self-Regulation Behaviors

Code	Description of items	Example
GS1 (item 1 for Goal setting in solution generation)	Suggest an understanding of a problem or providing a solution	"I think we need to meet with the principal to discussion suspending them"
PR5 (item 5 for Monitoring in problem representation)	Aware of others' view points	"oh now I see"
GS9 (item 9 for Reflecting in solution generation)	Justifying a position	"because the bullies obviously have something in their past that disturbed them"

Three graduate students coded the discussion logs independently by (1) identifying self-regulation, (2) reconciling the discrepancies among the coders, (3) creating a final list of coding, and (4) summing up the counts of self-regulation behaviors. First, the coders read a discussion log, which included all the conversation among the participants in a particular group. Using the rubric, the coders identified participants' self-regulation behaviors, and gave the segments of the conversation different codes to identify the types of self-regulation behaviors. A segment of the coding for one group is showing in Table 4.

Table 4. A Segment of the Coding of Self-Regulation Behaviors

Line number	Name	Code
1	Student 1	GS1
2	Student 2	PR1
3	Student 3	PR1
3	Student 3	GS1
4	Student 3	GS1
4	Student 3	GS9
5	Student 4	GS1

The above segment showed that Student 1 suggested a solution for problem at the beginning of the conversation. Then, Student 2 provided her understanding of the problem. Then, Student 3 offered her understanding of the problem, suggested two possible solutions, and also a justification of a solution. Finally, Student 4 provided another possible solution. After the coders identifying all the self-regulation behaviors in the discussion log, they met and discussed the discrepancy of coding among them. A final list of coding for each group was created that based on the agreements of the coders. Then, the coders identify the frequency of each code for each participant. The self-regulation measures were created by summing the number of counts of different components of self-regulation behaviors. For instance, goal setting in problem representation phase was operationalized by adding the frequency of PR1, PR2, and

PR3. Finally, a self-regulation score was created by summing all the self-regulation sub-component scores for each individual.

Co-Regulation Rubric

A 7-point scale was used to infer groups' co-regulation from their discussion logs (see the details of the rubric in Appendix F). The rubric was based on the two-dimensional theoretical framework of co-regulation suggested by Volet, Summer, and Thurman (2009). They proposed a theoretical framework of co-regulation with two dimensions — the first dimension represents the number of members engaging in co-regulation behaviors, and the second dimension represents participants' cognitive processing during collaborative problem solving, implicitly assuming high self-regulation during high cognitive processing (see Figure 2).

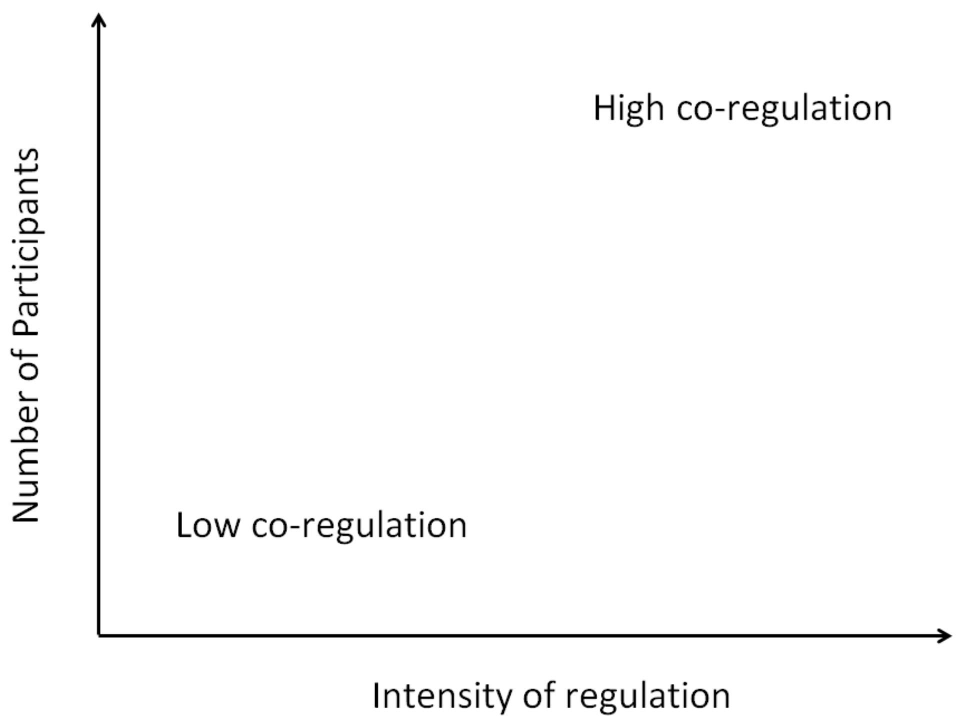

Figure 2. A Theoretical Framework of Co-Regulation

A group with a low level of co-regulation has most of the members engaging in a low intensity of self-regulation behaviors; while a group with a high level of co-regulation has many members engaging a high intensity of self-regulation behaviors. The intensity of self-regulation behaviors was demonstrated by the nature of the self-regulation behaviors, the number of types of self-regulation behaviors, and the frequency of the self-regulation behaviors. Low intensity behaviors included giving out information and opinion, and showing agreement or disagreement. Supporting or refuting an argument, asking for information, and explaining someone's ideas, were medium intensity behaviors. Summarizing was a high intensity behavior. When a participant showed more types and higher frequency of self-regulation behaviors, the intensity was also higher. For example, when no problem solver showed any co-regulation behaviors, the team score of co-regulation was 0. When all of the problem solvers showed co-regulation behaviors intensely, the team score of co-regulation was 7.

Three graduate students followed the procedures below to code each group co-regulation independently. First, using the reconciled self-regulation behavior list, each of the coder sorted self-regulation behaviors by student names. Then, they tabulated the frequency of each self-regulation behaviors in a table. An example of a tabulation outcome of a group with a low co-regulation in problem presentation score is shown in Table 5. In this group shown in Table 5, all three of the participants, (1) had very few self-regulation counts (2 or 3); (2) the types of different co-regulation behaviors were few (only 2-3 types of self-regulation behaviors per person), and (3) the intensity of those self-regulation behaviors were either low or medium, such as providing an idea, agreeing/disagreeing with an idea, and supporting/refuting an idea. Based on the Co-Regulation Rubric, the coder gave a score for this group (which was 1 in this case). If the coders found discrepancy among them, they discussed and negotiated until they agreed on the score.

Table 5. An Example of the Coding of Self-Regulation Behaviors from a Group with a Low Co-Regulation Score

Name	Code	Frequency
Student 10	PR1	1
Student 10	PR7	1
Student 11	PR1	1
Student 11	PR8	1
Student 12	PR1	1
Student 12	PR4	1
Student 12	PR9	1

Measurement of Ill-Structured Problem-Solving Performance

Balanced Proposition Matching –An Index to Measure Students' Knowledge Structures

One approach to assess ill-structured problem solving is to compare students' knowledge structures with an expert's knowledge structure (Jonassen, Beissner, & Yacci, 1993). When studying how expert instructional designers solve ill-structured problems, Eseryel (2006) found that although expert instructional designers provided different solutions, their knowledge structure was generally very similar, characterized by the factors that were central to the problems and the relationships among those factors. Based on her findings, Eseryel (2006) suggested that it was appropriate to measure ill-structured problem solving by comparing learners' knowledge structure with an expert's knowledge structure. Hence, the current study adopted the balanced propositional matching measure to capture students' ill-structured problem solving. The balanced propositional matching measure compares the sets of concepts within a graph and fully identical propositions between a learner's knowledge structure and an expert's knowledge structure (Ifenthaler, 2011).

The balanced propositional matching measure is generated by Automated Knowledge Visualization and Assessment (AKOVIA), which compared students' knowledge structure to an expert's knowledge structure by (1) parsing students' essays and an expert's essay into concepts, (2) creating students' knowledge structure maps and an expert's knowledge structure map based on the concepts from the essays, (3) generating similarity measures based on the structures of the maps and the content of the maps. Balanced propositional measure concerned the correct use of concepts and their correct relatedness. For instance, Figure 3 and Figure 4 depict two examples of mental models generated by AKOVIA, the expert's model and the novice's model. A balanced propositional measure for the novice (her mental model as shown in Figure 4) should be relatively low because many concepts in the expert map (as shown in Figure 3), such as counseling, administration, policy, and so on, could not be found in the novice maps. Moreover, the concepts in the expert's maps were a lot more interrelated than concepts in the novice map.

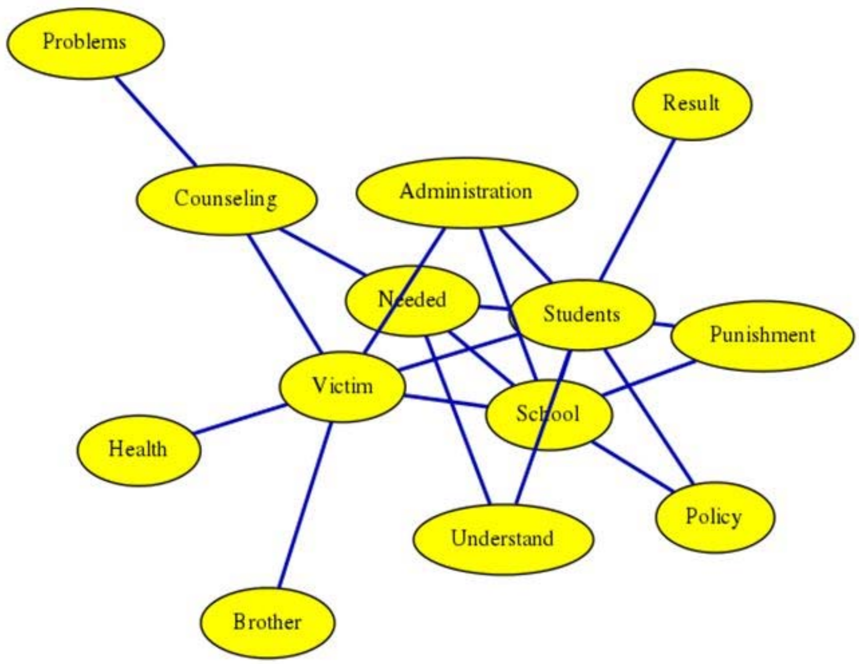

Figure 3. An Expert's Mental Model Representation

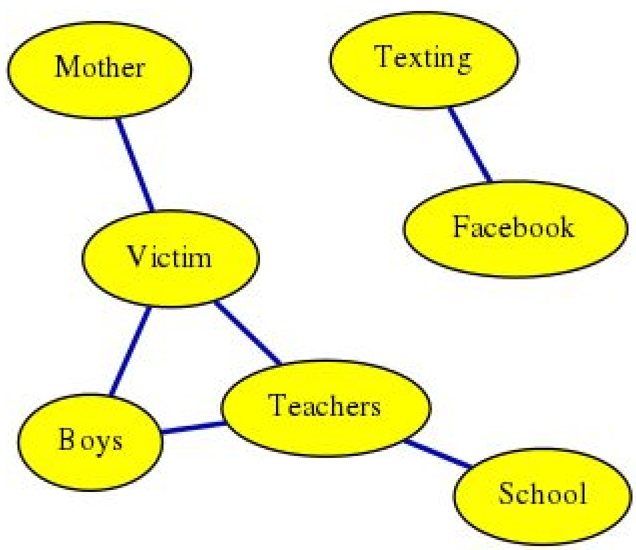

Figure 4. A Novice's Mental Model Representation

The reliability and validity of the AKOVIA measures have been tested in multiple studies (Eseryel, Ifenthaler, & Ge, 2011; Ifenthaler, 2010; Pirnay-Dummer, Ifenthaler, & Spector, 2010). For example, Eseryel, Ifenthaler and Ge (2011) validated students' ill-structured problem-solving outcomes against measures of a problem-solving rubric to AKOVIA measures. They found that the two measures of ill-structured problem solving were highly correlated.

MATERIALS

An ill-structured problem on cyberbullying was provided to the participants (see Appendix A). The problem had a vague problem definition, multiple solution paths and solutions, and ill-defined evaluation criteria of the solution. Cyberbullying is a catchy and current topic that has been a social concern for American educators and parents in this digital age.

In the hypothetical scenario, a parent reported to a principal that her son, a ninth grader, had been bullied electronically by two other classmates via email, texting, and other social media. The participants of this study were asked to discuss the problem and possible solutions in D2L chat in groups of 3 or 4. Then, they were asked to write an individual report to describe their understanding of the problem and their proposed solution and include the following elements in the report: (1) the relevant issues related to the problem, (2) the relationships among those issues, (3) their proposed solution(s), (4) their justification of their solution, and (5) their explanation of how their solution(s) addressed the relevant issues.

The background information about this case involved the facts about the bullying behaviors, the school policy about bullying, the bullies' perspective of the case, and the perspective of the victim's parent. A jigsaw strategy was used to create the necessity for collaboration. In the jigsaw problem-solving activity, each of the participants was provided with only one piece of the information regarding the problem to allow team members to share information with one another and contribute to the team's problem understanding. The background information of this case was divided into three or four pieces depending on the group size, which is illustrated by Table 6.

Table 6. Information Given to Participants

Information given to groups of 3		Information given to groups of 4	
Participant A	Facts about bullying & school policy regarding to bullying	Participant A	Facts about the bullying
Participant B	An interview report from the victim's parent	Participant B	An interview report from the victim's parent
Participant C	An interview report from the bullies	Participant C	An interview report from the bullies
		Participant D	School policy regarding to bullying

The details of the scenario, task, and information provided to the participants can be found in Appendix A. Since each of the team members held a different piece of information, it would lead to different perspectives of team members regarding problem understanding, monitoring of solution process, and reflection on the information provided by the other members. The jigsaw strategy encouraged all the team members to share their perspectives and collaboratively generate optimal solutions for the problem. By sharing the information with each other, the whole group could see a bigger picture than an individual.

IMPLEMENTATION PROCEDURES

The experimental procedure involved five steps that an individual participant must complete within one hour of experimental study conducted in a computer lab: (1) random assignment of research participants in groups of three or four, (2) reading the problem scenario and piece of information related to the scenario, (3) group discussion in D2L chat rooms, (4) individual writing the problem solution report independently, and (5) completing a questionnaire of sixty-one items on self-regulation and co-regulation. The experimental procedures are outlined in Figure 5:

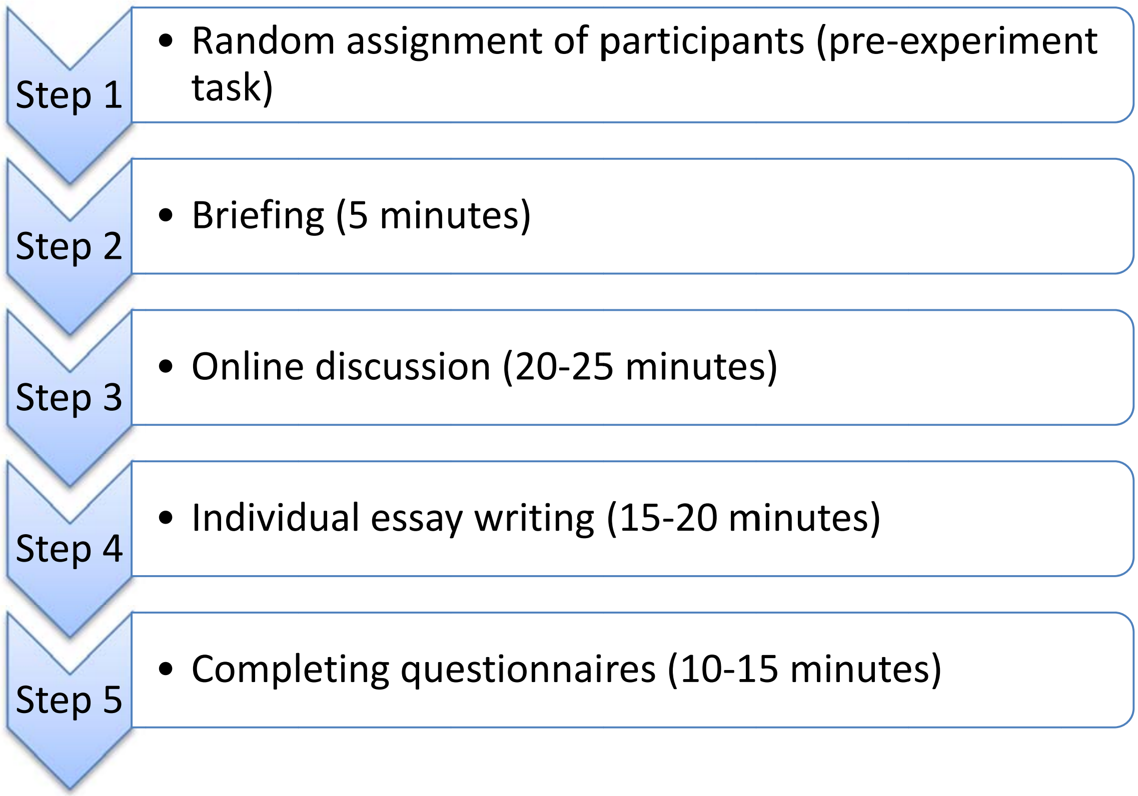

Figure 5. An Outline of the Experimental Procedure

Step 1: Random assignment of participants

Participants were randomly assigned into groups of three to four. There were two major concerns of the group assignment – group size and the gender composition. The choice of the group size was to maximize the problem-solving performance and to optimize peer interactions and self-regulation behaviors. Furthermore, since the current study examined the phenomenon at the group level, it was important to maximize the number of groups to increase the power of statistics. In a meta-analysis, Lou, Abrami and d'Apollonia (2001) found that groups of three to five performed better than pairs.

From the perspective of self-regulated learning, small groups with students in groups of three to six led to more self-regulated behaviors (Lohman & Finkelstein, 2000). Therefore, the group size of three to four was adopted for this study.

Gender composition was another concern for the group assignment. Gender has been found as a factor affecting collaboration (Jonassen, Lee, Yang, & Laffey, 2005; O'Donnell, 2006; Webb & Palincsar, 1996). To control the gender effect, female only groups and mixed-gender groups were created. Because the participant pool had a limited number of male participants, no male only group could be created.

Step 2: Distributing and reading the problem scenarios and tasks

To ensure each participant received different pieces of information of the scenario, different forms were given to the participants depending on the group size (see details of the problem scenarios and tasks in Appendix A). The participants spent about five minutes to read the problem scenarios, the information given to them, and the task.

Step 3: Discussion of the problem

After the participants read the scenario and their information about the case, they discussed their understanding of the ill-structured problem and possible solutions in D2L's chat rooms for about twenty to twenty-five minutes. Each group was assigned a designated chat room so that the problem-solving tasks and outcomes were not affected by any cross-group communication. All the interactions among the participants were recorded as chat logs, which were used as a data source for data analyses.

Step 4: Writing of individual essays

At the end of the group discussion, each member wrote an individual essay that explained his or her individual understanding of the problem and the solutions for the problem. The reports were submitted to D2L dropbox that could only be accessed by the researcher. About fifteen minutes were allocated for essay writing.

Step 5: Completing questionnaires

Finally, the participants filled out an electronic questionnaire, which was designed to elicit their perception of their *self-regulation* behaviors and their group *co-regulation* behaviors during the collaborative problem-solving activities. Participants would be given about fifteen minutes to finish the questionnaire, which included both demographic data and instruments measuring participants' regulative behaviors.

DATA ANALYSIS

Descriptive Statistics & Case Analysis

The first and second research questions examine *self-regulation* and *co-regulation* during collaborative ill-structured problem-solving processes. Descriptive statistics of self-regulation and co-regulation were run to provide a general picture of the distributions of all the variables. In addition to the descriptive statistics, quantitative descriptive analyses were chosen to describe participants' self-regulation and co-regulation during the collaborative problem solving processes. Three groups with high, medium and low ill-structured problem-solving scores were chosen for the analysis (one group from the top 33%, one group from the second 33%, and one group from the last 33%). Graphical representations of participants' regulation were created to demonstrate the dynamics of regulation behaviors throughout ill-structured problem solving.

Automated Knowledge Visualization and Assessment (AKOVIA)

In order to analyze problem-solving performances, AKOVIA was applied to analyze participants' problem-solving essays. AKOVIA is a newly developed version of Highly Integrated Model Assessment Technology and Tools (HIMATT), which compares students' knowledge structures with an expert's knowledge structure (Pirnay-Dummer et al., 2010). This tool provides useful information about students' mental models. Drawing from mental model theory, graph theory, and set theory (Pirnay-Dummer et al., 2010), AKOVIA consists of a set of technology tools that are used to examine the structural and semantic relationships between students' identified concepts and relationships and their similarity to those of an expert.

AKOVIA requires an expert solution to be developed to generate similarity measures. Two experts on bullying were interviewed to identify an expert's knowledge structure and to develop an expert solution. The first expert was a teacher with more than 15 years of teaching and counseling experience in dealing with bullies and bullying victims at schools. The second expert was a professor who had conducted numerous studies on the topic of bullying. The cyberbullying task of the experiment was given to the experts, and they provided their own solutions for the case during the interviews. Based on the two experts' interviews, an expert solution was developed. Then, the participants' problem-solving outcomes were compared with the experts' solution using AKOVIA. AKOVIA first transferred the students' and expert's texts into graphs using T-MITOCAR algorithm, which parsed the concepts from texts and generated a graphical representations of the knowledge structure (Pirnay-Dummer & Ifenthaler, 2010). Finally, AKOVIA generated the balanced propositional measures which compared students' knowledge structure with an expert knowledge structure.

Multilevel Analyses

To answer the third, fourth and fifth research questions, a set of multilevel analyses was conducted to examine the relationships between the social aspects of self-regulation and ill-structured problem solving. Multilevel analysis is appropriate for small group research where participants are nested in groups. Indeed, multilevel modeling has been applied in many small group research studies in many different contexts such as math problem solving and the learning of social science (e.g. Chiu, 2008; Strijbos, Martens, Jochems, & Broers, 2004) because of its ability to examine relationships of constructs from different levels (Tabachnick & Fidell, 2007). Furthermore, multilevel analysis can model cross-level interactions (Osborne, 2000). In the current study, one hundred and thirty-two participants were nested in thirty-nine groups. It was hypothesized that group-level co-regulation would interact with the individual-level self-regulation to influence ill-structured problem solving.

Common statistical analyses, such as ordinary least square (OLS) method, cannot model cross-level analyses, and thus it is not appropriate to deal with cross-level analysis, nor the dependent nature of the data in the current study (Osborne, 2000). Also, because the participants collaborated in a group environment, they probably influenced each other regarding their self-regulation and ill-structured problem solving. For instance, if one person refuted his/her group members' ideas, his/her group members might defend their own positions, and, thus, increased social regulation behaviors. The independence of observations assumption for OLS would probably be violated, and thus, Type I error would probably be inflated. Therefore, multilevel analysis was preferred since independent observation was not a requirement for multilevel analyses (Tabachnick & Fidell, 2007).

Two sets of multilevel analyses were conducted using HLM 7 to examine the main effects and the interaction effects of self-regulation in the social context and co-regulation on ill-structured problem solving. The basic models of the two sets of analyses were the same, but they used different measures of self-regulation and co-regulation. The first set of multilevel analyses used the self-report measure of self-regulation and co-regulation to run the analyses, whereas the second set of multilevel analyses use the research coding measures of self-regulation and co-regulation to run the analyses. The analytical process is explained below.

A four-step process was used to examine the individual-level, group-level and cross-level effects of self-regulated learning on ill-structured problem solving (Hox, 2010). In Step 1, the unconditional model with no predictors was tested to determine if there were significant variations in problem solving among different groups. The regression model is shown as follow:

Level 1 (Individual) Model:

Ill-structured problem $\text{solving}_{ij} = \beta_{00} + e_{ij}$

Level 2 (Group) Model:

$\beta_{00} = \gamma_{00} + \mu_{0j}$

where γ is the grand mean of ill-structured problem solving, and μ_{0j} is the unique effect of group j on the intercept.

In Step 2, the individual-level *self-regulation* was added as an individual-level predictor to predict problem solving. Self-regulation was centered around the group means to facilitate interpretation of the results (West, Ryu, Kwok, & Cham, 2011). The new centered variable was calculated by subtracting the self-regulation scores from the grand mean of the self-regulation scores. This model could answer research question 3: "does self-regulation have an impact on students' collaborative ill-structured problem-solving performance?" The updated regression model is shown as follow:

Level 1 (Individual) Model:

Ill-structured problem solving$_{ij}$ = $\beta_{00} + \beta_{1j}$ (self-regulation) + e_{ij}

Level 2 (Group) Model:

$\beta_{00} = \gamma_{00} + \mu_{0j}$

$\beta_{1j} = \gamma_{10}$

where γ_{00} is the grand mean of ill-structured problem solving, and μ_{0j} is the unique effect of group j on the intercept. γ_{10} is the overall regression coefficient between individual self-regulation problem solving.

In Step 3, the group-level co-regulation was added as a level 2 predictor to predict ill-structured problem solving at the individual level. Co-regulation was centered around the grand mean to facilitate interpretation of the results (West et al., 2011). The centered co-regulation variable was calculated by subtracting the co-regulation scores from the group mean score. This model provided an answer for research question 4: "does co-regulation influence the group's collaborative ill-structured problem-solving performance?" The regression model is shown as follow:

Level 1 (Individual) Model:

Ill-structured problem solving$_{ij}$ = $\beta_{00} + \beta_{1j}$ (self-regulation) + e_{ij}

Level 2 (Group) Model:

$\beta_{00} = \gamma_{00} + \gamma_{01}$ (co-regulation)$+\mu_{0j}$

$\beta_{1j} = \gamma_{10}$

where γ_{00} is the grand mean of Ill-structured problem solving, and μ_{0j} is the unique effect of group j on the intercept. γ_{10} is the overall regression coefficient between self-regulation and ill-structure problem solving, and γ_{01} is the overall regression coefficient between group co-regulation and ill-structured problem solving.

In Step 4, the group-level co-regulation was added as a level 2 predictor to predict ill-structured problem solving at the individual level. This final model provided an answer for research question 5: "is the relationship between self-regulation and students' collaborative ill-structured problem-solving performance influenced by different levels of group's co-regulation?" The final regression model is shown as the following:

Level 1 (Individual) Model:

Ill-structured problem solving$_{ij} = \beta_{00} + \beta_{1j}$ (self-regulation) $+ e_{ij}$

Level 2 (Group) Model:

$\beta_{00} = \gamma_{00} + \gamma_{01}$ (co-regulation)$+\mu_{0j}$

$\beta_{1j} = \gamma_{10} + \gamma_{11}$ (co-regulation)

where γ_{00} is the grand mean of ill-structured problem solving, and μ_{0j} is the unique effect of group j on the intercept. γ_{10} is the overall regression coefficient between self-regulation and ill-structured problem solving, and γ_{01} is the overall regression coefficient between group co-regulation and ill-structured problem solving. Finally, γ_{11} is the overall regression of the interaction between self-regulation and co-regulation that may account for differences in ill-structured problem solving in the individual slope.

At each level, the intra-class correlation coefficients were calculated and interpreted to understand the general group level effect on ill-structured problem solving. Moreover, the regression coefficients in Step 2 and Step 3 were explained to examine the relationships between both individual-level self-regulation and ill-structured problem solving, and group-level co-regulation and ill-structured problem solving.

Bivariate Correlation

Finally, the last two research questions compared the self-report measures with the behavioral count measures of self-regulation and co-regulation. Bivariate correlation was used to examine whether the self-report measures of self-regulation were significantly related to the behavioral count measures of self-regulation. In addition, two sets of multilevel analysis results were compared to examine whether the self-report measures and the behavioral count measures of self-regulation yielded similar results.

To answer research question seven, I ran bivariate correlation to examine whether the means of self-reported co-regulation were significantly related to the researcher coding measures of co-regulation. Two sets of multilevel analysis results were also compared to examine whether the self-report measures and researcher coding measures of co-regulation yielded similar results.

CHAPTER 4: RESULTS

The goal of this study was to explore self-regulation and co-regulation, and their effects on collaborative ill-structured problem solving. To address the first two research questions concerning students' self-regulation and co-regulation in an ill-structured problem solving, the descriptive statistics of students' self-regulation and co-regulation are shown to describe how participants' self-regulate their own behaviors while co-regulating their shared understanding at the same time. Then, the case comparisons *of high, medium,* and *low* performing groups are presented to provide an in-depth understanding of students' self-regulation and co-regulation. To address the third, fourth and fifth questions concerning the relationships among self-regulation, co-regulation, and ill-structured problem solving, the results of the multilevel analyses are reported. Specifically, the results of the following multilevel models are presented: (1) the main effect of self-regulation on ill-structured problem-solving, (2) the main effect of co-regulation on ill-structured problem solving, and (3) the interaction effect of self-regulation and co-regulation on ill-structured problem solving. Finally, to address research the sixth and seventh question, concerning how the self-report measures of self-regulation and co-regulation comparing to the behavioral count measures of the self-regulation and co-regulation, the results of correlation are presented. Moreover, the results of multilevel analyses were discussed to compare the students' self-reports with behavioral counts coded by the researchers regarding self-regulation and co-regulation. Table 7 presents the summary of findings of all the research questions, followed by specific details of the findings.

Table 7. Summary of the Findings

RQs	Hypotheses/Description	Findings
RQ1	Describing students' self-regulation in a collaborative context	From descriptive statistics • Above average self-perception on self-regulation (rating>0.488, except goal setting at solution generation at 0.421) • Few problem representation behaviors (counts<2.5), and more solution generation behaviors (counts > 3.5) From case comparison • The high performing group showed more self-regulation behaviors than the low performing group did • The high performing group showed more problem representation behaviors than the low performing group did • The high and medium performing groups showed some high intensity self-regulation behaviors, but low performing group did not
RQ2	Describing team's co-regulation in a collaborative context	From descriptive statistics • Above average self-perception on co-regulation (rating >0.478) • Co-regulation at problem representation (2.03) < Co-regulation at solution generation (4.21) • Rating of self-regulation ≈Rating of co-regulation From case comparison • The high and medium preforming groups had higher co-regulation than the low performing group
RQ3	H1: Students' self-regulation will have a positive effect on students' ill-structured problem-solving scores	Multilevel analysis using self-report measures • Non-significant positive relationship between self-regulation and ill-structured problem solving was found Multilevel analysis using behavioral count measures • Non-significant positive relationship between self-regulation and ill-structured problem solving was found
RQ4	H2: Students' co-regulation will have a positive effect on students' ill-structured problem-solving scores	Multilevel analysis using self-report measures • Non-significant positive relationship between co-regulation and ill-structured problem solving was found Multilevel analysis using behavioral count measures • Non-significant negative relationship between co-regulation and ill-structured problem solving was found
RQ5	H3: The interaction between self-regulation and co-regulation will have a positive effect on students' ill-structured problem-solving scores	Multilevel analysis using self-report measures • Non-significant negative relationship between self-regulation x co-regulation and ill-structured problem solving was found Multilevel analysis using behavioral count measures • Significant negative relationship between self-regulation x co-regulation and ill-structured problem solving was found
RQ6	H4: Self-report measures &. behavioral count measures of self-regulation yielded similar results	• Significant positive correlation between self-report and behavioral count measures of self-regulation (Correlation coefficient = 0.302) • The self-report and behavioral count measures of self-regulation yielded similar results
RQ7	H5: Self-report measures &. behavioral count measures of co-regulation yielded similar results	• Significant positive correlation between self-report and behavioral count measures of co-regulation (Correlation coefficient = 0.424) • The self-report and behavioral count measures of co-regulation yielded opposite results

Descriptive Statistics

The results suggested that the participants perceived themselves and their teams performed at above mid-point of the scale regarding self-regulation in both problem representation and solution generation phases (scoring 5 points or above out of a 7-point scale). However, the self-regulation behavioral count measures were very low (less than 2.5 counts), especially in the problem representation phase.

Descriptive statistics of the students' self-regulation and co-regulation (measured by self-report questionnaires) are shown in Table 8. Table 9 shows the descriptive statistics of students' self-regulation and co-regulation (measured by the count of the researcher coding of students' behaviors).

Table 8. Descriptive Statistics of the Self-Report of Self-Regulation and Co-Regulation during the Problem Representation and Solution Generation Phase

		Self-Report of Problem Representation					Self-Report of Solution Generation				
		Mean	SD	Range	Skewness	Kurtosis	Mean	SD	Range	Skewness	Kurtosis
Self-regulation	Goal Setting	4.88	1.04	2-7	-.22	-.00	4.21	1.19	1-7	.20	-.28
	Monitoring	5.00	1.00	2-7	.01	-.67	5.48	.94	3-7	-.36	-.47
	Reflecting	4.90	.95	3-7	.04	-30	4.99	.93	3-7	-.16	-.58
Co-regulation	Goal Setting	4.78	.73	3.39-6.11	-.02	.77	4.21	.89	1.83-5.75	-.26	.22
	Monitoring	4.93	.53	4.00-6.01	.15	-.66	5.47	.70	4.00-6.78	-.54	-.20
	Reflecting	4.99	.67	3.42-6.25	-.22	-.37	5.20	.65	4.00-6.12	-.16	-1.19

N=131 at individual level (self-regulation)
N= 39 at group level (co-regulation)

Table 9. Descriptive Statistics of the Behavioral Counts of Self-Regulation and Co-Regulation during the Problem Representation and Solution Generation Phase

		Behavior Counts of Problem Representation					Behavior Counts of Solution Generation				
		Mean	SD	Range	Skewness	Kurtosis	Mean	SD	Range	Skewness	Kurtosis
Self-regulation	Goal Setting	2.48	1.81	0-10	1.32	1.78	7.97	7.56	0-33	1.05	.38
	Monitoring	1.24	1.55	0-7	1.69	3.06	3.48	.89	0-13	.89	.29
	Reflecting	1.27	1.53	0-8	1.62	2.81	6.99	5.11	0-27	1.23	2.16
Co-regulation		2.03	1.55	1-7	1.66	2.28	4.21	2.00	0-7	-.36	-1.05

N=131 at individual level (self-regulation)
N= 39 at group level (co-regulation)

An interesting finding regarding the self-report measures was that the means of the goal setting, monitoring, and reflecting scores of self-regulation were close to the means of the goal setting, monitoring, and reflecting co-regulation scores (see the self-regulation scores and co-regulation scores in Table 8). In other words, participants rated their own regulation and their teams' regulation similarly.

The self-report scores for self-regulation and co-regulation during problem representation had a mean above 4.78, except for the mean of goal setting and monitoring for solution generation, where the mean of goal setting for solution generation was 4.21 for both self-regulation and co-regulation (see Table 8). This result suggested that the participants had a good perception on their own self-regulation and team's co-regulation (above the mid-point of the scales). However, they have a slightly lower perception of goal setting during solution generation phase.

Although the means of the self-report measure of self-regulation and co-regulation were above the mid-point of the scales, the participants did not exhibit many self-regulation behaviors, especially in the problem representation phase. The participants only exhibited on the average 1.24 to 2.48 times of different self-regulation behaviors during problem representation phase (see Table 9). The researcher rating of the co-regulation during problem representation phase was also low. The co-regulation score was 2.03 on a 0-7 scale, which suggested that, on the average, most of the participants in the teams regulated themselves briefly during the problem representation phase. Another interesting finding is that despite the lower perception of self-regulation and co-regulation (4.21; see Table 8), the teams had 8 goal settings behaviors during the solution generation phase (see Table 9), which had the highest frequency among all the self-regulation behaviors.

Case Analysis

The above descriptive statistics show the central tendency of the self-regulation and co-regulation in a social context. To provide an in-depth understanding of the self-regulation behaviors of the participants, a quantitative descriptive analysis was performed on three selected groups' problem solving representing different levels: High, Medium and Low. Based on the ill-structured problem-solving scores generated by AKOKIA, three groups scoring high, medium, and low problem solving respectively, were chosen for cross-case comparisons. Figures 6, 7, and 8 depicted the self-regulation behavior patterns of the three groups graphically.

Each of the Figure 6, 7, and 8 consists of two parts, a chart of self-regulation behaviors in problem representation phase, and a chart of self-regulation behaviors in solution generation phase. The charts showed the coded behaviors of individual members during the discussion. The Y-axis of Figure 6,7, and 8 represented ten different self-regulation behaviors in problem representation phase (from PR1-PR10) and 10 different self-regulation behaviors in solution generation phase (from SG1-SG10; details of the codes can be seen in Appendix E). For example, PR1 represented a participant providing his/her understanding of the problem; SG2 represented a participant requesting a feedback on his/her proposed solution. The X-axis represented time. Each of the point at the chart represented one self-regulation behavior shown at a given time by one participant. For instance, in Figure 8, at Time 1, Student I provided her understanding of the problem; at Time 2, Student J provided her understanding of the problem, and at Time 3, Student H provided her understanding of the problem. The figure showing self-regulation behaviors in problem representation phase and the figure showing self-regulation behaviors in solution generation phase were shown next to each other to demonstrate the dynamics of the self-regulation between those two types of behaviors.

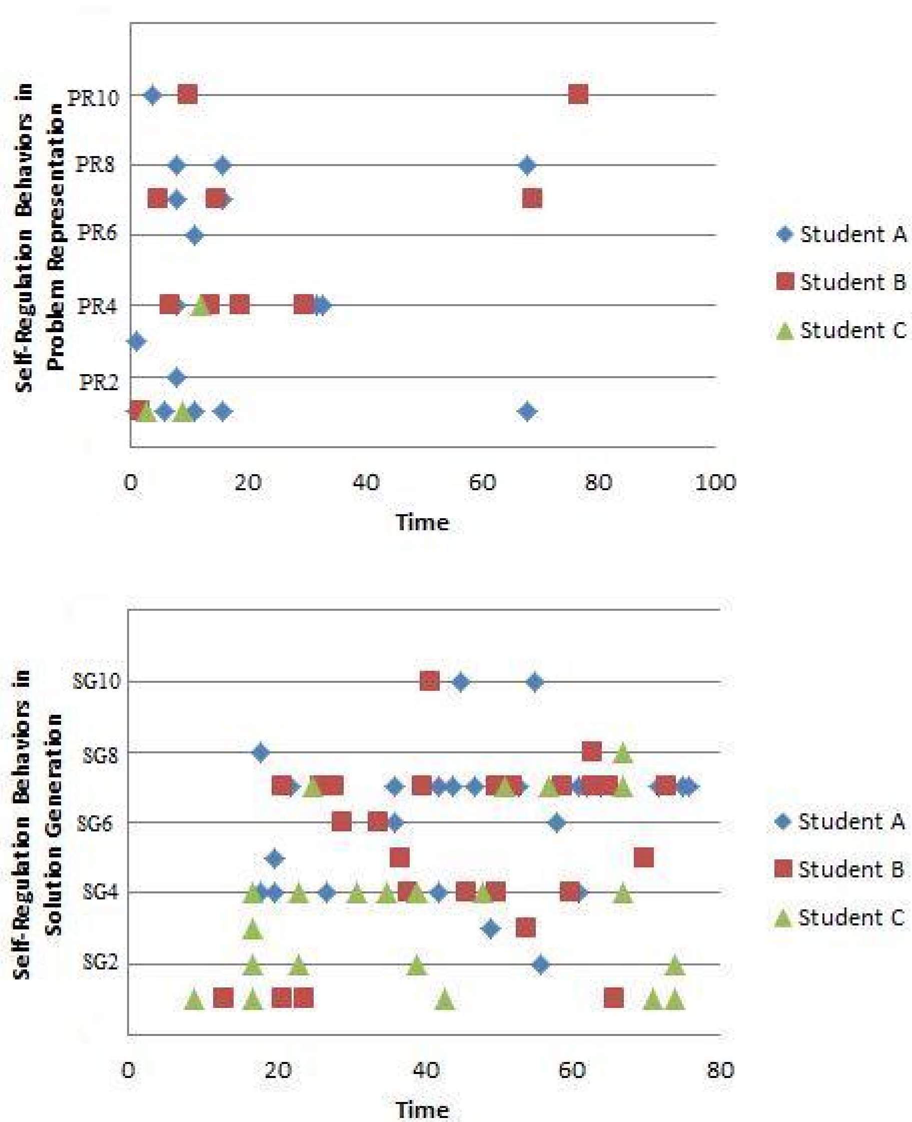

Figure 6. The Conversation Patterns in a High Performing Group

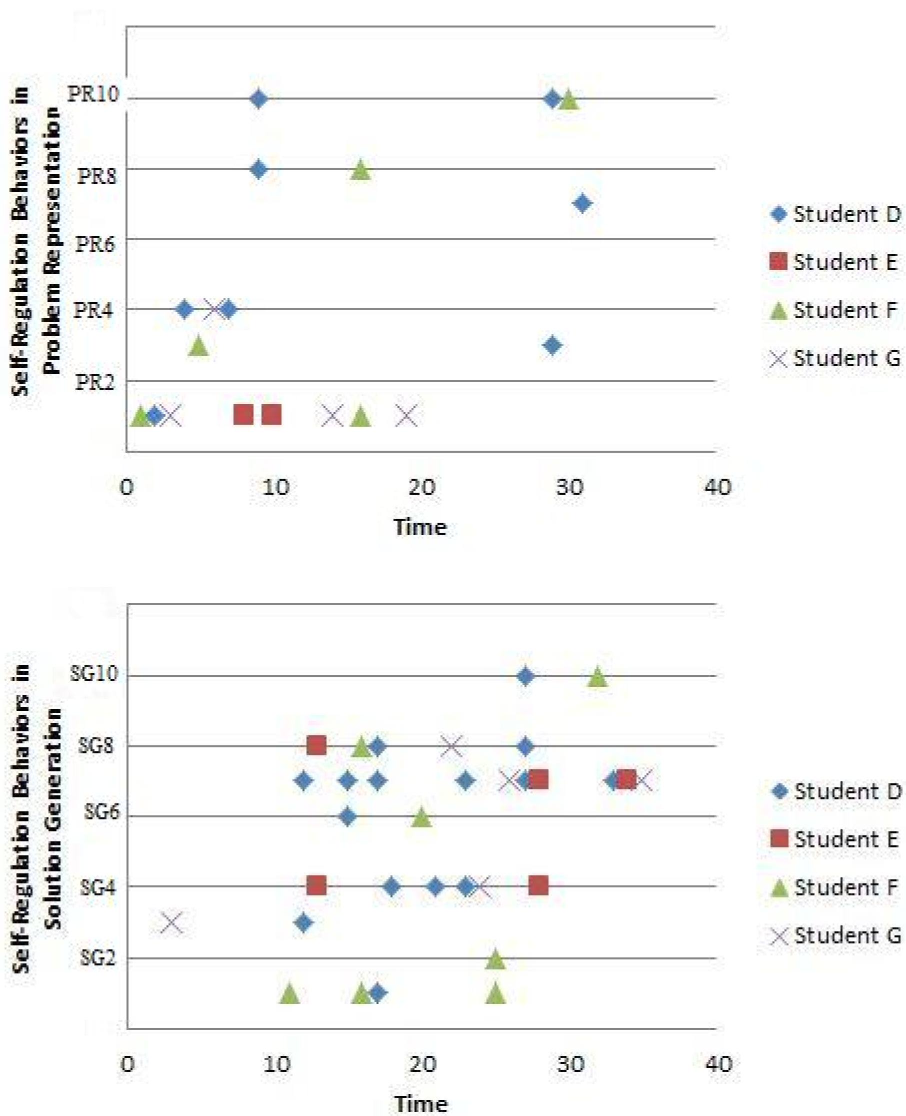

Figure 7. The Conversation Patterns in a Medium Performing Group

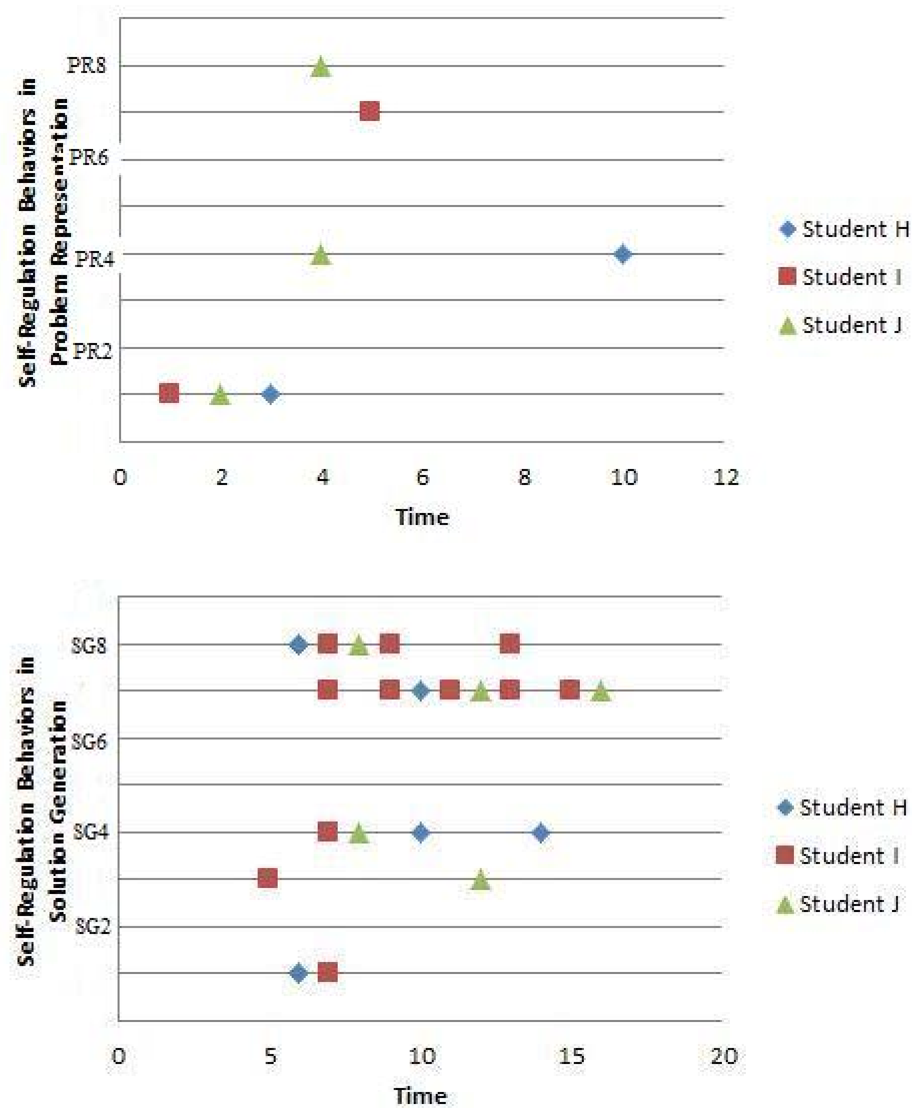

Figure 8. The Conversation Patterns in a Low Performing Group

It is noted that the high performing group spent more time in the discussion than the medium and low performing groups did. 103 self-regulation behaviors were found in the high performing groups, whereas only 52 and 30 self-regulation behaviors were found in the medium and low performing group respectively. Because of the higher frequency in self-regulation behaviors, the co-regulation scores of high performing group was also higher than the co-regulation scores of medium and low performing groups.

As indicated by Figure 6, the high performing groups (Student A, B, and C) not only engaged in more self-regulation behaviors (103 self-regulation behaviors), but also more problem representation behaviors throughout the discussion than the other two groups did (30 self-regulation behaviors in problem representation phase from the beginning to the end of the discussion; see details in Figure 6). By comparison, the low performing group (Student H, I and J), as shown by Figure 8, only shared their information briefly at the beginning of the activity, with very little discussion about their understanding of the problem (only 5 self-regulation behaviors in problem representation phase). At Time 1-3, Student H, I, and J each shared their information of the problem. At Time 4, based on the information shared at Time 1-3, Student J elaborated that victims of bullying could become bullies, and used the bullies in as an evidence to support her claim. Then, Student I agreed with Student J without any elaboration ("Yeah, that makes sense"). Since Time 5, the group started discussing different solutions of the problem, except in one incident at Time 10. At Time 10 when discussing a cyberbullying campaign as a solution to the problem, Student H suggested that the bullies might not know the impact of bullying. Whether the bullies understand the impact of bullying could be one factor influencing this case. However, none of the group members followed up with this point in the discussion. In conclusion, the low performing group jumped into the solution generation phase early in the discussion (Time 5 in this case) and rarely tried to understand the problem (after sharing their understanding of the problem, they only discussed the problem representation at Time

4, 5, and 10). Instead, the high performing group went back and forth between problem representation and solution generation throughout the discussion (as seen in Figure 6).

Figure 6 and 7 indicated that both the high and the medium performing groups showed some high intensity self-regulation behaviors – summarization of ideas. For example, after the high performing group discussing different possible solutions of the problem, at Time 50, Student A summarized a list of solutions that suggested by different team members (see Figure 6). However, the low performing group did not engage in any of those summarization behaviors (no PR10 nor SG10 found in the charts; see Figure 8). Hence, the co-regulation scores in the high and medium performance group were higher than those of the low performing group. One interesting fact was that only a few team members in the group summarized the team's ideas in the high and medium performing groups. In the high performing group, two participants out of three (Student A and Student B) summarized the group's ideas. In the medium performing group, two participants out of four (Student E and Student G) summarized the team's ideas.

RELATIONSHIPS BETWEEN THE SOCIAL ASPECTS OF SELF-REGULATION AND ILL-STRUCTURED PROBLEM SOLVING

Research Questions 3, 4, and 5 examined the impact of students' self-regulation and teams' co-regulation on their ill-structured problem-solving outcomes. Specifically, Research Question 3 examined the impact of students' self-regulation on their ill-structured problem solving. Research Question 4 examined the impact of team's co-regulation on their ill-structured problem solving, and Research Question 5 examined the impact of co-regulation on the relationship between self-regulation and ill-structured problem solving. Two sets of multilevel analyses were run using self-report and behavioral count measures of self-regulation and co-regulation. The results of those analyses are presented below.

Before running the multilevel analyses, the distributions of each variable were examined for the normality assumption. Self-regulation, co-regulation and ill-structured problem solving met the normality guideline –skewness < 2 and kurtosis < 7 (Lomax, 2007; West, Finch, & Curran, 1995). To examine the internal reliability of the measures, Cronbach alpha's of self-reported self-regulation and co-regulation were computed. Cronbach alpha's of the self-regulation and co-regulation scales were .904 and .899 respectively, which demonstrated acceptable internal consistency of the scales.

The multilevel analysis results of all the models are presented in Table 10 and Table 11. Table 10 shows the effects of self-regulation and co-regulation on collaborative ill-structured problem solving based on the data of students' self-reports, and Table 11 shows the effects of both self-regulation and co-regulation on collaborative ill-structured problem solving based on the data of behavioral counts.

Table 10. Results of Multilevel Analyses Showing the Effects of Self-Regulation and Co-Regulation on Ill-Structured Problem Solving Based on the Self-Report Data

	Model 1 (ICC=15.81%)		**Model 2 (ICC=15.51%)**		**Model 3 (ICC=15.71%)**		**Model 4 (ICC=18.89%)**	
	γ	SE	γ	SE	γ	SE	γ	SE
Intercept	.264*	.020	.264*	.020	.264*	.020	.264*	.020
Self-regulation			.013	.021	.012	.021	0.012	0.024
Co-regulation					.0024	.0037	0.024	0.037
Self-regulation x Co-regulation							-0.021	0.040

* p< .05

Table 11. Results of Multilevel Analyses Showing the Effects of Self-Regulation and Co-Regulation on Ill-Structured Problem Solving Based on the Behavioral Counts

	Model 5 (ICC=15.81%)		Model 6 (ICC=16.00%)		Model 7 (ICC=16.76%)		Model 8 (ICC=18.89%)	
	γ	SE	γ	SE	γ	SE	Γ	SE
Intercept	.264*	.020	.264*	.020	.264*	.020	.264*	.020
Self-regulation			.003	.002	.003	.002	0.006	0.003
Co-regulation					-0.013	.015	-0.017*	0.015
Self-regulation x Co-regulation							-0.004*	0.002

* p< .05

In Step 1 of the multilevel analyses, a null model was run to determine whether the groups scored differently in ill-structured problem solving (Hox, 2010). Since this step did not include self-regulation nor co-regulation, Model 1 in Table 10 and Model 5 in Table 11 were identical. The null model only predicted one parameter –the intercept, which represented the grand mean of the ill-structured problem-solving score which was .264 (see Model 1 in Table 10 or Model 5 in Table 11). The null model suggested that the group had an effect on participants' problem-solving scores ($p<0.05$). The ICC of the null model indicated that the group accounted for 15.81% of the variability of students' ill-structured problem solving. 84.19% of the variability of students' ill-structured problem solving occurred at the student level.

In Step 2 of the multilevel analyses, the individual level variable, self-regulation, was added to the model. The self-report measure of self-regulation did not have significant impact on ill-structured problem solving ($p> 0.05$; see Model 2 in Table 10). Therefore, Hypothesis 1 was not confirmed. The ICC of Model 2 was 15.51%, which was decreased by 0.3% compared with the ICC in the null model. The result suggested that self-regulation could not explain additional variance in ill-structured problem solving above what the null model explained.

Similar to the result of Model 2, the results of Model 6 also failed to support Hypothesis 1 ($p>0.05$; see Table 11). The behavioral count measures of self-regulation did not predict ill-structured problem solving. The ICC of Model 6 was 16.00%, which was increased by 0.19% compared with the null model. The results suggested that self-regulation could only explain a small percentage of additional variances in ill-structured problem solving.

In Step 3, the group level variable, co-regulation, was added to the model. The coefficients of self-report measure of co-regulation were not significant ($p>0.05$; see Model 3 in Table 10). Thus, Hypothesis 2 was not confirmed. This result suggested that co-regulation, when controlled with self-regulation, did not have a significant effect on students' ill-structured problem-solving scores. The ICC of Model 3 was 15.71%, which was increased by 0.2% when compared with the ICC in Model 2. This result suggested that co-regulation only explained a small percentage of variance of ill-structured problem solving.

When examining the effect of behavioral count measure of co-regulation on ill-structured problem solving, the effect was also insignificant ($p>0.05$' see Model 7 in Table 11). Thus, Hypothesis 2 was not supported. The ICC of Model 7 was 16.76%. The ICC of Model 7 only increased by .76% when compared with the ICC of Model 6 (see Table 11). This result also suggested that co-regulation could only explain a small percentage of variance of ill-structured problem solving. Another interesting finding was that the directions of the coefficients of the self-report measures and behavioral count measures of co-regulation were different. The coefficient of the self-report measure of co-regulation was positive, but the coefficient of the behavioral count measure was negative (see Model 3 in Table 10 and Model 7 in Table 11).

In Step 4, the interaction effect between self-regulation and co-regulation was added to the final model. The results of Model 4 failed to support Hypothesis 3, that is, co-regulation would positively affect the relationship between self-regulation and ill-structured problem solving ($p>0.05$; see Model 4 in Table 10). Indeed, the regression coefficient of the interaction term in Model 4 was -0.021, which suggested that the interaction between self-regulation and co-regulation negatively related to ill-structured problem solving. The ICC of Model 4 was 18.89%, which was 3.18% above the ICC for Model 3 (see Table 10). This result suggested that the interaction between self-regulation and co-regulation explained additional 3.1% of the variance above the models that included only the main effects of self-regulation and co-regulation.

Although the interaction effect of self-regulation and co-regulation (using behavioral count measures) on ill-structured problem solving was significant ($p>0.05$; see Model 8 in Table 11), Hypothesis 3 was not supported. The direction of the relationship was opposite to Hypothesis 3. In other words, co-regulation had a significant negative impact on the slope between self-regulation and ill-structured problem solving ($p<0.05$), which means that as co-regulation increased, the relationship between self-regulation and ill-structured problem solving was weakened. The ICC of Model 8 was 18.89%, which was 2.13% above the ICC of Model 7 (see Table 11). The result suggested that the interaction between self-regulation and co-regulation explained

2.13% above the models that included only the main effects of self-regulation and co-regulation.

COMPARISON BETWEEN SELF-REPORT MEASURES AND BEHAVIORAL COUNT MEASURES OF THE SOCIAL ASPECTS OF SELF-REGULATION

The last two research questions compared the self-report measures with the behavioral count measures of the social aspects of self-regulation. The self-report measures and the behavioral count measures of self-regulation and co-regulation were statistically correlated. Furthermore, the multilevel analyses using self-report and behavioral count measures yielded similar results, except for the fact that co-regulation had a negative relationship with ill-structured problem solving when using behavioral count measures, but, co-regulation had a positive relationship with ill-structured problem solving when using self-report measures.

The correlation results supported Hypothesis 4, which suggested that the self-report and behavior count measures of self-regulation would yield similar results. Self-report measures and the behavioral count measures of self-regulation correlated significantly (Correlation = 0.302, $p<0.05$;). The significant correlation of the self-report measures and the behavioral count measures suggested that when participants reported that they self-regulated more, they also showed more of those behaviors. To provide additional evidence of validity of those two measures, I compared the multilevel analysis results between the models using the self-report measures and the behavioral count measures (see Table 10 and Table 11 for details).

Besides being supported by a significant correlation between the self-report and behavioral count measures, Hypothesis 4 was also supported by the comparison of the multilevel analyses. The models using self-report measure and the model using behavioral count measures of self-regulation yielded similar results. Both models, which used different self-regulation measures, confirmed that self-regulation had a positive relationship with ill-structured problem solving ($\gamma_{self\text{-}report}$ = .013; $\gamma_{behavioral}$ = .003). However, self-regulation and ill-structured problem solving were not significantly related according to the Model 2 in Table 10 and Model 6 in Table 11 ($p>0.05$).

Hypothesis 5, which suggested that the self-report and behavior count measures of co-regulation would yield similar results, was partially supported by the findings. Hypothesis 5 was partially supported by the significant correlation between the self-report and behavioral count measure of co-regulation (Correlation= 0.424; $p<0.05$). This result suggested that when a team rated their team co-regulation high, the team would also showed good co-regulation.

Although the correlation of the self-report and behavioral count measures of co-regulation was significant, the effects of the two measures of co-regulation on ills-structured problem solving were opposite. Therefore, Hypothesis 5 was not supported. Model 3 in Table 10 and Model 7 in Table 11 showed that neither of the co-regulation measures showed significant relationships with ill-structured problem solving ($p>0.05$). However, the coefficient of the self-reported co-regulation was 0.024 (see Table 10) while the coefficient of the behavioral count co-regulation was -0.013 (see Table 11). The results above suggested that the self-report co-regulation were not related in the same way as behavioral count measures to ill-structured problem solving.

Finally, the results from Model 4 in Table 10 and the results from Model 8 in Table 11 partially supported Hypothesis 5. The interaction effects of both models were negative; however the interaction effect in Model 4 was insignificant ($p>0.05$). Still the interaction effect of Model 8 was significant ($p<0.05$). This result partially supported Hypothesis 5 that the self-report and behavior count measures yielded similar results in the context of ill-structured problem solving.

CHAPTER 5: DISCUSSION AND CONCLUSION

The purpose of this study was to examine the social aspects of self-regulation and their effects on students' ill-structured problem solving in a collaborative task. Self-regulation has been found to be a predictor of ill-structured problem solving (Shin et al., 2003), yet it is not clear whether this relationship holds true in a collaboration context. Nevertheless, a critical review of the literature of self-regulation, ill-structured problem solving, and collaboration indicated that self-regulation could influence students' ill-structured problem-solving outcomes in the collaborative context (Feltovich et al., 1996; Jonassen, 1997; Pintrich, 2000; Zimmerman, 2001). Therefore, the current study was an effort to investigate the relationship between self-regulation, co-regulation, and ill-structured problem solving in a collaborative context. Two constructs were introduced to test the relationships between the social aspects of self-regulation and ill-structured problem solving: self-regulation and co-regulation. Both self-regulation and co-regulation were measured by a self-report questionnaire and the students' behavioral counts coded by the researcher. The findings of the current study are summarized, followed by the discussion of implications for instructional design and future research.

OVERVIEW OF THE FINDINGS

<u>Exploration of Self-Regulation and Co-Regulation</u>

In general, students perceived themselves as sufficient self-regulators in the context of collaborative ill-structured problem solving. The results suggested that more than ninety percent of the participants perceived themselves scoring at least above the mid-point of the self-regulation and co-regulation scales. These results are consistent with self-regulation studies that have used self-report measures (e.g., Cho & Jonassen, 2009; Dabbagh & Kitsantas, 2005). By comparison, the behavioral counts provided different results regarding students' self-regulation. The participants only showed a few self-regulation behaviors in the problem representation phase. In contrast, the participants showed more self-regulation behaviors in the solution generation phase. When compared with other studies that counted self-regulation behaviors, the participants in this study exhibited about the similar level of self-regulation behaviors (Azevedo & Cromley, 2004; Azevedo, Moos, Greene, Winters, & Cromley, 2008). Furthermore, these results are consistent with the ill-structured problem-solving literature which found that students spent more time in the solution generation phase than in the problem representation phase, particularly when there was an absence of instructional guidance or expert support (Ge & Land, 2003).

Similarly, the scores of the behavioral count measures of co-regulation were lower than the scores of students' self-reported team co-regulation, which tended to be positive. The discrepancy between the self-reported and behavioral counts of co-regulation might indicate that the students over-estimated their team's co-regulation behaviors. This phenomenon is consistent with similar observations in the literature. For instance, Ge (2001) found that students self-reported their problem-solving skills overall high, but their actual problem-solving performance did not agree with their self-ratings. In another study, Ge, Planas and Er (2010) also found that some pharmacy students were over confident in their problem-solving performance.

<u>Relationships among Self-Regulation, Co-Regulation and Ill-Structured Problem-Solving Performance</u>

The findings of the current study suggested that neither students' self-regulation nor co-regulation had a significant relationship with collaborative ill-structured problem-solving performance. This result was inconsistent with the self-regulation literature, which suggested that self-regulation or co-regulation had a positive influence on problem solving (Boekaerts & Corno, 2005; Lajoie & Lu, 2011; Schellens et al., 2007; Shin et al., 2003). In addition, the result of the multilevel analyses found that the relationship between self-regulation and ill-structured problem solving was weakened as co-regulation increased.

Several possible reasons could have led to these results, which seemed inconclusive yet. First, the students might not have the needed self-regulation and co-regulation skills to enable them to collaborate effectively in ill-structured problem-solving tasks. The results of the study found that students showed very few self-regulation behaviors, especially during the problem representation phase. Ill-structured problem solving is not a linear process but rather a cyclic process, which requires problem solvers to self-regulate throughout the problem solving processes in order to better understand the problem and come up with better solutions (Eseryel, 2006). In a collaborative problem-solving environment, it is important that problem solvers ask questions, clarify information, negotiate understanding, and engage in self-regulation and co-regulation activities. However, students are rarely trained to solve ill-structured problems and to solve ill-structured problems collaboratively. As a result, students' self-regulation and co-regulation during ill-structured problem solving could be weak. This explanation is supported by the (Ge, 2001) study, which found similarly that peer interaction did not have significant impact on ill-structured problem solving when there was a lack of scaffolds. Thus, scaffolding of self-regulation and co-regulation are needed to help students self-regulate and co-regulate effectively in a collaborative ill-structured problem-solving context.

Second, the measurements of the self-regulation and co-regulation might also lead to the results. The self-report questionnaire asked the participants to make judgment on the teams' co-regulation. This judgment could be difficult because it required individual participants to infer their team members' metacognitive thinking.

Besides, the complicated nature of self-regulation and co-regulation also make the two constructs difficult to be operationalized. Self-regulation and co-regulation can be two multidimensional constructs, which include an individuals' effort to get feedback, such as evaluating others' input, providing feedback to other members, encouraging other members to share ideas, as well as groups' effort to discuss ideas, negotiate meanings, and share understandings. In the descriptive analyses, the high performing team showed stronger interactions among the team members and reflected their understanding of the problem more than the low performing team did. The inconsistent results between the descriptive analyses and multilevel analyses might indicate the measurement issues of self-regulation and co-regulation. In light of these difficulties, further research on measurement of self-regulation and co-regulation in a collaborative problem-solving context is necessary.

Third, the results could be due to a number of constraints of the study, including the short duration of the 1-hour experiment and the ad hoc teams that were randomly formed for the study. These constraints limited the development of team member relationships that requires substantial period of time. According to the literature on team performance, groups normally go through four different phases throughout their collaboration, including forming, storming, norming, and performing (Tuckman, 1965). It takes time for a group to build group relationships and develop group dynamics. Studies found that the development of group dynamics influences the group performance outcomes (e.g., Sweet & Michaelsen, 2007; Zhang & Ge, 2006). In the current study, many of the ad hoc groups only discussed the issue for about fifteen minutes or less, which did not allow sufficient time for members to collaborate effectively.

Fourth, the participants might not perceive the problem-solving task as relevant or meaningful, knowing that their participation was for a study, which might also demotivate them to self-regulate and co-regulate in the collaborative ill-structured problem-solving environment. Although the problem scenario was relevant for the participants, the pre-service teachers who were likely to face similar problems in their future careers, lack of extrinsic rewards (e.g., a grade) demotivate the participants from making effort to actively participating in the discussion, represent the problem and generate solutions. Slavin's (1996) model of group learning suggested that motivation is a key mediator in group learning outcomes. Lack of motivation might be the reason why the effects of self-regulation and co-regulation had no significant effect on ill-structured problem solving. To support this explanation, Lajoie and Lu's (2011) study showed that there was a significant positive relationship between group co-regulation and problem solving performance on authentic diagnoses when the participants were highly motivated medical students. Hence, there is a need to motivate students to engage in the collaborative problem-solving task in a replicated study, in which the problem-solving task will be included as a course project and that student teams will have reasonably sufficient period of time to develop their team relationships and group dynamics and work on the problem-solving tasks.

Relationships between Self-Report Measures and Behavioral Count Measures of Self-Regulation and Co-Regulation

Based on the correlation results, the self-report measures and the behavioral count measures of self-regulation were significantly related. Furthermore, both measures of self-regulation yielded similar results when predicting ill-structured problem solving. The results of the two multilevel models suggested that neither the self-report nor the behavioral count measures of self-regulation had significant impact on ill-structured problem solving. The results of this study were consistent with the prior literature that both self-reported engagement and students' behavioral engagement yielded the similar results when their relationships with autonomy support were examined (Jang, Reeve, & Deci, 2010).

The self-report measures and the behavioral count measures of co-regulation were also significantly correlated. Nevertheless, the multilevel models that used the self-report measures and the behavioral count measures did not yield similar results. While the self-reported co-regulation had a positive effect on ill-structured problem solving, the behavioral count measures of co-regulation had a negative effect on ill-structured problem solving.

As indicated by the moderate correlation coefficients and the results of multilevel analyses, the self-report measures and behavioral count measures are similar, but not identical. The two instruments measured the same phenomena – self-regulation and co-regulation, but they took different approaches. The discrepancy of the results between the two analysis approaches (i.e., self-report and behavior count measures) might be due to the fact that the students overjudged their team co-regulation in the self-report questionnaire. Scaffolding is needed to guide students to precisely evaluate their self-regulation and co-regulation, which would also help to address the measurement issues.

IMPLICATIONS

Implications for Instructional Design

In this study, the participants showed few self-regulation and co-regulation behaviors, especially in the problem representation phase. Although problem representation is crucial in the ill-structured problem-solving process (Eseryel, 2006; Ge & Land, 2003), some of the groups in the current study spent very little time sharing their given information, and quickly started discussing possible solutions. Thus, scaffolding is necessary to guide students' self-regulation and co-regulation in a collaborative ill-structured problem-solving environment. Two prominent scaffolding strategies— modeling and question prompts – are discussed in the current section.

Providing modeling can be an effective solution to help students to acquire collaborative learning strategies, which may lead to better problem-solving outcomes. In a study conducted by Saab, van Joolingen, and van Hout-Wolters (2007), they found that the students who received modeling communicated more effectively and had better learning performance than the control group. Although communication is a key aspect of collaborative learning, it is important for the students to self-regulate others' input.

Based on the findings of the current study, I suggest that modeling of collaborative learning strategies should not only include the communication component, but also reflection component that help students effectively evaluate and incorporate peers' input in the collaborative problem-solving environment.

Another effective scaffolding strategy is question prompts (Ge & Land, 2003; Kauffman et al., 2008). Question prompts can be used as scaffolds to enhance students' problem representation when collaboratively solving an ill-structured problem. One of the main problems in our study was that the participants did not demonstrate sufficient reflection on problem representation. Therefore, providing question prompts to guide learners in updating their problem representation throughout the problem-solving process may direct their attention to developing more complete understanding of the problem. For example, a question prompt can be provided when the groups discuss possible solutions. Questions such as "Has your understanding of the problem been updated? If so, in what ways? " may prompt problem solvers to focus on problem representation instead of only focusing on the solutions.

Implications for Future Research

The current study was an attempt to examine the social aspects of self-regulation, along with other efforts in understanding this phenomenon (e.g., Efklides, 2008; Hadwin et al., 2010; Järvelä & Järvenoja, 2011; Järvenoja & Järvelä, 2009; McCaslin, 2009; Volet, Summers, et al., 2009). This section discusses four main issues that will lead to future research in the area of self-regulation in a collaborative learning context.

The Cognitive Aspects of Self-Regulation in a Collaborative Learning Context

In understanding the social aspects of self-regulation, past studies have focused on the emotional and motivational aspects of co-regulation (e.g., Järvelä et al., 2008; McCaslin, 2009; Volet & Mansfield, 2006). Little research has been conducted on understanding the cognitive aspects of self-regulation in a collaborative learning context. To understand self-regulation and co-regulation in the context of collaborative ill-structured problem solving, the current study examined self-regulation and co-regulation in a collaborative learning context using the lens of cognitive psychology.

Although Volet, Summers, and colleagues (2009) also focused on understanding co-regulation from the perspective of cognitive psychology, in their study co-regulation was operationalized as knowledge co-construction by multiple members of the group. Co-regulation may lead to knowledge construction and problem solving, which is the main argument of the current study. In Volet, Summers, et al.'s (2009) study, the two constructs, which should be distinctively different, were integrated into one construct. However, it is argued that the two constructs – co-regulation and problem solving or knowledge construction should be distinguished, especially when the goal of the study is to test the relationship between co-regulation and learning outcomes. Therefore, in the current study co-regulation involves regulation behaviors *only*. If Volet's et al. (2009) operationalization were used, the shared variance between co-regulation and ill-structured problem solving could have been inflated, which might lead to an error of incorrectly accepting the relationship between co-regulation and ill-structured problem solving. Hence, it is crucial to separate the construct of knowledge construction or problem-solving from the construct of co-regulation.

Relationships between the Social Aspects of Self-Regulation and Learning Outcomes

The current study was the first attempt to examine the relationship between the social aspects of self-regulation and learning outcomes with a quantitative approach. The research on the social aspects of self-regulation has focused on describing the phenomenon of self-regulation and co-regulation (e.g., Efklides, 2008; Salovaara, 2005; Volet, Summers, et al., 2009). Undoubtedly, it is important to describe the phenomenon. At the same time, in order to move the research forward, it is crucial to empirically examine whether social aspects of self-regulation have any impact on students' learning outcomes.

Recently, some qualitative studies were conducted, which showed a positive relationship between the social aspects of self-regulation and learning outcomes (e.g., Lajoie & Lu, 2011). Inconsistent with the results in Lajoie and Lu's study (2011), the current study failed to provide evidence to support the relationship between the social aspects of self-regulation and learning outcomes. Issues such as the lack of scaffolding, measurement issues, and limited experimental context might have affected the results of the current study. More quantitative research in this area with appropriate scaffolding, better measurements, and authentic context should be conducted to explain the relationships among of self-regulation, co-regulation, and ill-structured problem solving.

The Use of Multilevel Analysis in Understanding the Social Aspects of Self-Regulation

One of the quantitative research methods, which is appropriate for studying group phenomena, is multilevel analysis (Tabachnick & Fidell, 2007). The current study was the first one to employ multilevel analysis to understand the social aspects of self-regulation. This statistical method has been used in many other studies in understanding motivational constructs, such as self-efficacy and collective efficacy, and their cross-level effects on performance outcomes (e.g, Chen, Thomas, & Wallace, 2005; Dithurbide, Sullivan, & Chow, 2009). The results of the current study suggested that the individual-level self-regulation interacted with the group-level co-regulation and influenced collaborative ill-structured problem-solving performance. However, the interaction found in the current study was opposite to the hypothesized direction: instead of co-regulation enhancing the effect of self-regulation on ill-structured problem solving, as it was hypothesized, the results of this study showed that co-regulation would impede the effect of self-regulation on ill-structured problem solving. It is possible that contextual factors and individual characteristics influenced collaboration and the effect of collaboration on learning outcomes. For instance, in the current study, some of the groups had a member with strong leadership to guide the team in discussion, while other teams did not have group leadership. It is interesting to see how leadership, as a group-level factor, influenced self-regulation and ill-structured problem solving.

The Use of Multiple Data Sources in Understanding the Social Aspects of Self-Regulation

The current study employed two sources of data to understand the phenomenon of the social aspects of self-regulation: self-report data and behavioral count data. Although the self-report measures and the behavioral count measures were moderately correlated, the multilevel modeling results using those two measures were not totally consistent. Specifically, while the main effect of co-regulation on ill-structured problem solving was positive when it was analyzed using self-report measures, the main effect was negative when it was analyzed using the behavioral count measures. These results suggested that while the self-report measures and the behavioral count measures of co-regulation shared some characteristics, they were distinctively different measures and thus have distinct contributions to research. The results of the current study suggested that students might overjudge their own self-regulation. As a result, when using self-report data, it is important to take into consideration of the fact that participants might not accurately make a judgment on their self-regulation.

One of the challenges of the self-regulation measurement is the alignment of multiple sources of data and the triangulation of the findings from multiple sources of data (Schraw, 2010). Additional research should be conducted to help us understand how we interpret and triangulate the results of different measures of the social aspects of self-regulation more effectively.

CONCLUSION

The research in the social aspects of self-regulation is still in its infancy. The current study took the first step to investigate self-regulation and co-regulation from a cognitive perspective, and their effects on ill-structured problem solving. Although the results of the study did not support some of the hypotheses, which tested the relationships among self-regulation, co-regulation, and ill-structured problem solving, the current study took the first step to investigate the phenomena of self-regulation and co-regulation quantitatively. It contributes to the advancement of self-regulation research in three ways. First, this study provides a new conceptualization of self-regulation and co-regulation that include the peer interaction aspects but exclude the knowledge construction aspects in the constructs. Second, self-report questionnaires and a rubric for coding self-regulation behaviors in the collaborative learning context were developed to measure self-regulation and co-regulation. Finally, this is the first study which uses multilevel modeling technique to examine the cross-level relationships of self-regulation and co-regulation. Further studies are needed to carry forward the research on the relationships among self-regulation and co-regulation in the context of ill-structured problem solving.

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APPENDIX A: SCENARIO, TASK, AND PIECES OF INFORMATION GIVEN TO THE PARTICIPANTS FOR THE COLLABORATIVE PROBLEM-SOLVING ACTIVITY

SCENARIO OF THE COLLABORATIVE PROBLEM-SOLVING ACTIVITY

Mr. Robinson, an assistant principal of a high school, has recently received a report from a parent that her son, John, who is a 9th grader, has been bullied repeatedly this semester by two other classmates, Dan and Matt, who have frequently sent John messages through emails, texting, and Facebook that disturbed him.

Mr. Robinson has approached your team, a group of teachers, to look into the issue of bullying and help him in addressing the problem. So, your team divided up the task and respectively investigated the problem, one member investigating the bullies' behaviors and locating the school policy regarding bullying, one member talking to John's parent, and one member talking to Dan and Matt. Then you come together with your findings.

TASK OF THE COLLABORATIVE PROBLEM-SOLVING ACTIVITY

As a team of educators, please analyze the problem and discuss possible solutions in D2L chat.

Then, write up an individual report to

(1) describe your understanding of the problem, and your proposed solution including

a. the relevant issues related to the problem,

b. the relationships among those issues

c. your proposed solution(s), and

d. justify your proposed solution(s) and how your solution(s) address(es) those relevant issues that you identified in 1a.

(2) post your report in the D2L dropbox.

Please work with your team members so that each of the team members will feel comfortable in writing up his or her individual report, although each of you may have a different understanding of the problems and/or a different solution to the problem.

PIECES OF INFORMATION GIVEN TO PARTICIPANTS

Information regarding the cyberbullying case was divided into pieces before it was given to the participants. Depending on the group size (three or four), information was divided differently. The pieces of information given to each participant are shown in as below.

Pieces of Information Given to Participants in a Three-Person Team

<u>Participant A</u>

You investigated the bullies' behaviors and the school policy regarding bullying. You found that the bullies started with infrequent attempts using text messaging and phone calls about 1 month ago. Then, the frequency of bullying increased and they also used more channels, such as email and MSN Messenger. The situation got worse when the bullying behaviors extended to Facebook, where other classmates and friends also saw the postings. John probably got 5-10 bullying messages every day at different times through different channels. He got those messages on the school bus, at the cafeteria, at home, or even in the middle of the night.

Your school has a zero-tolerance policy towards any kind of bullying behavior. However, the policy is not well understood by the students nor the teachers. According to the policy, bullies can be suspended or even expelled. If needed, the school may get assistance from the local police.

<u>Participant B</u>

You have talked to Dan and Matt. Actually, they thought bullying was fun when they started to bully in different ways, such as bullying with texting, MSN Messenger, and Facebook. Because John was a quiet boy in the classroom, and they thought John probably would not stand up for himself, they felt that they could make fun of John without consequences. They called John names such as “Hey Freak”, “What a Geek”, “LOSER!”, “Teacher’s pet”…. However, you also found that they were victims of bullying in the past.

<u>Participant C</u>

You talked to John’s mother. She was worried about her son and found that he had been depressed for many weeks. She said John had always been a delightful kid, but he was obviously emotionally disturbed. She tried to ask John what had happened in his life, but John did not tell her in the beginning. He lost his appetite and could not sleep well; she was really worried about his health. And, his grades had also being going down. Lately, John started bullying his little brother. Finally, she found that John had been cyber-bullied for one month.

Pieces of Information Given to Participants in a Four-Person Team

<u>Participant A</u>

You investigated the bullies’ behaviors. You found that the bullies started with infrequent attempts using text messaging and phone calls about 1 month ago. Then, the frequency of bullying increased and they also used more channels, such as email and MSN Messenger. The situation got worse when the bullying behaviors extended to

Facebook, where other classmates and friends also saw the postings. John probably got 5-10 bullying messages every day at different times through different channels. He got those messages on the school bus, at the cafeteria, at home, or even in the middle of the night.

Participant B

You have talked to Dan and Matt. Actually, they thought bullying was fun when they started to bully in different ways, such as bullying with texting, MSN Messenger, and Facebook. Because John was a quiet boy in the classroom, and they thought John probably would not stand up for himself, they felt that they could make fun of John without consequences. They called John names such as "Hey Freak", "What a Geek", "LOSER!", "Teacher's pet"…. However, you also found that they were victims of bullying in the past.

Participant C

You talked to John's mother. She was worried about her son and found that he had been depressed for many weeks. She said John had always been a delightful kid, but he was obviously emotionally disturbed. She tried to ask John what had happened in his life, but John did not tell her in the beginning. He lost his appetite and could not sleep well; she was really worried about his health. And, his grades had also being going down. Lately, John started bullying his little brother. Finally, she found that John had been cyber-bullied for one month.

Participant D

Your school has a zero-tolerance policy towards any kind of bullying behavior. However, the policy is not well understood by the students nor the teachers. According to the policy, bullies can be suspended or even expelled. If needed, the school may get assistance from the local police.

APPENDIX B: THE BLUE PRINT OF THE SOCIAL ASPECTS OF SELF-REGULATION

		Problem Solving Phases	
		Problem representation (identifying immediate constraints & requirements, alternative opinions & perspectives)	*Solution Generation*
Self-regulation phases	*Goal setting* (including activation of prior knowledge)	• identify the problem definition, contextual constraints, requirements, alternative opinions & perspectives • request feedback on the problem , contextual constraints, requirements, alternative opinions & perspectives • invite others to identify the problem , contextual constraints, requirements, alternative opinions & perspectives	• generate possible solutions • request feedback on ideas for possible solutions • invite others' input on possible solutions
	Monitoring (monitoring of cognition)	• elaborate on others' problem definition, contextual constraints, requirements, alternative opinions & perspectives • be aware others may have different problem definitions, constraints, requirements, or perspectives • request others to explain their problem definitions, contextual constraints, requirements, alternative opinions & perspectives	• elaborate on others' solutions • be aware others may have different solutions • request others to explain their solutions so the group can reach consensus
	Reflecting (evaluation)	• agree or disagree with others' problem definition, contextual constraints, requirements, alternative opinions & perspectives • justify or refute others' problem definition, contextual constraints, requirements, alternative opinions & perspectives • resolve misunderstanding of others' problem definition, contextual constraints, requirements, alternative opinions & perspectives, then select a problem definition & constraints • summarize relevant problem definitions, contextual constraints, requirements, alternative opinions & perspectives	• agree or disagree with others' solution alternative • justify or refute others' solution alternative • resolve misunderstanding on other's solution alternative • select a viable solution

APPENDIX C: THE QUESTIONNAIRE FOR SELF-REGULATION

QUESTION ITEMS FOR SELF-REGULATION DURING PROBLEM REPRESENTATION PHASE

Goal Setting

1. When I solved the problem I explained my interpretation of the problem to my peers.
2. I asked my peers whether they interpreted the problem in a different way.
3. When I tried to define the problem I asked my peers whether we missed any important information.
4. When I solved the problem I explained the factors related to the problem to my peers.
5. I asked my peers to identify any factors that related to the problem.
6. When I solved the problem I described the relationships between stakeholders and the problem to my peers.
7. I asked my peers to identify relationships between stakeholders and the problem.

Monitoring

8. When my peers explained their understanding of the problem I elaborated on their understanding.
9. I was aware that my peers had a different understanding of the problem.
10. When I did not understand my peers' understanding of the problem I asked them to clarify it.
11. When my peers stated possible problem constraints I elaborated on their understanding.
12. I was aware that my peers had different perspectives than mine regarding this problem.
13. When I did not understand my peers' perspectives I asked them to clarify their perspectives.

Reflecting & Evaluating

14. After my peers explained their understanding of the problem I shared my understanding with them.
15. After my peers explained their understanding of the problem I provided additional justifications to their reasoning.
16. I refuted my peers' understanding(s) of the problem.
17. After my peers explained their understanding of the problem I asked other peers regarding their opinions.
18. When I saw a misunderstanding of the problem among the team members I tried to resolve the issues.
19. I summarized the group's understanding of the problem to understand problem better.

QUESTION ITEMS FOR SELF-REGULATION DURING SOLUTION GENERATION PHASE

Goal Setting

1. When solving the problem as a group I explained the possible solution alternative(s) to my peers.
2. I asked my peers whether they had encountered a solution to a similar problem before.
3. As we were trying to solve the problem I asked my peers whether we had missed any information.

Monitoring

4. When my peers suggested a solution I elaborated on their understanding.
5. I was aware that my peers might have different solution alternatives.
6. When I did not understand my peers' solution alternatives I asked them to clarify it.

Reflecting & Evaluating

7. After my peers explained their solution alternatives I shared my understanding with them.
8. After my peers explained their solution alternatives I provided additional justifications to their reasoning.
9. I refuted some of my peers' solution alternative(s).
10. When there was a misunderstanding of the solution alternatives among the team members I tried to resolve the issue.
11. I summarized the input of our team to come up with a solution.

APPENDIX D: THE QUESTIONNAIRE FOR CO-REGULATION

QUESTION ITEMS FOR CO-REGULATION DURING PROBLEM REPRESENTATION PHASE

Goal Setting

1. My team thought about whether we understood the problem correctly.
2. My team asked whether we had encountered a similar problem before.
3. When my team solved the problem, we considered the constraints of the problem.
4. When my team solved the problem, we considered the relationships between stakeholders and the problem.
5. My team asked ourselves if we had considered all of the relationships between stakeholders and the problem.

6. My team asked ourselves whether we missed any information regarding this problem.

Monitoring

7. My team elaborated on our understanding of the problem.
8. During our discussion, my team tried to determine which issues we did not understand well.
9. During our discussion, my team asked ourselves whether we understood the problem correctly or not.
10. My team elaborated on our understanding of the problem constraints.
11. My team was aware that we might miss some important constraints or perspectives regarding this problem.
12. My team tried to clarify our understanding of the problem.

Reflecting & Evaluating

13. My team discussed whether our problem interpretation was appropriate.
14. My team refuted certain problem interpretations
15. My team tried to correct our misunderstanding of the problem definitions.
16. My team summarized our understanding of the problem to get a better understand of the problem.

QUESTION ITEMS FOR CO-REGULATION DURING SOLUTION GENERATION PHASE

Goal Setting

1. When my team solved the problem we shared different solution alternatives.
2. My team asked whether we had encountered a solution to a similar problem before.

Monitoring

3. My team elaborated on the team's solution alternatives.
4. My team was aware of different solution alternatives.

5.	When my team tried to solve the problem, we asked ourselves whether we had missed any important information.

Reflecting & Evaluating

6.	My team questioned the validity or practicality of the team's solution alternatives.
7.	My team discussed whether our solution alternatives were the best.
8.	My team provided justifications to our solution alternatives.
9.	My team refuted some possible solution alternatives.
10.	When my team saw a misunderstanding of the solution alternatives among our team members, we tried to resolve the issues.
11.	My team summarized our opinions to come up with solution alternatives.

APPENDIX E: THE SCORING RUBRIC FOR SELF-REGULATION

Code	Variable	Descriptions	Examples
PR1/SG1	Goal settings	When someone suggested his/her understanding of the problem or provide a solution.	"I think we need to meet with the principal to discussion suspending them"
PR2/SG2		When someone requested a feedback on his/her understanding of a problem or his/her proposed solution.	"Maybe encourage John to join a club or extra-curricular activity?"
PR3/SG3		When someone asked for others' input without providing any ideas.	"Did it say any other information on the bullying they had in the past?"
PR4/SG4	Monitoring	When someone elaborated on an idea.	"maybe an awareness meeting with all the teachers of the school"
PR5/SG5		When someone was aware that other people might have a different understanding or a different solution. It could be demonstrated by restating another group member's point.	"oh now I see"
PR6/SG6		When someone requested others to explain their understanding of the problem or their solution, such as asking the practicality of a solution.	"how would the school go about investigating their home life?"
PR7/SG7	Reflecting	When someone agreed/disagreed on an understanding or a solution without providing any justification.	"Yeah, I think so"
PR8/SG8		When someone justified why he/she agreed/disagreed on a position.	"because the bullies obviously have something in their past that disturbed them"
PR9/SG9		When someone resolved a mis-understanding.	"it doesn't say that they bullied him in person"
PR10/SG10		When someone summarized the group understanding of the problem, or summarized a group solution	"So, 1. Assembly with school, 2. Assembly with teacher, 3. Meeting with parents, 4. Maybe meeting with the teachers of these specific kids."

APPENDIX F: THE SCORING RUBRIC FOR CO-REGULATION

Score	Description
0	When no problem solver showed co-regulation behaviors.
1	All problem solvers ONLY showed co-regulation behaviors briefly.
2	1 problem solver showed co-regulation behaviors moderately, and the other problem solvers showed co-regulation behaviors briefly.
3	1 problem solver showed co-regulation behaviors intensely, and the other problem solvers showed co-regulation behaviors briefly.
4	2 problem solvers showed co-regulation behaviors moderately, and the other problem solvers showed co-regulation behaviors briefly. OR 1 problem solver showed co-regulation behaviors intensely, and 1 problem solver showed co-regulation behavior moderately, and the other problem solvers showed co-regulation behaviors briefly.
5	All the problem solvers showed co-regulation behaviors moderately.
6	At least one problem solver showed intense co-regulation behaviors, and other problem solvers showed co-regulation behaviors moderately.
7	All of them showed co-regulation behaviors intensely (engaging in ALL three kinds of co-regulation behaviors intensely).